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Heterogeneity, control, social infrastructure, and possibilities of participation: Their interplay in modern understandings of heredity and in interpretation of science

Peter J. Taylor
University of Massachusetts Boston, peter.taylor@umb.edu

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PETER J. TAYLOR

GRADUATE PROGRAM IN CRITICAL AND CREATIVE THINKING
University of Massachusetts, Boston, MA 02125, USA
http://scholarworks.umb.edu/cct_sicw/7

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Peter J. Taylor
Science in a Changing World graduate track
University of Massachusetts, Boston, MA 02125, USA
peter.taylor@umb.edu
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Abstract

This working paper is a prospectus for research, writing, and engagement. It consists of vignettes, sketches of lines of inquiry, and proposals for engagement, all of which concern modern understandings of heredity and development over the life course as well as the social interpretation of science. The various items address a range of areas of science and of its interpretation: heritability studies, the social uses of genetic information, gene-by-environment interaction, personalized medicine, IQ paradoxes, racial group membership, biobanks, and life events and difficulties research. Fresh perspectives in these areas are opened up by examining the ways that research and application of resulting knowledge address—or suppress—heterogeneity in a range of senses (including individual particularity and variation around a mean). The prospectus is presented in the spirit of unfinished and open inquiry, aiming to encourage readers to make further contributions of their own. Adopting or adapting items in the prospectus is encouraged, as is critical commentary on practical and theoretical issues raised by the items.

I. Introduction: A Contention And Four Vignettes

> 'Gessen's genetic counselors recommended an oophorectomy. But Gessen balked…
>
> Our culture doesn't yet have the infrastructure to handle the consequences of the recent revolution in genetic testing. But we'll need it…'
>
> Review of Gessen, *Blood Matters*, in International Herald Tribune 10-11 May 2008

* * *

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understandings of heredity and development over the life course as well as the social interpretation of science. The various items address a range of areas of science and of its interpretation: heritability studies, the social uses of genetic information, gene-by-environment interaction, personalized medicine, IQ paradoxes, racial group membership, biobanks, and life events and difficulties research. Fresh perspectives in these areas are opened up by examining the ways that research and application of resulting knowledge address—or suppress—heterogeneity in a range of senses (including individual particularity and variation around a mean). The prospectus is presented in the spirit of unfinished and open inquiry, aiming to encourage readers to make further contributions of their own. Adopting or adapting items in the prospectus is encouraged, as is critical commentary on practical and theoretical issues raised by the items.

Let me begin to set the scene by reviewing a personal story that involves the simplest sense of heterogeneity—a group made up of two distinguishable subgroups. At my annual physical when I turned 50 my doctor recommended a regimen of half an aspirin a day to help prevent a stroke or heart attack. Not long afterwards I learned that some fraction of the population is *resistant* to aspirin—it does not produce the desired anti-platelet effect. This subgroup is, however, still subject to aspirin resulting in an increased risk of serious gastrointestinal bleeding. Could I find out if I was in the resistant fraction? My doctor informed me that health insurance companies do not consider testing to be a justified expense for healthy subjects. It was, he advised, up to me to decide whether to take the daily aspirin. Some Internet follow-up on my part revealed that testing for resistance is possible, but is undertaken only when patients under treatment for a cardiovascular attack do not seem to be showing the anti-platelet effects of aspirin intake. Would I devote energy to find others with similar concerns about their aspirin-resistance status and agitate for access to testing? No—I went along with the health insurance company's determination and followed the doctor's advice to make a personal choice, in this case, *not* to take the daily pill.

Consider my experience. In the doctor's initial recommendation, aspirin-resistant and normal subgroups were treated as a single group of over-50s, all of us subject to the same positive trade-off between cardiovascular and gastrointestinal risks. The doctor could have been troubled by the heterogeneity within this group, especially after I raised my concerns. Instead he invoked the rhetoric of patient choice and the constraints of the health insurance system. I entertained the possibility of joining with others to agitate for testing to determine which subgroup we belonged to. In the end, I complied with my doctor's framing of my position, namely, I should see myself as a member of an over-50s group subject to a degree of uncertainty about the positive trade-off.

In this story we can see the three parts of a broad contention that the prospectus will explore from many angles—

- *Research and application of resulting knowledge are untroubled by heterogeneity to the extent that populations are well controlled*—As the story conveys, I did not comply with my doctor's initial recommendation, but accepted his subsequent advice.

- *Such control can be established and maintained, however, only with considerable effort or social infrastructure*—The authority of medical professionals was not sufficient to achieve my compliance, but the rhetoric of patient choice and the reimbursement guidelines of the health insurance system eventually were.
- *The interplay of heterogeneity, control, and social infrastructure provides an opening to give more attention to possibilities for participation instead of control of human subjects*—The Internet gave me a means to go beyond the consultation with my doctor. It would have been my first port of call if I had embarked on a journey of finding whom to collaborate with to agitate for change in the guidelines for aspirin-resistance testing.

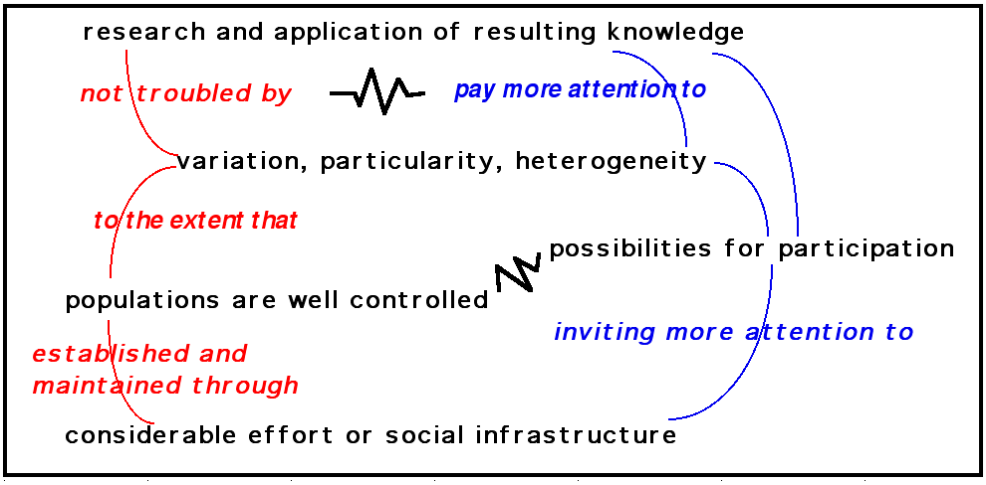

Figure 1. Schema that summarizes the central contention of the project (see text above). The contention applies both to the modern understandings of heredity and to interpretations of science in Science and Technology Studies (STS). (Colored text narrates the connection between terms linked by the curves. Zigzag lines indicate a tension or contrast, e.g, populations are harder to control if members of the population are able to participate in ways that draw attention to heterogeneity within the population.)

The four vignettes that make up the rest of the introduction explicate the terms of the contention and introduce several of the topics and themes for the eight cases that form the main body of the prospectus (section II). The vignettes are also intended to convey the critical and reflexive spirit of the prospectus—*critical* in the sense of exposing how things could be (or could have been) otherwise if more attention were paid to heterogeneity; *reflexive* in the sense of exploring the relationships that science and technology studies (STS) scholars make between interpreting scientific projects and influencing their direction. In STS, research and application of resulting knowledge (i.e., the interpretations of science) also involve the interplay of heterogeneity, control, social infrastructure, and possibilities of participation.

The project connects a number of STS traditions, as the vignettes will illustrate: critical commentary by scientists who make use of their understanding of the technical dimensions of the science (e.g., Lewontin et al. 1984, Fausto-Sterling 2000, Gilbert et al. 2005); conceptual reconstruction by philosophers of controversial or current issues about science in society (e.g., Kitcher 1997, Sesardic 2005); historians collaborating with scientists to re-examine conventional interpretations (e.g., Paul and Spencer 1995, 2008); and STS interventions in public controversies and decision-making around science (Martin and Richards 1994). The prospectus emphasizes scientific concepts and methods (in this case, primarily around quantitative analysis) and, in this respect, differs from interventionist STS that highlights the knowledge-making and activism of local or subaltern groups (e.g., Hess 1995) and from ethnographic and sociological accounts of science in practice. Yet, the familiar emphases from sociology and anthropology of science on heterogeneous resources and actors (Clarke 2005) as well as on reflexive examination of STS strategies for making our knowledge count are both central to the project. These emphases will become clear in the last of the vignettes and in the three-frame process of exposition for each case described in section II.

Vignette 1: Fluoridation, Gaps in racial group average achievement

Imagine a comparison of the dental health of two communities that have the same range of health problems except that the one with naturally high level of fluorides in its water supply has better than average dental health. In each community there will be variation around the average dental health. However, if the variation is small relative to the differences in the two averages, it might seem reasonable to advocate fluoridation of water supplies lacking natural fluoride. In doing so the variation around the average (the very simplest form of heterogeneity) is discounted, as are other deviations from type, such as teeth discoloration that occurs in some individuals. Public health policy-makers discount the variation because the benefits exceed the costs when summed up for the community. The policy-makers are able to do this as long as the infrastructure for water-supply fluoridation remains part of public expenditures covered by taxpayers and as long as individuals who bear disproportionate cost (e.g., those who teeth are discolored) do not effectively mobilize resources and allies to resist—in other words, as long as the population is well controlled. Opponents of fluoridation of the water supply who accept the data on benefits and costs (many opponents do not; Colquhoun 1997) could still promote a participatory alternative: fluoride tablets to be taken by each individual, which would allow people subject to teeth discoloration to adjust the dosage or to choose to manage their dental health without fluoride. This approach is not preferred by most public health policy-makers, who point to lack of "compliance" when individuals are responsible for administering their own preventative medicines. Participation is seen as unreliable; control is more effective. Population health is the guiding idea; variation within the communities is not troubling (Rose 2008).

Suppose now that two "racial" groups show persistent differences on average in some scholastic achievement tests (where racial categories are as defined, say, by the U.S. census). By analogy with the

fluoride case, we should ascribe the difference to race, that is, to some social or biological variable(s) that differ from one race to the other. Identifying those variables will not be as simple as noting the presence or absence of fluoride, but should researchers even try to find them? What if they were to succeed?—If the variable were unalterable (say, a matter of genes), would we resign ourselves to the difference? If the variables were biologically or socially alterable, would we administer the same "antidote" to all in the lower-achieving group? What kind of social infrastructure would be involved? (Think here of No Child Left Behind measures mandated in the name of decreasing racial disparities in K-12 test results.)

In contrast to the fluoridation case, we can readily imagine researchers and policy-makers, unhappy with explanations and policies based on group membership, who want to shift the focus to the heterogeneous pathways of development, in this case, of scholastic achievement. Given the social context in which such a move would be envisaged and enacted, these researchers and policy-makers are likely to face troubling tensions or conundrums—How can attention be given to diversity of pathways without bolstering the popular fiction that racial group membership in the United States no longer brings social benefits and costs and without providing support for various initiatives that have been attempting to prohibit the collection and use of racially classified information by state and local governments (e.g., the failed 2003 Proposition 54 in California)? At the same time, the racial categories used in censuses and other surveys continue to change—as does people's identification with those categories (Hirschman et al. 2000)—yet longituidinal analysis depends on data collected under the same categories for extended periods of time. In short, researchers and policy-makers concerned about heterogeneity within and across racial groups have to use data collected under racial categories, and, despite the shifting nature of those categories, get drawn into defending the continued collection of such data lest there be no information and thus no pattern (such as the average IQ test score differences) to push away from (Taylor 2009a).

As a corollary of this prospectus's central contention, it is always illuminating to reconstruct how researchers negotiate the tension between, on one hand, analyses and action based on averages for groups or populations, and, on the other hand, paying attention to variation from those averages and heterogeneous pathways of development.

Vignette 2: Heritability and underlying heterogeneity

Studies of heritability of human traits associate the similarity among twins or a set of close relatives with similarity of (yet-to-be-identified) genes or genetic factors. ("Heritability" is a technical term with a statistical basis, readily confused with, but quite distinct from, the colloquial idea of genes transmitted from parents to offspring; Taylor 2010a.) The methods of data analysis cannot rule out the possibility that the factors underlying the development of observed traits may be heterogeneous. That is, although relatives may be similar for a given trait because they share more genes or environmental conditions than unrelated individuals, the genes and environmental conditions underlying the

development of the trait *need not be the same from one set of relatives to another*. It could be that pairs of genetic variants (alleles) at a number of positions on the genome, say, AAbbccDDee, subject to a sequence of environmental factors, say, FghiJ, are associated, all other things being equal, with the same outcome for the trait as are variants aabbCCDDEE subject to a sequence of environmental factors FgHiJ (Taylor 2010a).

Some prominent geneticists have noted that heritability estimates are not helpful in identifying specific genetic factors (e.g., Rutter 2002, 4), but the possibility that the underlying genetic and environmental factors influencing development of a trait may be heterogeneous has yet to be recognized as a significant methodological concern by quantitative geneticists or by critical commentators on heritability research (e.g., Downes 2004 and references therein, but see Taylor 2008a). However, the common use of heritability as a basis for judging a trait to be a good candidate for molecular research (e.g., Nuffield Council on Bioethics 2002) is not so helpful if underlying factors can be heterogeneous (Taylor 2010a). In the case of agricultural breeding (where quantitative genetics originated) the absence of attention to underlying heterogeneity can be understood given that researchers have enough control of their varieties and conditions in test locations to take compensatory steps when results of selection informed by heritability studies (and related data analysis) do not meet predictions. Moreover, the agricultural extension system allows recommendations to farmers that match varieties with conditions of cultivation or husbandry (Taylor 2009b). Such control over materials and human subjects (through an established social infrastructure for providing advice that shapes their practice) is not, however, readily available to social scientists and other commentators on the nature-nurture debate. Nor is it straightforward to control the subjects of human molecular biology and biotechnological advances (as the next vignette and several cases in this prospectus illustrate).

Two issues are raised by this vignette: the possible heterogeneity of factors that underlie observed traits warrants attention; and the lack of attention to it invites historical, sociological, and philosophical interpretation. The potential significance of these two issues has motivated all of the inquiries that make up this project. Of course, realizing *potential* significance is not a simple matter; as any STS student can remind us, changes in the social structure of research fields are needed if the inevitable resistance from the mainstream is to be overcome.

Vignette 3: Social infrastructure needed to use genetic information

> The man of the moment [was] J. Craig Venter, Ph.D., whose pioneering work to sequence the human genome — our essential code for life — had whetted public appetite for medical miracles in the diagnosis, treatment and prevention of even the most complex of common diseases. "Imagine a world where families leave the hospital with their newborns and take their baby's complete genetic profile with them on a CD-ROM," Venter told his audience. "And imagine a world where your physician has as part of your medical record your genetic code, which can be used to determine, for example, your risk profile for side effects from drugs or other medical treatments. These might be possible in a genomics-based medical system in the near future." (Massoglia 2003)

"Imagine a world..." If the case of phenylketonuria (PKU) is any guide to our imagination, significant complexities should be expected to arise if neonatal genetic diagnosis and advice about risks and possible protective measures become widespread. Until the 1960s people with two PKU genes (i.e., homozygous) always suffered severe mental retardation. But now the brain damage can be averted by a special diet free of the amino acid phenylalanine following detection of those newborns having high phenylalanine levels. Yet, as Paul's (1998) history of PKU screening describes, the certainty of severe retardation has been replaced by a chronic disease with a new set of problems. Screening of newborns became routine quite rapidly during the 1960s and 70s, but there remains an ongoing struggle in the USA to secure health insurance coverage for the special diet and to enlist family and peers to support PKU individuals staying on that diet through adolescence and into adulthood. For women who do not maintain the diet well and become pregnant, high phenylalanine levels adversely affect the development of their non-PKU fetuses; such "maternal PKU" is a public health concern that had not previously existed.

In contrast with the picture of environment overcoming genetic determination, PKU individuals are subject to heterogeneous influences on their pathways of development over the life course. The more complex picture involves questions about control and social infrastructure and opens up possibilities for participation. Who is responsible if a baby is diagnosed with PKU, protective measures are not taken or are not sustained, and the child becomes a retarded adult or mother of a child with maternal PKU? Anyone wanting to improve the lives of PKU individuals needs to consider where they are prepared to get involved—Would the best point of engagement be around reduction in false positives or negatives? Diagnosis of variability in effects of exposure? Personal motivation and understanding of people with some mental deficits? Support groups for individuals and families? Insurance coverage for the special diet and for counseling? Paid family leave, or…? The possibilities for participation are diverse, depending on how people who want to help—which may include scientists and STS interpreters of science—can build or adjust the relevant social infrastructure (Taylor 2009a).

In short, the common claims that molecular biology and biotechnology will allow genetic information to reshape human life are fantasies in the sense that in practice many diverse materials, tools, and other people have to be engaged to realize any enduring result (Robinson 1984).

Vignette 4: What can we do with interpretations in STS

It is routine in STS to portray scientists and engineers shaping society as they establish knowledge or make technologies work. Yet, to interpret science is also to make knowledge claims, so STS scholars might reflexively ask what aspects of society we are trying to shape (Taylor 2005a). After all, STS interpretations often suggest that things could be (or could have been) otherwise (such as paying attention to underlying heterogeneity in heritability studies; see Vignette 2 and Case 1). Are we envisaging then that our critical social/historical/conceptual interpretations will influence scientists? Would this happen directly, through contributions in scientific publications and meetings; indirectly,

through science journalism and writing for a wider audience; or perhaps over the long term, through STS-informed courses taken by some scientists-to-be? How do we decide whether and when to “go native” among the scientists in their labs or field sites or to become active citizens or consultants in policy debates?

Tensions around heterogeneity and control run through any reflexive examination of STS efforts to shape society. Answers to the questions of the previous paragraph and, more generally, decisions about what we want to do with knowledge depend on our particular situations as STS scholars and the ways these have evolved over our personal and professional life courses. At the same time, conventions and constraints of influencing an audience lead us to push to the background the particularities of situatedness—our own and the audience members.' There is a premium on claims that appear general, i.e., adoptable by others; subjectivity in knowledge-making is played down in favor of the objective and reliable. Then again, the audience in STS is familiar with the idea that heterogeneous resources are brought into play in establishing knowledge and making technologies reliable—scientists employ or mobilize equipment, experimental protocols, citations, the support of colleagues, the reputations of laboratories, metaphors, rhetorical devices, publicity, funding, and so on (Latour 1987, Law 1987, Clarke and Fujimura 1992, 4-5, Taylor 2005, 93ff). Yet this emphasis means that each case of science-in-process has its own particular, even idiosyncratic, complexity. To convey such complexity is to run the risk of our STS interpretations being intelligible only to the group of specialists interested in the particularities of the given case. STS scholars often, instead, acknowledge techno-scientists' efforts to control heterogeneous resources and actors, but then focus audience attention on key concepts concerning those efforts, such as Pasteur's laboratory as an "obligatory passage point" (Latour 1988) and the creation and management of "boundary objects" (which include concepts, tools, institutional arrangements) that many actors can employ in their particular social worlds without jeopardising the object's integrity (Star and Griesemer 1989). We might, in light of the prospectus's overall contention, examine the social infrastructure that has grown around the invocation of such key concepts in STS. For this vignette, however, I want simply to note some possibilities for participation among, more than control of, audiences and other human subjects.

My formative experience as an agricultural and environmental researcher and activist led me in the late 1980s to suggest that anyone wanting to influence developments in some area of science might benefit having some kind of map of the complexity of resources or practical commitments involved in knowledge construction in their own area. Such maps expose multiple places at which concrete alternative resources could be mobilized, thus allowing a range of researchers to identify specific changes that they could effect given their own particular background and interests. In this way, a diversity of engagements that might change science can be guided by STS interpretations of the diversity of things scientists do in practice (Taylor 2005a, 93ff, 148ff; Clarke 2005; Akera 2007). In practice, mapping opens up "the challenge of bringing into interaction not only a wider range of researchers, but a wider

range of social agents, and to the challenge of keeping them working through differences and tensions until plans and practices are developed in which all the participants are invested" (Taylor 2005a, 200). This is a challenge I continue to work on as a teacher and workshop organizer (NewSSC 2010, Taylor and Szteiter 2011, Taylor et al. 2011). For this prospectus, however, a different response to the interplay of heterogeneity, control, social infrastructure, and participation runs through the proposed work of interpreting scientific projects and influencing their direction. The STS approach of the prospectus is described in the next section.

II. Three Frames, Eight Cases

> [T]he audience I envisage is defined not by field or discipline as much as by three qualities: an interest in exploring new propositions, themes, questions, or framings and seeing how these might adapt to their own inquiry; a sense that disciplinary boundaries (for example, between science and interpretation of science) give them trouble in their work; and a disposition to reflect on the conceptual and practical choices they have made in relation to alternative possibilities, past and future…
>
> I believe that conceptual exploration is valuable for researchers trying to deal with… scientific and social complexity. But let me acknowledge at the outset that contrasting approaches, especially learning from long-term engagement in particular controversies or in larger social mobilizations, keep me questioning my emphasis on such abstract concepts as heterogeneity... I see conceptual exploration as the area in which I have been best able to make a contribution, but I look forward to dialogue that keeps such tensions active and productive—that stretches what I am able to offer in the text of a book.
>
> Taylor, *Unruly Complexity: Ecology, Interpretation, Engagement* (2005a, xviii, xx)

* * *

The prospectus takes up eight cases that concern research on heredity and development over the life course. On the level of the science, each case involves, as prefigured in vignettes 1-3, the relationship between, on one hand, variation, particularity, or heterogeneity, and, on the other hand, control and social infrastructure—in other words, the left hand side of Figure 1. On the STS level, each case is to be viewed through three frames that acknowledge the situatedness of the audience but seek to control that particularity/heterogeneity in different ways. All three frames focus attention more on concepts and methods reconstructed from publications than on ethnographic observations or other analyses of science in practice. This emphasis builds on my particular interests, training, and skills in quantitative analyses in the life sciences (Taylor 2005a), which, as the quote above indicates, I see as a plausible basis for me to contribute to "shaping society"—in various modest ways—as I seek to establish knowledge. As befits a prospectus, the lines of inquiry under Frames A and B are only sketched and the proposed engagements under Frame C are not yet implemented.

Frame A. Short presentation that opens up questions

Like the vignettes (though longer and thus less compressed), the presentations within Frame A are to be written to communicate to a wide audience that includes scientists, STS scholars, and students. In a pedagogical style, the presentations open up or highlight themes and questions around heterogeneity that have been overlooked or under-emphasized. I do not set out to convince readers to reject standard accounts and take up alternative concepts, methods, and perspectives. In a spirit of critical thinking my primary aim is that readers see is that they understand things better when they have placed established facts, theories, and practices in tension with alternatives (Taylor 2008b). What I expect readers to do beyond that critical thinking is not answered within Frame A with any definiteness or specificity. After all, the questions I raise constitute only one (potential) resource among many in readers' diverse constructions and reconstructions of knowledge. Perhaps the questions will crystallize for readers *in their own particular circumstances* an impetus to mobilize different resources and organize them in new directions.

Frame B. Critical reconstruction of a specific aspect of the case

The reconstructions within Frame B will dig deeper into the concepts and methods related to a specific aspect of the case, especially the quantitative analysis involved. Technical details will be taken up, so the primary audience I seek to influence is necessarily smaller and more specialized than under Frame A. By showing that attention to heterogeneity makes a difference to specialists' lines of inquiry, results, and interpretations, I aim to push harder on such specialist readers to mobilize whatever different resources are needed to move their work beyond the limitations that follow from discounting heterogeneity. Again, I do not delve into the particular situatedness of any researchers and try to abide by the accepted conventions for articles submitted for publication in the appropriate specialist journal.

Frame C. Participatory postscripts

Of course, there is no guarantee that specialist readers will accept my critical reconstructions of established accounts that have neglected heterogeneity. Within the third frame, therefore, I extend the presentations (Frame A) and reconstructions (Frame B) by proposing experiments designed to allow diverse readers to pull on strands that interest them and thereby contribute to a collective result over which I have less control. Blogs, nings (facebook-like online social networks), wikis, and other internet-hosted resources, and small interaction-intensive workshops (NewSSC 2010) are to be organized. Tracking what happens in these experiments will be the topic of future publications; the scope of this prospectus extends only as far as designing postscripts that provide openings for wider participation.

By applying these three frames to the eight cases below, varied aspects of my overall contention about heterogeneity, control, social infrastructure, and participation (sect. I) are teased out. The result, as

will become evident, is an intentionally heterogeneous mix of contributions. I aim to push back against the expectation that an author should wrap things together in a way that readers can view as a take-home message. Although my broad overall contention informs each contribution, readers are offered a range of entry-points and reasons to delve further into the complexities of particular areas of scientific activity with which they are (or might be) engaged. I write in ways meant to be consistent with the ideal of drawing more attention to possibilities for *participation* among, instead of control of, human subjects.

Case 1. The uses of heritability given the possibility of underlying heterogeneity

Frame A. In an extension of Vignette 2, I ask the question: If the method of data analysis does not allow researchers to tell whether or not the genetic and environmental factors underlying the observed trait are heterogeneous, what can researchers do on the basis of knowing a trait's heritability? Following Taylor (2010a), six answers are identified, each of which raises issues of control or social infrastructure. For example, researchers can *restrict attention to within a set of relatives*. This seems useful because, even if the underlying factors are heterogeneous and/or unknown, high heritability still means that if, say, one twin develops the trait (e.g., type 1 diabetes), the other twin is more likely to as well. This information might stimulate the second twin to take measures to reduce the health impact if and when the disease starts to appear. However, given that this scenario assumes that the timing of getting the condition differs from the first twin to the second, researchers can also ask: What factors influence the timing? How changeable are these? How much reduction in risk comes from changing them? To address these issues researchers have to identify the genetic and environmental factors involved in the development of the trait and to secure larger sample sizes than any single set of relatives allows. The question then arises whether the results can be extrapolated from one set of relatives to others. In short, the possibility of underlying heterogeneity reasserts itself.

Frame B. A re-examination of the limited success of Genome-Wide Association (GWA) studies in light of the possibility of underlying heterogeneity.

GWA studies have identified variants at large numbers of genetic loci that confer statistically significant changes in traits, including increases in risk for diseases such as diabetes, heart disease, and cancers in defined populations (Khoury et al. 2007). A consensus has emerged that most medically significant traits are associated with many genes of quite small effect (McCarthy et al. 2008). The detection and identification of variants is further complicated by genetic heterogeneity in its various forms (e.g., mutations in a gene may occur at a variety of points in the gene; the clinical expression of such mutations can vary significantly; and different genetic variants may be expressed as the same clinical entity). The implications to be drawn from difficulties identifying causally relevant genetic variants are now the subject of active debate (Couzin-Frankel 2010). So is the proposition that, taking genetic heterogeneity into account, future advances will come from finding rare alleles having a strong effect (McClellan and King 2010). This re-examination shows how the possibility of

underlying heterogeneity renders unreliable the core assumption that high heritability values for a trait, such as incidence of heart disease, indicate a strong genetic contribution, which makes the trait "a potentially worthwhile candidate for molecular research" that might identify the specific genetic factors involved (Nuffield Council on Bioethics 2002, chapter 11). I provide a different perspective on why GWA and the move from heritability studies to identification of causally relevant genetic variants have not produced the results and insights hoped for (Couzin-Frankel 2010).

Frame C. Blog chronicling my submissions to journals in which I expose points overlooked in the long history of heritability studies and critical commentaries. Reviews will be posted with brief observations by me informed by Myers' (1990) accounts of negotiations around scientific texts. The blog will eventually be opened to comments from others.

Case 2. Social infrastructure around the use of genetic information

A. An extension of Vignette 3. The case of PKU screening and treatment shows that social infrastructure has to be built if human life is to be reshaped based on genetic information. This presentation builds on Paul's (1998) history of PKU screening and brings it up to date.

B. A reconstruction of the methods of a specific school of agricultural research (originating at the University of Queensland in Australia in the 1970s) that reduce the possibility of underlying heterogeneity by grouping varieties that are similar in responses across locations (Byth 1976, Cooper and Hammer 1996, Taylor 2006). Observing how this is done—what forms of control of biological materials and conditions are needed—clarifies the difficulty of generating and applying hypotheses about the genetic and the environmental factors underlying the development of complex traits in *human* research. Grouping is possible whenever a number of varieties or animals or plants are raised or grown in multiple replicates over many locations (which is not the case for human studies). The wider the range of locations in the measurements on which the grouping is based, the more likely it is that the ups and downs shared by varieties in a group are produced by the same conjunctions of underlying genetic and environmental factors. This gives researchers some license to discount the possibility of underlying heterogeneity within a group, allowing them to hypothesize about the group averages—about what factors in the locations elicited basically the same response from varieties in a particular variety group, a response that distinguishes them from other groups.

C. Another blog will juxtapose two kinds of entries: a. Stories shared by family members, care-givers, and other actors—including STS researchers—that amplify the PKU picture of diverse influences shaping pathways of development over the life course for those with distinct genetic conditions (Rapp 1988, Rapp et al. 2002, Ginsburg and Rapp 2002); b. Claims that molecular biology and biotechnology will allow genetic information to reshape human life. Readers will be

invited to contribute entries of both kinds as well as to make comments contrasting the claims with infrastructure-building measures (including measures sometimes taken by the same researcher making the claims).

Case 3. Social infrastructure implied by knowledge about gene by environment interaction

A. In 2002 Avi Caspi, Terrie Moffitt and colleagues published two articles in *Science* that examined psychological traits in relation to measured genetic and environmental factors. One of them reported on anti-social behavior in adults in relation to the activity of monoamine oxidase typeA (MAOA) and childhood maltreatment; MAOA deficiency was a strong predictor of aggressive behavior only when the child had also been maltreated. The authors conclude that their results "could inform the development of future pharmacological treatments" (Caspi et al. 2002, 853). In the context of research on childhood experiences in relation to adult behavior, the implication is that, if low MAOA children could be identified, prophylatic drug treatment could reduce their propensity to anti-social behavior as adults. An easy rejoinder would be that, if childhood maltreatment could be identified and stopped early, this action could reduce their vulnerability to low MAOA levels leading to undesired adult outcomes. Indeed, eliminating childhood maltreatment would seem to be unconditionally positive, while prophylatic drug treatment may have side-effects, and some of these may not emerge till many years have passed. The rejoinder is too easy, however. The social infrastructure needed to detect and prevent childhood maltreatment would intrude into many households, require surveillance, monitoring, and intervention by state agencies, divert government budgets from other needs, and so on. Reduced childhood maltreatment may be a positive outcome, but the means are not unconditionally positive to all—How would decisions about investment in the social infrastructure be decided? How would individuals decide where to engage with that social infrastructure once it is established? (These questions can be raised about the gene by environment interaction research program even though some meta-analyses have cast doubt on the generality of the specific 2002 Caspi and Moffitt results; Risch et al. 2009.)

B. An examination of variation of outcomes within the genetic and environmental categories (e.g., low/high MAOA and no/probable/severe childhood maltreatment) and its implications for the idea of early detection and intervention on the basis of MAOA status (building on Taylor 2009a). Among children who experienced probable or severe maltreatment, the ranges overlap, that is, some of the high MAOA individuals ended up with higher anti-social behavior scores than some of the low MAOA individuals. The potential for misclassifying children in or out of the category of people who may end up antisocial is not eliminated by adjusting what counts as antisocial. (If we count as antisocial, for example, only those individuals whose score exceeds some value that is higher than the upper limit of the range for high MAOA individuals, this increases the numbers of low MAOA individuals who do not end up counting as antisocial. If we lower the cutoff score, many high MAOA individuals end up

with behavior classified as antisocial.)

The issue of misclassification could be troubling because, once the resources are invested to screen children for MAOA levels, attention would be focused on *all* low MAOA children. Indeed, how could this stereotyping be avoided if we do not know from a childhood MAOA assessment whether any particular individual is one who would go on, after maltreatment, to be an antisocial adult? Additional research would be needed to identify other characteristics that differentiate among the low MAOA children (and perhaps help predict who among the high MAOA children are also vulnerable). If that research were successful, additional resources would have to be invested to customize the way that parents, teachers, doctors, social workers treated the different low and high MAOA children and to educate everyone not to treat children according to their MAOA group membership. In short, just as in the PKU case, the meaning of new genetic knowledge (in this case in combination with environmental knowledge) is contingent on the presence or absence of social infrastructure; the positive benefits depend on extensive control of human subjects.

C. Submission of a research proposal on this topic for cloud funding or open source peer-review (e.g., the Open Source Science Project).

Case 4. The path to personalized medicine may run through social stereotyping

A. Suppose the MAOA example concerned not antisocial behavior but a less charged condition, say, some specific adult disease. What kinds of medical conditions would receive the necessary investment in pharmaceutical and sociological research, screening, and preventative treatment/monitoring to address the conjunction of genetic and environmental factors involved? Some well-organized parental advocacy groups may secure funding to address the prenatal diagnosis and post-natal treatment of rare debilitating genetic disorders (such as PKU). However, public and corporate policy would more likely focus on conditions for which the number of vulnerable people times the average benefit of ameliorating the effect of the genetic difference would be large. In such cases, if the MAOA case is any guide, if the effect of the genetic difference depends on identified social or environmental factors, and if variability within the groups that have on-average high and low vulnerability produces a problem of misclassification, pressure would arise for researchers to differentiate among individuals within the groups. Until distinguishing characteristics were found, parents, teachers, doctors, social workers, insurance companies, policy makers, friends, and the individuals themselves could do no better than treat individuals according to their group membership. If the additional research were not conducted or not successful, or if the cost of differentiating among individuals were too high, we might never get beyond treating individuals according to their group membership.

The scenario speaks to the prospect of personalized medicine. In its simplest form, this involves the use of genetic information to predict which patients with a given condition (e.g., heart aryhthmia) will benefit

from a particular drug treatment (e.g., beta blockers). More ambitiously, personalized medicine promises to inform people of their heightened vulnerability (or resistance) to specific environmental, dietary, therapeutic, and other factors early enough to adjust their exposure and risky behaviors accordingly. If the MAOA analogy holds, the path to personalized medicine will, ironically, pass through a phase in which large numbers of people are treated according to their group membership. Moreover, this phase may not be a passing one: What conditions—what social infrastructure—can ensure that the information and resources needed to move beyond it are forthcoming?

B. The presentation above raises a potential association of personalized medicine with treatment of individuals according to their group membership. The generality and implications of this paradoxical association will be examined in three steps: a. by surveying the range of projects promoting and applying personalized medicine (with a special focus on use of genetic information); b. by comparing and contrasting these projects with research on race-specific medical treatment (Whitmarsh and Jones 2010, especially Kauffman and Cooper 2010); and c. by comparing and contrasting the presentations of personalized medicine with analogous appeals in the genes and IQ debates to the need for education that is matched to the individuals' aptitudes at the same time as individuals are classified into racial groups (Jensen 1969, Block and Dworkin 1976).

C. A Collaborative Exploration (CE) around a scenario concerning possibilities for bringing into wider discussion the potential association of personalized medicine with treatment of individuals according to their group membership. (CEs are an extension of Problem-Based Learning and related approaches to education in which students address a scenario or case in ways that allow them to shape their own directions of inquiry and develop their skills as investigators and prospective teachers. CEs, hosted by the Science in a Changing World graduate track at UMass Boston, are open to participants around the world.)

Case 5. From social stereotyping to developmental pathways whose heterogeneous components differ among individuals

A. Flynn (1994) has pointed to large gains in average IQ test score between generations (now called the Flynn effect). No environmental factor, or composite of factors, such as diet or years of education, has been shown to be associated strongly with the generational differences (Flynn 2007). At the same time, according to the current consensus, heritability of IQ test scores is high (Neisser et al. 1996; but see Taylor 2007). In parallel with this generational difference, persistent large differences in average IQ test score exist between racial groups. No environmental factor, or composite of factors, seems to be associated strongly with the group average differences (Flynn 2007; but see Fryer and Levitt 2004). This has led many psychometricians and human behavioral geneticists to make a two-part argument: the high heritability of IQ test scores within racial groups *coupled with* a failure of environmental hypotheses to

account for the group differences supports—or lends plausibility to—explanations of mean differences in terms of genetic factors (even if these factors have yet to be elucidated) (e.g., Jensen in Miele 2002, 111ff). There must, however, be a problem with this logic because it would also lead us to favor explanations of *generational* differences in terms of genetic factors, yet we know that the change in gene frequencies in a human population over one generation is negligible. What is wrong with the two-part argument? How, if that argument is discarded, can large differences between generations—or racial groups—in this highly heritable trait be explained? These questions constitute the IQ paradox to which Dickens and Flynn (2001) draw our attention.

B. This reconstruction begins from the IQ paradox and ends up wit the focus on developing methods to collect and analyze the data so as to discriminate among possible models of developmental pathways whose heterogeneous components differ among individuals at any given point of time. The initial step is to expose a flaw in the logic that makes high heritability and average generational differences a paradox. Estimates of heritability derive from statistical analysis of variation in traits among related and unrelated individuals; this analysis involves no reference to measurable genetic or environmental factors involved in the development of those traits. (Translation from this analysis to validated hypotheses about the underlying factors is difficult, even in agricultural or laboratory breeding where the variety of organisms and environment can be controlled and replicated; Taylor 2006; see Case 2, Frame B.) The two-part argument about average group or generational differences dissolves into symmetrical situation: no environmental factor is associated strongly with the group or generational average differences, and no genetic factor is either (Nisbett 1998, 89-90).

The large average differences between groups and between generations on IQ test scores still need to be explained. Dickens and Flynn (2001) propose reciprocal causation models, which involve two key features: a matching of environments to differences that may initially be small (e.g., children who show an earlier interest in reading will be more likely to be given books and receive encouragement for their reading and book-learning); and a social multiplier through which society's average level for the attribute in question influences the environment of the individual (e.g., if people grow up and are educated with others who, on average, have higher IQ test scores, this will stimulate their own development).

These models can be taken a step further. Once it is recognized that the potency of social multipliers depends on different groups' capacity to capitalize on historical changes in society, there is no reason to assume that the multipliers apply uniformly across individuals, given their differences in age, gender, geographical location, culture, and so on. It need not even be the case that the multipliers move different individuals in the same direction but at different speeds. To adapt a basketball analogy that Dickens and Flynn employ, the onset of TV coverage of basketball acted as a social

multiplier by eliciting greater participation in basketball, while, at the same time, it elicited more couch-potato spectatorship.

If researchers envisage developmental pathways whose heterogeneous components differ among individuals at any given point of time, the challenge the researchers face is to develop the necessary infrastructure, in this case, in the form of methods to collect and analyze the data so as to discriminate among possible models. A number of approaches to quantitative analysis of pathways of development of behavior and disease over the life course are examined in relation to their potential to contribute to research that does not obscure the possible heterogeneity of factors: Life-course analyses in education (Woodhead 1988, Ou 2005); Multivariate developmental models of mental illness (Kendler et al. 2002); and Life course analyses in epidemiology (Kuh and Ben-Shlomo 2004, Head et al. 2005).

C. Using a "diigo" group that allows sharing and annotating of bookmarks to materials available via the internet (http://groups.diigo.com/group/HeteroEdPathways), people will be invited to contribute to an expanding catalogue of studies and practical projects that address educational disparities without emphasizing group differences, instead giving attention to diverse developmental pathways (i.e., ones whose heterogeneous components differ among individuals at any given point of time).

Case 6. Racial group membership and the paradox of emphasizing heterogeneous developmental pathways

A. As Vignette 1 implies, a deep paradox that applies to the use of IQ test scores in U.S. society seems to be that researchers and policy-makers who want to move beyond explanations and policies based on racial group membership and shift the focus to heterogeneous pathways need to take into account the disadvantages and benefits individuals experience because of their group membership. The situation for research is even stickier once we move from models to analysis of data so as to compare and test those models (Taylor 2009a).

B. Two recent critical anthologies on race and science, Hammonds and Herzig (2008) and Whitmarsh and Jones (2010), will be reviewed with attention to the ways that the authors and the scientists they write about negotiate the tension between, on one hand, analyses and action based on averages for groups or populations, and, on the other hand, paying attention to variation from those averages and heterogeneous pathways of development.

C. New England Workshop on Science and Social Change in May 2013 (provisional date) on the theme "Who gets to use race--or stop using it--and at what cost?" This four-day interaction-

intensive workshop (NewSSC 2010, Taylor et al. 2011) will: a. explore current and past uses of racial and ethnic divisions as well as attempts to complicate or jettison such categories; b. examine the ways that the researchers negotiate the tension stated above (Frame B); c. assemble working papers and audio recordings of discussions as "Online Resources for Science in Society Education and Outreach" (http://sicw.wikispaces.umb.edu/ORSSEOdev).

Case 7. The data that researchers collect shapes the kinds of patterns and hypotheses or predictions they can make

A. Epidemiologist John Frank (2005) asks what data needs to be collected over the life course of individuals so that researchers in say, thirty years, have the information needed to identify the key risk factors and interactions that account for variation in disease incidence and differential age of onset in a population, and for changing patterns for diseases over time. He assumes that "diseases and conditions of later life occur in some and not others because of intense interactions between particular genetic constitutions and particular sequence of social and physical environments." There is, however, an uneven playing field. Genetic samples are cheap to collect and store and need to be collected only once in a lifetime. Environmental exposures vary over time so that "new samples are needed whenever exposure changes, are difficult to store, and are getting costlier (as awareness of chemical/physical/ biological complexity increases)." Some epidemiologists have secured resources to follow small cohorts through time and collect a rich array of data on the individuals (e.g., The Southampton Women's Survey; Inskip et al. 2006), but the major investments are being made in collecting primarily genetic and disease data for large samples (e.g., the UK Biobank). Epidemiologists such as Frank have warned that analyses of such data will depend on crude estimates of environmental factors and be subject to large errors, uncertainties, and non-replicated findings about genetic influences. Yet, in the absence of longituidinal data on environmental exposures, biomedicine has almost no option but to emphasize the effects of genetic factors (but see Davey-Smith and Ebrahim 2007).

B. A reconstruction of constraints on social epidemiology and responses to them. Under the life-course perspective that has developed in social and psychological epidemiology since the 1990s, researchers seek to reconstruct the complex causal processes that generate specific diseases and behavioral attributes (Kendler et al. 2005, Kuh and Ben-Shlomo 2004). However, some prominent social epidemiologists are becoming skeptical about the availability of the kinds of data and analyses needed to separate the effects of diverse biological and social factors that operate on a range of temporal and spatial scales and build up over a person's life course (Davey-Smith 2007), or more generally, to "to identify modifiable causes of disease that can be utilized to leverage improved population health" (Davey-Smith 2008a, b; but see Lynch 2007). Grounds for such skepticism are amplified by the possibility of heterogeneity, that is, when similar responses of different individual (e.g., genetic) types are observed, researchers need not assume that similar conjunctions of risk or

protective factors have been involved in producing those responses. This state of play leads me to emphasize the possibility of an *agent-oriented focus*, in which researchers depart from the traditional emphasis on exposures impinging on subjects and, instead, elucidate people's resilience and reorganization of their lives and communities in response to social changes (Sampson et al. 1997).

C. Open source extension of "Epidemiological Thinking and Population Health," a syllabus that gives "special attention given to social inequalities, changes over the life course, and heterogeneous pathways"— http://ppol753.wikispaces.umb.edu. This course emphasizes epidemiological literacy with a view to collaborating thoughtfully with specialists, not technical expertise. Originally developed with extensive input from colleagues at the University of Bristol's Department of Social Medicine, the course has continued to evolve through the requirement that students contribute annotated additional references corresponding to each week's themes. The wikispace is structured to allow non-students to contribute as well.

Case 8. Bio-social science that allows for heterogeneity of pathways and meaning

A. A line of research from England, initiated by the sociologists Brown and Harris in the late 1960s, has investigated how severe events and difficulties during people's life course influence the onset of mental and physical illnesses (Harris 2000). Brown and Harris use wide-ranging interviews, ratings of transcripts for the significance of past events in their context (with the rating done blind, that is, without knowledge of whether the person became ill), and statistical analyses. Because what might be recorded as the same event, e.g, death of a spouse, might have very different meanings and significance for different subjects according to the context, the Life Events and Difficulties (LEDS) methodology accommodates events with diverse meanings. At the same time, apparently heterogeneous events can be subsumed under one factor, such as, in explanation of depression, a severe, adverse event in the year prior to onset. In sum, the LEDS integrates “the quantitative analyses of epidemiology and the [in] depth understanding of the case history approach” (Brown and Harris 1989a, x).

B. An account of the uptake and subsequent sidelining of Brown and Harris's LEDS methodology by U.S. researchers (making use of interviews conducted in 2002-6). In many cases, researchers have adapted the LEDS methodology, making more use of surveys so it is less labor-intensive, but then not sustained their research along these lines.

C. Collection of "intersecting processes" case studies for teaching. Inspired by LED research, cases will be solicited in which students examine the development of biomedical and social phenomena in terms of linkages among processes of different kinds and scales that build up over time—genetics, treatment, family and immediate social context, social welfare systems and

economics, wider cultural shifts, etc. (Taylor 2005b). Annotated links to the cases will be assembled and made available through http://sicw.wikispaces.umb.edu.

III. Open Questions

At the close of this prospectus let me highlight the open questions that are engaging me most concerning the interplay of heterogeneity, control, social infrastructure, and participation. To do so, I will revisit each of the four introductory vignettes.

1. Taking the first vignette as an entry point, I will examine the key tension in research and policy on health improvement articulated by Rose (2008). Epidemiologists and public health policymakers who focus on determinants of the average level of any given disease, tend to discount heterogeneity and assume or promote control over whole populations. Clinicians, however, focus on treating sick or high-risk individuals and seek to understand, treat, or, better still, forestall, the illness. In principle, this focus allows them to pay more attention to heterogeneity, but in what situations does this happen in practice?

The first vignette also leads to more general issues about the foundations of statistical analysis. In particular, I explore contrasts between: the statistical emphasis on averages or types around which there is variation or noise; variation as a mixture of types; the dynamics (or heterogeneous mix of dynamics) that generated the data analyzed; and participatory restructuring of these dynamics in the future. A key issue is who is assumed to be able to take action—who are the "agents"—and who are the subjects that follow directions given by others.

2. The second vignette leads to the question: What do you do as a philosopher of science if you conclude that researchers have overlooked a significant issue, in this case, the possibility of underlying heterogeneity, for 100 years? What does philosophy of science prescribe in such circumstances? I will review some possible answers and note that Anglo-American philosophy of science does not provide much guidance. Why is that? We can also ask what sociology of science suggests will result from the various ways to influence scientific debates, such as those presented in this prospectus, which range from direct to backdoor or indirect.

3. The third vignette noted that a focus on genetic information without attention to building social infrastructure has left the families with PKU children struggling to secure and maintain the required diet and to the emergence of the maternal PKU. Can we expect the same crisis-inducing effect for other interventions that invoke the fantasy articulated by Venter and Dawkins, whereby human genetic information serves to reshape life and solve social problems?

The thread of paying more attention to the actual or implied social infrastructure also carries over into an area of STS that needs more development, namely, conceptualizing the structure of the social context of scientific and technological developments and the nature of human agency in the ongoing restructuring of that context (Taylor 2009a).

4. The final vignette noted that researchers can map the heterogeneous resources brought into play in establishing knowledge and making technologies reliable. These maps could inform researchers' efforts to influence ongoing developments in their area of science and technology. However, as vignette 4 also noted, paying attention to heterogeneous resources, which are drawn from a range of social worlds, raises "the challenge of bringing into interaction not only a wider range of researchers, but a wider range of social agents, and to the challenge of keeping them working through differences and tensions until plans and practices are developed in which all the participants are invested" (Taylor 2005a, 200). The vignette noted that the research, writing, and engagement would not directly tackle this challenge. However, issues will get raised about collaboration among unequal social agents in light of the range of opportunities for participation. In the spirit of open questions, let me note three tensions regarding such collaboration (Taylor 2009a):

- between solidarities forged through working and living together in particular places and the application of translocal perspectives or abstract knowledge;
- between contributing or withholding translocal resources—including but not limited to knowledge—that could be brought to a locality; and
- among local people with respect to their solidarities versus their accommodation to translocal knowledge and resources.

The last item will be to by describe a participatory activity that addressed these tensions, namely, a "future ideal retrospective" that exposed and organized the diverse considerations involved in collaboration among diverse parties (Taylor 2010c). The result, Figure 2, is evocative, and only a beginning.

DISRUPTION OF WHAT/WHERE WE CAME IN WITH/FROM CAN, WITH ATTENTION TO SUPPORT, RESULT IN SOMETHING ENDURING & EXTENDING BEYOND US								
SUPPORT COMPLEMENTS DISRUPTIVE STEPS			INSTITUTIONAL & MENTAL DEVELOPMENT RESULTS IN SOMETHING ENDURING & EXTENDING BEYOND US					
			PROCESS OF LEARNING FROM EACH OTHER ALLOWS NEW UNDERSTANDINGS TO EMERGE			STRETCHING & CONSOLIDATING BEYOND OUR TIME & PLACE		
STEPS TAKEN TO DISRUPT WHAT WE SEE AT FIRST			DEVELOP STRUCTURES & DISPOSITIONS OF LEARNING FROM OTHERS				IN THIS FOR THE LONG HAUL & IT'S MORE THAN US	
BEYOND SURFACES/ PERSONAS	VARIATION/ DISRUPTION OF STUCK SPACES	FEAR IS REAL, BUT WE HAVE HAD SECURE BASES	LEARNING TO PARTICIPATE BY EXPERIMENTING & DEVELOPING SHARED PRACTICES	REVIEW FOR UPTAKE & BUILDING ON	SYSTEMATIC ARTICULATION OF UNDERSTANDING	CHANGING THE UNIVERSITY AS SCHOLARLY WORK IS NO LONGER CENTERED THERE	TAKE A LONG VIEW & NOT BE DERAILED BY FAILURES & WITHDRAWALS	OTHERS WILL COME AFTER US, BUILD ON WHAT WE'RE DOING
INVISIBLE PARTICIPANTS	INVOLVE FAMILY & FRIENDS	FOLLOW THE FEAR	USE EXPERTISE TO FACILITATE COLLABORATIVE PROCESS	EVERY GATHERING ENDED WITH REVIEW, REFLECTION, APPRECIATION	UNDERSTAND SOURCES OF TENSION	ACTING COUNTER-CULTURALLY	RESPECT RECIPROCITY A LONG VIEW	DOCUMENTATION A GIFT TO FUTURE
GET TO KNOW EACH OTHER	ALTERNATING BETWEEN PERSONAL REFELCTION & COLLABORATIVE TIME	TOLD STORIES OF "PLACES" WE'VE BEEN COMMITTED TO	TRAINED EACH OTHER AT EVERY OPPORTUNITY	FOSTER CONSISTENT REVIEWS OF PRODUCTIVE COLLAB. PROJECTS	ARTICULATED DISCIPLINARY ASSUMPTIONS	USE THE UNIVERSITY AS A COUNTER-HEGEMONIC SPACE	HAVE AN EXIT PLAN	TAKING GOOD NOTES & SUMMARIES
NOTICE POWER DISPARITIES	PLAYFUL DIGRESSIONS	OPENLY DISCUSS CONCERNS/FEARS THROUGHOUT PROCESS	BLOCKED OUT REGULAR SPACES & TIMES		USE DIALOGUE PROCESS TO IDENTIFY A SERIOUS PROBLEM	IN THE UNIVERSITY BUT NOT OF IT	PAID ATTENTION TO LUCK	
MISUNDERSTANDINGS EXPECTED & CHUCKLED AT WHEN EXPOSED	TAKE BREAKS AS NEEDED		DIGITAL USED ONLY WHEN VALUE IS ADDED		REMOVE HIERARCHY OF ENGAGEMENT/ INVOLVEMENT	MOBILIZED MATERIAL SUPPORT	EXPECT (BUT NOT EXCUSE) FAILURES & WITHDRAWALS	
	NOTICING WHEN DIVERSE PERSPECTIVES ARE LACKING		EVERYONE TOOK A LEARNER'S POSITION			MULTIPLE BRIDGES B/W ACADEMICS & NON-ACADEMICS		
	MAKE SPACE FOR EACH PERSON TO DEFINE OWN ROLE		FLEXIBILITY WITH SCHEDULES & TRAVEL			DEVELOP COMMUNITY OWNERSHIP OF COLLABORATION		
	BALANCE OF PHYSICAL & MENTAL PARTICIPATION		ORGANIZED WAY TO WELCOME NEWCOMERS/LATECOMERS			OWNERSHIP OF ENGAGEMENT (MULTIPLE LEVEL/ AREA/ REGION)		

Figure 2. Post-it brainstorming and clustering into themes from an activity in a faculty seminar on collaboration (Taylor 2010c). Participants were asked to imagine what had contributed to a future in which diverse participants collaborated in some project, "working through differences and tensions until plans and practices are developed in which all the participants are invested." The resulting post-its were organized into nine clusters (names in boldface), which were then grouped into progressively overarching themes.

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