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Investigating Research Practices: How Qualitative Methods Enhance Philosophical Understandings of Science

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Qualitative research provides rigorous methods not only for investigating behavioral or social issues, but can also be used for exploring epistemic issues related to science and its practices. There is growing scholarly awareness that important aspects of science can be best understood through qualitative analyses and cannot be captured using more traditional textual sources such as publications or archival documents or via more quantitative or formalized methodologies such as citation analysis or bibliometrics. Reflecting on our own research on the philosophy of scientific practices, particularly on the role of model organisms in biology, we discuss some of the challenges associated with the design and conduct of qualitative research in the philosophy of science. We then explore three issues in more detail: The extent to which qualitative methods support the identification of media and spaces for the study of epistemic questions in science; the investigation of social structures particularly relevant to scientific practices and reasoning; and the conceptual and interpretative significance of analytic choices in empirical research on science. In closing, we reflect on the value of qualitative research methods for understanding scientific practices as ways to identify novel research directions, refine and augment philosophically motivated research questions, investigate the rationales and procedures through which particular scientific choices become ingrained in research, and question the implications of such habits as norms for what counts as "best practice" in particular scientific fields, all of which are topics that deserve more attention from philosophers and other scholars interested in scientific practices.

Keywords: qualitative research, philosophy of scientific practices, scientific reasoning, epistemology, study design

Qualitative methods are increasingly being utilized in some subfields of philosophy, especially the philosophy of science. These methods have the potential to provide rigorous approaches for exploring philosophically salient issues, particularly for scholars focused on scientific practices and their epistemic features. This trend reflects growing awareness that many aspects of

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contemporary scientific practice and reasoning cannot be captured solely using more traditional textual sources such as publications or archival documents, but require broader inputs. In addition, many contemporary scientific practices cannot be usefully analyzed in terms of formalized, more quantitative methodologies such as citation analysis or bibliometrics, but require consideration of these practices along with their associated sociocultural, political, institutional, and other norms. In short, although science may be composed of distinct types of practices characterized by different fields, they nonetheless are still human practices that can be interrogated using qualitative approaches.

The advantage of adopting qualitative methodologies within the philosophy of science is that they are appropriate for exploration of the diverse conditions under which scientific research occurs, including locations, goals, methods, materials, and preferred forms of communication and dissemination. Most importantly, qualitative research allows consideration of the types of reasoning and forms of knowledge that are of central interest to those seeking deeper understandings about the epistemological features of science, which can range from know-how and embodied knowledge to collective and distributed reasoning.

Our contribution to these developments comes from a subfield within the philosophy of science often referred to as "philosophy of science in practice," a label derived from the mandate associated with a series of conferences organized by the international Society for the Philosophy of Science in Practice since 2009, the organization and conceptualization of which we have been actively involved (Ankeny et al., 2011; Soler et al., 2014; Wagenknecht et al., 2015; Zhu & Tong, 2019). These events and associated activities have greatly contributed to fostering methods and debates about how to use empirical and particularly qualitative methods to inform philosophical analysis. Philosophy of science in practice takes its cues from relevant scholarship in the integrated history and philosophy of science, historical epistemology, feminist philosophy particularly of science, and social studies of science, among other sources of inspiration (see for instance Feest & Sturm, 2011; Harding, 1998; Longino, 1990; Rouse, 2002; Stadler, 2017; Nersessian, 2022, among many other contributions). There are no hard and fast distinctions that can be drawn between philosophy of science in practice and many of these other fields, all of which pay very close attention to situating scientific efforts within their specific historical and social contexts. However the philosophy of science in practice is characterized by its close attention to the philosophical lessons learnt from examining the activities and commitments of working scientists. This feature is also what distinguishes scholarship in this field from other empirical approaches to philosophy, such as experimental philosophy, the main goal of which is to test philosophical theories through surveys and other methods (e.g., Machery, 2016) and philosophy *in* science, the main aim of which is to contribute directly to scientific inquiry (Pradeu et al., 2021).

We note from the outset that we do not take qualitative methodologies to be strictly separable from quantitative ones, particularly when it comes to inclusion and analysis of data such as texts, images, videos, and narratives, which are increasingly and often helpfully analyzed using statistical and computational techniques. Rather, we use the category "qualitative" to signal the highly contextualized and typically nonnumerical forms of data generated through methods associated with ethnography, interviews, participant observations, and various types of textual analysis.

Qualitative research is typically employed when researchers want to produce a deep and nuanced account or understanding of a given social phenomenon, and hence is particularly appropriate for use by those interested in understanding scientific practices and reasoning. Although beyond the scope of this article, the outcomes of such research can have important impacts such as informing scientific practice by drawing attention to key concepts or conflicts in a field, providing detailed accounts of a specific set of scientific practices, or fostering understanding of how technical decisions relate to social phenomena (Ankeny & Leonelli, 2024; Nersessian & MacLeod, 2022). However producing a rigorous and compelling philosophical account informed by qualitative research requires close attention to study design as well as reflections on what it means to do qualitative research in the context of the questions and themes typically pursued by those focused on the philosophy of scientific practices.

We begin this article by providing detailed advice on key considerations associated with each of the stages of qualitative empirical research that can be utilized to analyze scientific practices. We then identify three questions that anyone seeking to pay close attention to scientific practices must carefully consider: (a) how do our study design choices reflect our assumptions about which media and spaces are most relevant to explore in any philosophical studies of science? (b) why is taking a broader approach, and including social issues, necessary even for those interested in higher level philosophical issues? and (c) how do choices about analytic techniques used for qualitative research reflect underlying assumptions about what happens in science and what types of evidence are most relevant or useful?

We ground our discussion in a detailed and extended example from our own scholarship in the philosophy of scientific practices concerning the functions and implications of using specific organisms as models within various types of biological, psychological, and biomedical research (Ankeny & Leonelli, 2011, 2020). This work sought to contribute to the broader philosophical corpus of scholarship on the role of models, and particularly material models such as organisms, within the life sciences. We were also interested in providing conceptual nuance to ongoing scientific debates about the scientific status of, funding for, and implications of these and other practices associated with experimental organisms and model systems (e.g., Hunter, 2008).

Our research involved ongoing fieldwork and archival and textual research that we carried out separately and later jointly between 1996 and 2020 at a large number of sites and in a variety of contexts, with diverse informant-participants. The work yielded insights into how, why, and with which implications some organisms (but not others) came to be accepted as plausible representations of specific biological and even social phenomena, including organisms with very different characteristics and behaviors. These findings in turn informed our accounts of a range of epistemic and other philosophical issues connected to the role of material models within scientific practices, their relationships to other types of models, the significance of such models as sources of data and anchors for experimental cultures, the norms underpinning specific forms of scientific collaboration (Ankeny & Leonelli, 2016) among other topics.

Our extended example demonstrates the potential value of qualitative research methodologies for exploring scientific practices and reasoning, for instance, as ways to identify novel research directions, refine and augment philosophically motivated research questions, investigate the rationales and procedures through which particular scientific choices become ingrained in research practices, and question the implications of such habits vis-à-vis norms for what counts as "best practice" in particular scientific fields. However, as is the case with any type of qualitative research, our example also highlights the critical importance of reflection on study design, how particular choices embed unarticulated assumptions and may lead to notable limitations, and the need to consciously iterate study design as research progresses. We reflect on these issues and their methodological implications in some detail in the final substantive section of this article, where we discuss explicitly why analytic choices matter and what impact they are likely to have on research outcomes. These considerations are important to articulate in some detail when preparing to do qualitatively guided, philosophically focused explorations of scientific practices, given the recent turn to practice and relative absence of reflection on methods in this domain. In conclusion, we reflect on the advantages of using qualitative approaches in these contexts, and prospects for future research including areas and approaches within science ripe for exploration.

Stages of Qualitative Research in Philosophically Informed Studies of Science

Highly standardized organisms such as *Drosophila melanogaster*, the fruit fly, have been reference points for laboratory-based studies in the biological sciences for well over a century (Griesemer, 1990; Kohler, 1994; Rheinberger, 2010). They continue to play crucial roles as models for other organisms, particularly human, despite extensive critiques due to their inabilities to capture biodiversity and natural phenomena, and recognition of the considerable limits that these models can place on biological understanding (Bolker, 1995; Burian, 1993; Weber, 2005). These issues associated with the limitations of model organisms are particularly pronounced for those used for research in experimental psychology, such as rats and mice, where it is well-recognized that many of the behaviors and features under study are not characteristic of the wildtype, let alone of the humans being modeled (Davies, 2013; Huber & Keuck, 2013; Logan, 2019; Nelson, 2018).

An important example can be found in the study of alcohol addiction, where rodents feature as a key model despite marked differences in how those animals react to alcohol as compared to humans (Ankeny et al., 2014). Given the enormous influence of model choices on knowledge development in psychology, biology, and beyond, and scientists' continued consideration of them as suitable and plausible despite various critiques, investigating the role of model organisms in creating biological knowledge is an important task for philosophers interested in scientific reasoning and practice. At the same time, many of the assumptions and reasoning underpinning the choice of certain nonhuman organisms as a research focus, and the ways in which they are validated and justified, tend not to be articulated at length in scientific articles, and are often transmitted and maintained through exchange of informal know-how among researchers. Thus, the use of qualitative methods such as interviews and participant observation is particularly appropriate for pursuing a philosophical investigation of the function and implications of choosing and using specific organisms as models for biological research.

Suppose then that you wish to study the concept of a model organism in contemporary life sciences using qualitatively informed philosophical approaches. How do decisions made at each stage of the research shape the overall study design, inform philosophical analysis, and foster (or preclude) useful insights? In the following sections, we systematize and formalize the types of considerations that we have typically encountered in our own research practices according to the usual stages associated with qualitative research. We do not think that all of these stages will occur in the same order or manner in every research project, nor are we trying to be overly prescriptive. In addition, it must be emphasized that these stages will necessarily be highly iterative, with constant returns to earlier stages to refine previous decisions, informed by the research to date as well as the evolving goals of the research.

Stage 1: Identify Your Focal Question and Domain

Identify a broad question or phenomenon related to scientific practices, and a general domain or field in which you want to explore it. During this stage, the researcher is likely to review previous theoretical and more empirically informed philosophical, historical, and other types of literature on the topic and continuously refine both the question and the focal domain, which could be a scientific field or a particular research group, the underlying reasoning used, or even a concept. Sometimes those interested in scientific practices, including philosophers and scientists alike, search for a domain in which they can easily impose an already well-developed concept or view. This approach may help illustrate given ideas, but it does not constitute qualitatively informed research which is more open-ended and exploratory, precisely because that is meant to create space to challenge and potentially modify existing ideas about motivations, processes, and outcomes of research.

In our case, investigation was initially motivated by the desire to understand whether models used in the contemporary life sciences had distinctive characteristics as compared to models used in other scientific domains, and how their use shaped scientific practices, outcomes, and forms of reasoning. We narrowed our interests to model organisms, given their immense popularity and impacts within and beyond that specialized domain, and the fascinating opportunity that they seemed to afford to explore the significance of embodied, more-than-human interactions as a source of scientific insights. As concrete, material models, model organisms provide a window into how manipulating objects—and particularly, live organisms, which adapt and respond to human actions in a variety of surprising ways—may shape researchers' reasoning and imagination around the phenomena of interest. The ways in which data about model organisms are collected, curated, and modeled are another important source of insight, as are the institutional and funding structures established over the past 50–60 years to facilitate research on key model organisms, which in turn channeled further work on these models (though not necessarily funding: see Dietrich et al., 2014). We chose to focus on organisms recognized as key models by the U.S. National Institutes of Health, which meant acknowledging the significance of that institution, and the centrality of North American science in setting priorities for biological and biomedical research globally, as well as the impacts of specific forms of funding and institutional dynamics.

Stage 2: Select an Example

Select an example (or what some might call a case) that allows exploration of the question or phenomenon of interest associated with scientific practices. It is critical to select something that is (a) tractable in terms of the size of the project at hand (for instance, a PhD thesis vs. a large multiperson funded study); (b) represents a gap as a focus in the literature related to the philosophy of science in practice (at least in terms of the question or phenomenon of interest) or an opportunity to revisit and appraise existing assumptions (in a more or less critical manner); and (c) acquire preliminary background knowledge about scientific practices in this domain (including not only current practices but their histories), usually through published scientific literature but also informal discussions with relevant researchers. Choosing an example includes articulating a reflection on what it is likely to be an example or a case of, a question that is central to philosophical reflections on scientific practices.

In our studies, we realized that there were interesting philosophical questions raised by choice and use of model organisms, potential intersections with existing scholarship in the philosophy of science on uses of models and know-how within scientific research, and limited existing philosophical discussions of the role of experimental organisms in science (scholarship on the latter point increased significantly over the time period covered by our joint work: see for instance Davies et al., 2024). However, there was a vast scientific and grey literature on these species that could be mined for background, and which evidenced the existence of clearly defined communities of researchers devoted to their study. Given the complexities associated with studying more than one such species, and the distinctive histories that seemed to characterize them, we each decided to focus on a specific species (the nematode *Caenorhabiditis elegans* and the flowering plant *Arabidopsis thaliana*, respectively) to make the research more tractable. Ankeny started on this work in the late 1990s and pioneered the philosophically informed study of *C. elegans*; Leonelli was inspired by Ankeny's work to start on this topic in the early 2000s and settled on the study of Arabidopsis after discussion with Ankeny. These choices provided rich material and opportunities for qualitative investigation, but also had excellent potential to allow deeper questions about the underlying scientific reasoning and practices to be posed and answered.

Stage 3: Choose a Group or Locale

Make (an initial) decision about where the phenomenon of interest is likely to be instantiated in interesting ways, bearing in mind any relevant pragmatic and logistical issues, and assemble sources documenting the work and histories of those groups as found on institutional websites, materials disseminated within the communities or beyond them, and scientific publications. As we quickly discovered, each model organism community included hundreds of laboratories in locations around the globe, and we had to decide which locations to visit given our funding, citizenship and work/personal responsibilities (and thus our travel opportunities), and the availability and willingness of researchers to participate, all of which undoubtedly affected our perceptions as well as subsequent research and findings.[1]

These choices shaped our formal preparations and approvals required to conduct fieldwork, ranging from funding applications to support travel to the relevant locations to ethics clearance depending on national regulations in order to assess the potential risks and implications of research for ourselves and our informants. Much of this research occurred over 20 years ago: today, these requirements are likely to be more systematic and complex, and include more considerations with regard to ethics (e.g., amendments may need

[1] The challenges of gaining access to specific research domains or groups would deserve a paper in themselves, as illustrated by the ample relevant scholarship in anthropology. Given length constraints of this paper, we limit ourselves to noting that such challenges may be mitigated or amplified depending on scientists' existing perception of the humanities and social sciences in relation to their research. Many of the scientists with whom we engaged had no idea that the philosophy of science existed, let alone what the field could offer to them, even if in many cases they had read works within the field. This situation makes it difficult to attract their attention, especially in the case of busy principal investigators. More often than not, we found great interest in collaboration as soon as scientists realized what our goals and interests were; in cases, where our work was perceived as overly critical or as a "waste of time," we encountered resistance and hostility. These dynamics play key roles in determining who and what we worked with and on, and with which results.

to occur as a project is iterated and modified), formal data management plans, and other institutional requirements. Of course, these choices also affected our impressions of the scientific research that we were investigating and required various forms of triangulation and comparisons with other locales in later years.

Conscious reflection on trade-offs in research choices is always required, such as between convenience as compared to typicality, and the dangers of only exploring scientific "success stories" without incorporating consideration of what some might view as less successful communities or projects that often become invisible over time. On the latter issue, Ankeny (2001b) found the investigation of previous attempts to use the nematode *C. elegans* as a model to be extremely useful natural comparators (Ankeny, 2001a). Through analysis, it emerged that differences in fields and institutional locations, the availability of certain types of technologies, and the impacts of social and political alliances were critical influences on scientific practices: Arguably the nematode worm came to be important not only due to its natural characteristics but when associated with the social, economic, and political power of the Medical Research Council Laboratory of Molecular Biology in Cambridge (see also de Chadarevian, 2002; cf. Hilgartner, 2017) coupled with new technologies associated with genomics, but floundered in the previous periods when used by those working in nutrition science without the benefits of these resources (Ankeny, 2001a).

This research stage represents an important point at which iteration becomes critical: The choice of one or more group or location to study needs to be assessed in terms of its appropriateness for the focal question as initially articulated based on review of available published and grey literatures. The focal question may need to be rejigged accordingly depending on what the group or location permits you to study, or else the decisions made in various stages of the research may need to revisited and choices revised.

Stage 4: Plan and Perform Empirical Work

When planning and performing empirical work, researchers often begin with one methodology or approach (e.g., ethnography) and learn the key skills required to use it in the location in question. They must make a series of choices about what data are important to collect, and therefore what methods should be used. In our example, we were initially interested in how researchers thought and talked about their choices and use of various species, as well as how they conceptualized the goals of their research. We thus utilized interviews and observations of lab meetings, conferences, and other community interactions, and captured our observations in field notes.

We both began our direct engagements with model organism communities by visiting key laboratories associated with establishing these models and attending conferences sponsored by the communities focused on these organisms. When empirical work commences, it quickly creates additional occasions for reflection and refinement, and sometimes even overhaul, of study design. In the case of research on scientific practices within labs, we were confronted with the challenge of capturing the know-how associated with scientific practices (sometimes described as "tacit knowledge") in an accurate and meaningful manner that did not overly rely on post hoc propositional reconstructions such as those frequently found in scientists' own accounts of their practices or in more internalistic philosophy of science. These issues also raise what is termed the problem of embodied knowledge, namely that it can be difficult to ascertain scientific understandings that have become literally embedded in people and their practices. To address this problem, a researcher may decide to take photographs or videos, have detailed conversations with technicians or students, or spend time in a lab observing use of various techniques, as these can often permit glimpses into this type of embodied knowledge. But of course these approaches require specific types of skills and resources not only to produce such data, but also to analyze them. We used mostly written notes and photographs of research activities, which did not provide evidence as vivid as the use of videos, but could be mined through discourse analysis.

Refinements are likely to continue to occur about decisions made in early stages of the research process, such as which sites are most relevant for the questions or themes of interest. Lab work is heavily intertwined with practices in other settings, including classrooms and training programs, funding committees, administrative meetings, informal discussions at conferences, virtual interactions on social media or digital platforms, commercial production and marketing of relevant research instruments (hardware or software, reagents and media, microscopes and other visualization devices, and of course standardized biological specimens, in our cases), and so forth. Thus, we found it useful to attend graduate training classes on how to curate data about organisms, visit stock centers that store specimens for dissemination to researchers, participate in steering committees presiding over the allocation of funds to communities working with different species, and even learn techniques for working with the species of choice, all situations which provided important qualitative data that discussions and texts could not convey. For instance, through in-person visits to one of the Arabidopsis stock centers, Leonelli heard about the significance that initial classifications of plant specimens in the collections may acquire for experimental design down the line, including cases where mistakes made at the start of that process may become entrenched in the use of the specimens by the whole research community (Leonelli, 2007). This topic was one that we eventually explored at length as part of our philosophical analysis: Model organism traits are not simply those "naturally" associated with the wildtypes, but also include traits that come to be included in the strains that form the standardized collections or in specific experimental settings. We came to call these traits "induced" to highlight the partly artificial, constructed nature of model organisms, and the idea that such models are valuable precisely because they are simultaneously constructed and found in nature, and are both material and conceptual models (Ankeny & Leonelli, 2020).

Stage 5: Analyze and Interpret Data

Once some data have been collected, it is important to do initial analysis and make interpretative decisions. Again at this stage, choices must be made about what methods to use for data analysis. Images or material artefacts will require different approaches than textual analysis, including content, historical, structuralist, or even semiotic analysis; methods supported by artificial intelligence such as automated image recognition are increasingly popular given the quantity of data that tends to be generated even within a short period of fieldwork on a scientific topic (Donovan, 2023). All of these decisions come with underlying assumptions about the nature of the objects being analyzed and how meaning can be generated from them, as discussed in more detail below.

A critical and inseparable part of this stage is interpretation: Data collection already involves making choices that will affect future interpretive possibilities, but analysis narrows this process even further. Hence, it is crucial not only to consider the data that have been gathered but also potential missing data or gaps, particularly those that are a result of study design choices, to iterate accordingly to be able to fill these gaps through additional empirical work, or else to ascertain the likely causes and effects of these gaps on potential interpretations and incorporate these reflections into your analysis.

Leonelli discusses such a case in relation to classification systems used to describe organisms and related phenomena when disseminating data generated through model organism research. She initially adopted these classification systems because they were "actors" categories' articulated in her fieldwork in exploring how biologists were interpreting their findings, but she soon realized that these systems were ambiguous and contentious in ways that opened up philosophically relevant insights around disagreements and diverse practices among model organism researchers and the bioinformaticians in charge of curating their data (Leonelli, 2010). These findings led her to modify her initial plan to focus solely on lab-based research and extend her fieldwork to include meetings organized by biologists and bioinformaticians to debate classification practices, which meant modifying study design to include a much wider and more diverse group of informants than originally envisaged, drawn from a range of disciplinary backgrounds including computer engineering and statistics. The need to understand the background and skills of these—to her—novel domains ended up shaping Leonelli's subsequent research trajectory, resulting in projects fully devoted to the study of data science and related practices (e.g., Leonelli, 2016, 2019).

Analysis and interpretation also permit researchers to engage in a process of trial and error that allows consideration and further refinement of the philosophical ideas of interest as initially articulated in relation to the data. In the case of Ankeny's *C. elegans* work, she began her research by (rather uncharitably) proposing that the terminology of "model organisms" was rhetoric primarily developed to attract large-scale funding (Ankeny, 2001b). But as her research progressed, she began to articulate the complex ways in which researchers in the field use a range of practices (e.g., Ankeny, 2000) to form their overall concept of a model organism, how this concept was deployed in a range of different contexts within science, and how social, cultural, and institutional factors contributed to the evolution of this concept. The nematode was initially understood as a model that permitted production of a complete understanding of the fundamentals of biology, but these sorts of epistemic claims would not have been plausible but for the institutional context in which early research occurred (the Laboratory of Molecular Biology in Cambridge, U.K.), and particularly its access to longer term, blue skies funding and the close-knit community's culture of only publishing once research was truly complete (with papers of 300-plus pages articulating the complete cell lineages or neural connections setting the standards). By the time that the organism came to be associated with the genome projects of the 1990s, biomedical translation drove most modeling claims, and what was considered to be a publishable unit changed radically (i.e., short papers on small bits of genomic sequence became typical) due to this focus along with institutional pressures associated with tenure and promotion, competition to publish first, and growth of subcommunities with more variable norms.

More generally, this stage in qualitatively informed philosophical research often brings key concepts, classifications, standards, terminology, instruments, software, and other components into focus that are present in the scientific practices under investigation but that may have been invisible or assumed, or not obviously related to the philosophical questions of interest based on reading of the scientific literature alone or even in preliminary fieldwork. For example, published scientific research (particularly contemporaneous with the events under investigation) often does not discuss methodological, problem, or other choices (in our case, the choice of a particular species for intensive focus), with most documentation of these sorts of processes occurring in retrospective, often overly celebratory, and nonreflective literature written by scientists involved in these events.

Hence, in the interpretative stage, it is important for researchers to further extend their gaze and attention to context in several ways. First, these processes often require return to the history of the conceptual, material, and methodological choices and interpretations made by those in the scientific field in real time, which takes us back to Stage 2 including additional published, grey, and archival research. For Ankeny's project on *C. elegans,* these processes involved exploring long-ignored debates over genetic conservation which occurred contemporaneously with the organismal choice in the late 1960s and early 1970s, and which were important to understanding the motivations associated with it, as was a deeper understanding of the available technologies for observing and recording real-time cellular divisions in these earlier periods (Ankeny, 2003). In the case of Leonelli's work on *A. thaliana*, she combed through the newsletters circulated by the community between 1980 and 2000 to track the sharing of practical knowledge and tips about how to grow plants in the lab (Leonelli, 2007).

But just as importantly, there often is need to consider and analyze relevant broader elements, some of which might be construed both by many traditional philosophers of science as well as by scientists to be external to epistemic questions associated with scientific practice, but which we have previously argued are central to the ways in which science is practiced and around which some scientific communities and fields organize, which we call "repertoires" (Ankeny & Leonelli, 2016). These elements include conceptual and theoretical commitments, standards, infrastructures, communication strategies, social goals, funding, intellectual property, and institutional structures, among other factors.

Consideration of these factors and their potential influences on the philosophical questions under exploration often will require return to early stages in the research process but also reconsideration and refinement of the focal questions and the interpretation being developed. For instance through iteration, we both incorporated diverse types of science policy reports (some of which we obtained via our informants) on the future of certain types of biological research and sequencing technologies as gateways to understanding the influence of model organism researchers in the life sciences more generally. In turn, these broader trends helped us to better situate and contextualize the success enjoyed by concepts, models, infrastructures, and policies introduced by those communities, and their significant influences. For instance, through her research on the worm community, Ankeny contributed to collaborative historical research on the origins of the Bermuda principles for genomic data sharing (Jones et al., 2018) which were documented as having been initiated by members of the *C. elegans* community and had significant influence on the practices now associated with open science.

A final consideration that can assist with the interpretative stage of qualitative research on scientific practices is to develop comparative cases, in outline or in detail, such as adding additional locations or groups to the study, perhaps groups focused on a similar topic with different disciplinary training, and so on. Through such comparisons, it can become clearer what the variables are that could or should be compared for the investigative purposes at hand. So as part of the data gathering and analysis associated with articulating the reasoning associated with establishing and using *C. elegans* as a model organism, Ankeny identified and researched actual comparison cases of two "failed," much earlier attempts to use the organism in similar ways (Ankeny, 2001a). Comparison was also a key reason why, after initial discussions that started with Ankeny mentoring Leonelli's graduate research, we teamed up in our efforts to understand the concepts associated with model organisms: Our respective familiarity with two different communities fostered our abilities to reflect on shared practices, articulate significant differences, and propose relations to yet other uses of organisms as models and scientific modeling practices more generally.

Again, these processes will continue to be iterative and subject to refinement throughout the research even perhaps beyond initial publications. In the following sections, we turn to a more detailed analysis of several key issues relating to research design that are implicit in the account provided above but which warrant attention as they allow more reflection on the normative commitments associated with empirically informed studies of scientific practices.

Study Choices About Media and Spaces

In Stage 3 above, we briefly discussed the choice of media and spaces on which empirical research can focus when developing an analysis of philosophical issues relating to scientific practice. We now expand on this topic as one of the most significant in relation to the study of scientific practices from a philosophical perspective. As also exemplified by our own initial focus in approaching our research, there is still a strong tendency among philosophers interested in qualitative research to take the laboratory as an obvious starting point, a tendency informed both by existing excellent exemplars of this work (Nersessian, 2019) and by canonical laboratory ethnographies in early science and technology studies scholarship (Latour & Woolgar, 1987). While focusing on labs may be strongly informative for some questions, it is not an obvious or even relevant starting point for others. Indeed, the science and technology studies literature has long moved on from laboratory ethnographies to embrace multisited studies encompassing transnational networks and consortia; virtual collaborative platforms, crowdsourcing, or digital infrastructures; research at field stations, rural, or remote locations; or research including inputs from traditional and Indigenous knowledge systems (for an overview, see Sunder Rajan, 2022). Broadening our visions of where, how, and by whom science is practiced is well-supported by use of qualitative empirical methods.

In more recent work on evidential practices in organismal biology, for instance, we focused on a variety of sites and media through which relevant research is performed, including virtual platforms and infrastructures (Leonelli, 2016; Leonelli & Ankeny, 2012); consortia and communities of practice including "lay" contributors (Leonelli, 2019); and science policy debates where scientists engaged in discussion with entrepreneurs, history, and philosophy of science and science and technology studies scholars, and/or policymakers around the significance, potential, and implications of their work (e.g., Australian Academy of Science, 2017; Reardon, Ankeny, et al., 2016). These inclusions had clear methodological implications. Many interactions that did not initially appear relevant for our fieldwork suddenly became potential sources of evidence, including informal interactions, email exchanges, professional meetings, lab retreats, participation in steering or ethics committees, grant and article reviews, contact during other types of institutional activities, consultations, policy processes, and so on.

These activities provided significant opportunities to expand the scope of investigation and go beyond face-to-face observations or interviews as the only or best methods, with online interactions becoming a major source of insights and learning. These new directions also presented us with major practical and ethical challenges in terms of handling the resulting information as evidence: issues about informed consent, and decisions about what should be considered as confidential, personal, or off the record, meant that processes associated with obtaining ethics approval and doing the research itself required considerable reflection. Such processes helped considerably when we needed to determine which interactions would be acceptable as forms of data collection and which others would not, meaning that we could engage with the latter but only as general background and without being able to use them as cited sources available for analysis.

Confronting these complexities was not only useful, but necessary to our research, especially given our growing interests in understanding forms of scientific collaboration and coordination writ large (Ankeny & Leonelli, 2016, 2020). Opening up our conceptualization of the spaces in which and the media through which science is done allowed us to actively abandon assumptions that often lurk beneath even empirically driven studies of science with regard to how science is practiced. These processes deprivilege certain traditional actors (such as lab heads or Nobel prize winners) or at least force us to consider why we choose certain individuals or groups as a focus and allow us to think more creatively about who is best placed to shed light on issues that are most relevant to the considerations under study. For instance, when trying to understand the limitations of certain experimental techniques and how improvements were made over time that had considerable effects on the worm community's abilities to conceptualize the nematode as a model organism, having morning tea with the technicians who had worked in the lab for over 30 years, or interviewing a former researcher who left the lab before getting his PhD in part because of technological limitations, were much more fruitful lines of inquiry than reading the community's grey literature on these techniques and their evolution, let alone the published research literature.

This point brings us to a key issue revealed through attention to multiple sites and media in the context of studies of scientific practices: the crucial role that well-entrenched power dynamics, reputational cycles, and institutional settings play in structuring and channeling the direction and content of research. This issue is a foundational one in social studies of science, with a large corpus of literature devoted to methods and conceptual framings for analysts to make sense of how science is organized. Those seeking to explore scientific practices can learn much from such literature and techniques, notably that they always should frame their inquiries into the epistemology of science in such a way so as to permit consideration and interrogation of such systematic conditions, an issue that we explore in the next section.

The Importance of "Context": Investigating Social Structures

Science is not a level playing field, and philosophers of science have increasingly recognized the normative concerns that arise from unjust research systems and discriminatory practices. de Sousa Santos (2014) described the systematic undermining of knowledges that originate in vulnerable or stigmatized communities as a result of the dominance of science as a way of knowing as an "epistemicide" which results in the unwarranted elimination of relevant knowledge systems from consideration as contributors to science.

Our inquiry into the shape and size of communities working with model organisms quickly brought us to the realization that there were clear winners and losers in the race associated with what would come to be recognized as a reference model system for biological research particularly through large funding awards, and under which conditions such work would be regarded as reliable and robust. For instance, researchers with no access to next-generation genome sequencers would not be able to contribute fully to model organism research, given the prominence that such methods came to have in the field (Leonelli, 2017). Although comparative biological work beyond a few select model species has continued to grow in volume, diversity, and biological significance over the last decade, it also has been accompanied by uneven access to resources and investments (Ankeny & Leonelli, 2020).

These considerations present new conceptual dimensions which can be explored in philosophical inquiry, as well as novel opportunities to learn from social science and historical methodologies.

For instance, the investigation of scientific funding through different types of institutions, including how it is structured, pursued, implemented, and organized, is a critical example. Funding priorities not only can direct or constrain what research is done, but can influence or even shape the content of research itself. Key questions about trends in scientific practice focus on how researcher choices (e.g., technical, methodological, and conceptual preferences) and funding priorities are connected. Funding can channel or even canalize patterns of reasoning, and how people interpret and rationalize specific demands and priorities within a particular research context. Failure to access sources of funding, or the exclusion of specific groups from even being able to apply for funds, can have extensive implications for who are regarded as legitimate contributors to science in the first place, as funding reviews are often used as proxies for quality assessments in scientific circles (indeed, the ability to attract funding is a key criterion for academic hires in many parts of the world).

Some of these dynamics and patterns may remain invisible if solely quantitative approaches, such as bibliometric or citation analysis, are used to track and explore scientific practices, as data-intensive analysis can only provide insights into the volume and reach of funding opportunities (e.g., when used to identify key recipients of funding over time via their publications). Qualitative approaches permit research on the rationales and step-by-step thinking processes that underlie specific researcher or community activities and understandings relating to funding. Mixed methodologies can allow insights into key concepts associated with funding trends such as occurred with the emergence of the model organism concept (Dietrich et al., 2014). Participation in steering committees involved in lobbying funding bodies on behalf of the plant science community, for instance, was instrumental to Leonelli's understanding of the major role of community structures in directing and informing funding regimes in the United Kingdom (Parry et al., 2020).

In these examples, what we gain from using qualitative research to pursue philosophical questions about scientific practices is an understanding of the processes underpinning the trends observed. It also makes transparent underlying conceptual and epistemological choices that otherwise might well remain invisible.

Why Analytic Choices Matter

Questions not asked frequently enough by those engaging in qualitative research as part of philosophical studies of scientific practice relate to how our choices about analytic techniques or methods reflect our assumptions about what happens in science, and what types of evidence are most relevant or useful. Coupled with these considerations is the deceptively more concrete question of how we as philosophers make choices about which analytical techniques to use. The question is not merely practical or concrete but in fact requires us to make conceptual and ontological commitments in relation to the specific methodology, theoretical perspective, or research school associated with that approach to analysis. As scholars in the social sciences have argued, exposure to diverse modes of analysis allow researchers not only to make strategic and informed decisions about their methods, but also can permit them "to imagine new possible configurations" (Freeman, 2017, p. 4) for the ways in which their research is performed.

Philosophers of science are well-versed in analyzing language-based sources, given that arguments are the mainstay of our craft. Often this tendency, and our relatively higher comfort levels with analyzing texts (particularly published papers), means that we tend not to have the required skills to reflect on our methodological choices since we view content analysis as a default preferred method. In addition, given the long-standing disciplinary tradition associated with history and philosophy of science, many philosophers also are exposed to or even trained in use of historical techniques such as oral histories, the transcripts of which again are largely analyzed in terms of their content.

It is useful to go back to first principles when considering analytic choices associated with qualitative research particularly with regard to what analysis requires: In short, this stage of research is typically considered to include the organization, analysis, and interpretation of whatever qualitative data has been gathered, with the goal of answering the project's research questions in a productive and high-quality manner (for helpful overviews on the analytic methodologies to be discussed, see Denzin & Lincoln, 2017; Flick, 2013; Leavy, 2014).

Straightforward content analysis is an acceptable method, so long as its limitations are recognized: What is likely to be generated will be highly descriptive. Content analysis can be applied to a range of types of language-based data and may also be appropriate for visual imagery. The key focus for those using qualitative content analysis in the context of studies of scientific practice tends to be words and concepts, and the patterns in which they are used. So in the domain of our research discussed above, the "model-of" and "model-for" distinction (Keller, 2000, discussed primarily via analysis of published scientific work, but informed by her interactions with scientists and philosophical work by Morrison & Morgan, 1999) might be pursued using these techniques. The process for content analysis includes coding of data, likely in this case in terms of categories or concepts that are known to be key to the project's research questions.

Discourse analysis (or critical discourse analysis) also uses language-based sources but focuses on the ways in which participants express and communicate their views, values, and beliefs within their particular social contexts. Although this approach has been less common in philosophical studies of science than in science communication or rhetoric of science studies, this type of method might be particularly useful for analyzing policy documents relating to the practice of science including funding structures or media coverage of critical moments associated with scientific research (e.g., see Lysaght et al., 2006 on debates about human embryo research). For both methodologies, if coding is more complete rather than highly selective, it can reveal some concepts or terminology that were not anticipated when the research commenced, and hence can be structured to be more open-ended.

Note that these methodological choices prioritize certain types of sources as critical to the doing of science, notably those that are language- or text-based. Their rigor is highly dependent on the historical, sociocultural, and other types of contextual materials which are included in the analytical processes, including understandings of those practices and beliefs associated with the particular disciplinary and local cultures related to the research being explored. It also can problematically lead to reification of certain terms or concepts without adequately consideration of the contexts within which they emerged or are used. An excellent example can be found in the language used in discussions at field-specific or lab group meetings as compared to the rhetoric used in funding or institutional documents related to model organism research.

A second broad option is thematic analysis, which is an overarching or umbrella term used to describe a range of approaches focused on identifying patterns across qualitative data sets.[2] This approach is quite flexible as it is applicable to a range of research questions and can be used to generate theory- or data-driven findings (Braun & Clarke, 2006). Data coding is more systematic, with reorganization based on similarities which lead to categories and then themes, using methods such as memoing and coding that go beyond those that simply echo the questions posed to participants or preestablished categories. Depending on the research questions of interest, this approach might be useful for generation of material to support compare scientific groups and their work and is frequently used by those observing in lab groups or similar settings. It also is extremely open-ended, so may be appropriate for more exploratory research where the general area of interest has been identified but the key philosophical concepts or questions have yet to be articulated.

Framework analysis may be highly appropriate for many qualitative approaches to philosophical study of science practices, as it is used to examine data within a specific theoretical framework.[3] Hence, the researcher analyses data through the lens of a specific theory or model in order to understand how the data can be interpreted within it. This methodology can be especially useful when looking at a field or issue for which there is limited previous work or assessing the prospects or limits of a particular theory or model. Caution must be paid about not imposing a theory on the data: This approach to qualitative research still requires significant engagement with the data via

[2] Interestingly, a form of "thematic analysis" was explicitly discussed early in the historiography of science literature by Holton (1973, but traceable to work of his from the early 1960s) and further promoted by Merton (1975) as a potential interdisciplinary approach to understanding parts of scientific practice that are typically neglected.

[3] Explicit use of framework analysis has been less common in philosophy of science, although frames are frequently used in the field as analytic tools: for an extended and useful discussion of frame analysis in the philosophy of science particularly with reference to Thomas Kuhn's key concepts including immensurability, see Kornmesser (2018), including proposals for topics ripe for investigation in this manner.

iterative processes of coding, interpretation, and so on.

Grounded theory uses the collection and analysis of data to power the construction of hypotheses and theories, and typically begins with a very broad question or even a general domain in which data can be collected. Ideas and concepts are then said to emerge from the data, using coding and other techniques that overlap with thematic analysis as described above. However, it is critical to recognize the philosophical commitments connected to grounded theory techniques, which come out of a particular approach to sociology. Researchers using grounded theory seek to conceptualize the data obtained from participants without formulating hypotheses in advance. Hence, this approach is sometimes said to be aligned with positivism or postpositivism (Spencer et al., 2014), although constructive approaches to grounded theory have also been articulated and are widely used in the social sciences (Birks & Mills, 2011; Charmaz, 2006 argued that grounded theory can be coupled with diverse philosophical positions). Such an approach may be tricky for many interested in philosophical studies of science to employ given their underlying commitments about hypothesis testing. It also raises practical considerations about how to define the domain of interest in advance in a general way that still permits themes to emerge, but nonetheless may be attractive where time and budgets permit highly exploratory work to shape more narrowly targeted future research or to articulate research questions.

A final analytic methodology to consider when pursuing studies of scientific practices using qualitative techniques is narrative analysis, where the key focus is on using research participants' constructions of their own stories and narratives based on their experiences, which in some ways parallels methods often used in the history of science (for interesting discussions on narratives and narrative science more generally, see Morgan & Wise, 2017, and the articles in the special issue associated with this introduction). Note that this method remains merely descriptive unless there is interpretation at the meta-level of the participants' constructions of their narratives.

For any analysis that is performed, it is essential to make decisions about choices and their associated assumptions in a transparent manner: Hence, it is important for philosophers of science and other interested in epistemological questions associated with the study of scientific practices to include explicit methods sections in their publications, focused not just on how the data were gathered but also how they were analyzed, and ideally to make their data publicly available for verification and potential reuse. We return to these issues in our conclusions below.

Reflexive Conclusions

Our key message is that science is a distributed human activity and is situated in a complex network of sociocultural, political, economic, and other influences, what we have previously termed a scientific repertoire. It is critical when using qualitative approaches to the philosophical study of science to keep all of these influences in view. This distribution and situatedness is at the core of science itself, not just in the case of "Big Science" projects: Any research process will be scaffolded by, and interdependent with, material, conceptual, and social elements with histories and lives that go well beyond the science itself. Sequencing machines produced in California or China, funding guidelines from a variety of different national sponsors, dedicated scholarly societies and related conferences, newsletters and databases coordinated by smaller and larger research groups around the world, and of course nonhuman organisms themselves: These were all critical sites for our investigations about the representational value of model organisms as models. Qualitative research methods are essential for identifying, tracking, and understanding how science is distributed and situated, and how this context relates to philosophical questions.

Thus qualitative research methods used to study philosophical questions in relation to scientific practice can lead to identification of novel research directions, refinement and supplementation of research questions, investigation of the rationales and procedures through which particular scientific choices become ingrained in research practices, and questioning of the implications of such habits vis-à-vis norms for what does and should count as "best practice" in particular scientific fields.

We contend that it is important for philosophers of science and others who use qualitative methods to understand science to consider criteria for what marks quality in various forms of research. The classic articulation of quality markers in the social sciences relates to concepts such as credibility, transferability, dependability, and confirmability (e.g., Lincoln & Guba, 1985). These markers each are typically accompanied by certain methods: For instance, prolonged engagement with informants is necessary for research to have credibility, generation of thick descriptions is more likely to permit the reuse or transferability of these descriptions outside of the immediate domain of study, and transparency of data supports whether these data and their analysis are viewed as dependable and confirmable. However, even in the social sciences, there is limited consensus around precisely what counts as quality in qualitative research (see e.g., Tracy, 2010), with various scholars taking a range of positions depending on their overarching theoretical, methodological, or disciplinary norms.

Thus, there will never be a "one-size-fits-all" set of norms or criteria for philosophically informed studies of science. But, there are clearly issues that must be considered when planning and assessing such research, such as whether there is explicit articulation of the underlying theoretical perspective or the assumed conceptual commitments when making choices about methodologies and analyses, particularly in publications. To borrow a phrase from prominent social scientists who write on methodologies, the main point of such considerations is to ask the question, "how can an inquirer persuade his or her audiences that the research findings of an inquiry are worth paying attention to?" (Lincoln & Guba, 1985, p. 290).

Being able to ask such questions is particularly salient at a time when traditional research metrics, evaluative practices, and publication venues are undergoing rapid transformation due to increasing attention to research integrity, openness, new forms of communication and publication, and reproducibility. Acquiring a fine-grained understanding of scientific researchers' motivations and how they relate to the material, institutional, and social settings in which they occur is of paramount importance when attempting to shape the future of scientific institutions, methods, and policy. The value of qualitative methods for enriching our philosophical understandings of scientific practices is clear. More reflective use of such methods across a wider variety of scientific fields should be actively pursued, as these analyses not only shed light on philosophical questions related to scientific practices but also have considerable value for anyone wishing to improve science itself.

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