Science in Context (2021), **34**, 101–119
doi:10.1017/S0269889722000011

CAMBRIDGE UNIVERSITY PRESS

RESEARCH ARTICLE

An infrastructural account of scientific objectivity for legal contexts and bloodstain pattern analysis

W. John Koolage[1]*, Lauren M. Williams[1] and Morgen L. Barroso[2]

[1]Eastern Michigan University and [2]University of Connecticut
*Corresponding author. Email: wkoolage@emich.edu

Argument
In the United States, scientific knowledge is brought before the courts by way of testimony – the testimony of scientific experts. We argue that this expertise is best understood *first* as related to the quality of the underlying science *and then* in terms of who delivers it. Bloodstain pattern analysis (BPA), a contemporary forensic science, serves as the vaulting point for our exploration of objectivity as a metric for the quality of a science in judicial contexts. We argue that BPA fails to meet the minimal standard set by Helen Longino's social-procedural account of objectivity (1990, 2002). In light of some pressing issues for social-procedural accounts, we offer an infrastructural account of objectivity. This account offers what amounts to a friendly amendment to Longino's account and adds to the ways in which we might analyze social-procedural objectivity. Finally, we address an issue that is pressing in the legal context: given that scientific knowledge is delivered by individuals, not communities, at least in U.S. courts, we (may) need a way to evaluate individual scientific and epistemic agents. We suggest a means for making this evaluation that is derived from our infrastructural account of objectivity.

Keywords: Bloodstain Pattern Analysis; Scientific Objectivity; Social Procedural Objectivity; Democratization of Science; Expertise; Infrastructures; Legal Testimony; Intellectual Authority

Introduction

In this paper, we take up a set of questions and concerns that are illuminated by examining bloodstain pattern analysis (BPA) and its recent trials and tribulations through the lens of Helen Longino's social-procedural account of objectivity (1990, 2002). We argue that, in light of Longino's account of objectivity, recent objections to the use of BPA in US legal contexts are correct.[1] Our examination of BPA in light of Longino's account of social-procedural objectivity, however, reveals a pair of open questions regarding Longino's account. We resolve these questions with a friendly amendment to her account. The first question is general: how does a social-procedural account ensure that even its group membership norms are as objective as possible? The second question is local: how can an account of objectivity that focuses on groups and group processes interface with a legal system that highlights the knowledge of *individual* experts? Our exploration, we hope, provides more than just the groundwork for discussions of forensic sciences as sciences, of the role and nature of scientific expertise in legal contexts, and of social-procedural accounts of objectivity more broadly. By the end of the paper, we produce an account of social-procedural objectivity that frames the "social" component as an infrastructure, thus resolving several problems for Longino's account, including the ones noted above. We also demonstrate

[1]In this paper, we focus our arguments exclusively around the legal context of the United States. While we believe our work to elaborate Longino's social-procedural account of objectivity is quite general, our analyses of BPA and legal expertise assume the legal context of the United States. As a result, our arguments as they relate to BPA and its legal merits (such as they may be) may be quite difficult to generalize.

that current concerns over the use of BPA in legal cases are correct, and offer an initial framing of an interface between the social-infrastructural nature of objectivity and the testimony of individual experts in legal contexts.

In the United States, scientific knowledge is brought before the courts by way of testimony – the testimony of scientific experts. We argue that, for the purpose of legal decisions, the courts should only accept the testimony of scientific experts where the underlying science is (sufficiently) objective. Opposing Ian Hacking (2015), Inkeri Koskinen (2018) notes that the concept of objectivity is not merely negative: objectivity does not amount to merely reducing or eliminating certain biases or errors, but also carries a positive component. She puts this component (roughly) as follows: to say something is objective is to endorse it, tacitly saying that we rely on that thing and that others should do so too (Koskinen 2018, 7).[2] Koskinen identifies the positive component of objectivity as resulting from *successes* in averting or reducing epistemic risk that arises from the particularities of our cognitive capacities, for example illusions, idiosyncrasies, and collective biases (Koskinen 2018). Our account of objectivity agrees with Hellen Longino's social-procedural account (1990, 2002) in that the negative component of objectivity (at least) is met by properly structured epistemic communities. The positive component, however, is crucial for legal contexts, since lives may hang in the balance. While we do not address successes specifically in this paper, our infrastructural account suggests another set of possible successes for properly structured epistemic communities: the identification of infrastructures dynamics and activity in increasing and opening gateways. That is, our account takes Koskinen's positive requirement as critical and provides some additional kinds of potential successes to investigate.

We begin with Longino's influential account of objectivity (Longino 1990, 2002), which is both social and procedural (Hicks 2011), in order to demonstrate ways in which epistemic risks in the sciences may be averted or reduced.[3] At the heart of Longino's view are two important arguments: (1) well-structured epistemic (scientific) communities are open to transformative critique if they meet four core criteria for the sharing and evaluation of their central theories,[4] and (2) changes in membership should focus on adding or augmenting voices from traditionally excluded standpoints (an inclusion requirement).

Longino helps us to situate her account of objectivity by distinguishing between prescriptive and descriptive projects. She notes that some have foregrounded the prescriptive project, the Positivists for example. Here the idea is to locate the concept of objectivity in a logic of science, where it would be identified with "rationality" or some sort of formalism. Those who foreground the descriptive project, such as Kuhn (1962) or Daston and Galison (2007), locate the concept of objectivity in the (changing) uses of the idea in scientific communities, wherein it comes to appear as though objectivity is perhaps little more than the exercise of social power, or capricious and changing, culturally dependent norms. Specifically, she says, "Witnesses to the debate seem to be faced with a choice between two unacceptable alternatives: a logical analysis that is historically unsatisfactory and a historical analysis that is logically unsatisfactory" (Longino, 1990, 64). To address this problem, Longino suggests an account of objectivity which recognizes that the descriptive and normative elements are entwined. Her account is focused on identifying the

[2]The endorsement idea that Koskinen works with here traces directly back to Heather Douglas' work on objectivity, especially Douglas 2004.

[3]Many of the primary arguments for social accounts of objectivity rest on critiques of confirmation-based accounts of objectivity (see Longino 1990, for example). There are two main lines of critique of confirmation-based accounts of objectivity: first, appeals to Kuhnian or Quinean arguments against truth as a standard for judging scientific theories or practices; second, critiques of the value-free ideal (see Procter 1991). We hold that the first critique is weaker than many social objectivity theorists hold, siding with Sober and Hylton (2011). Thus, we think that the sciences are objective in more than one way (social-procedural and confirmation objectivity are consistent). The second line of critique of confirmation accounts, namely that the value-free ideal is false, *is*, in our view, an extremely good reason to insist on holding sciences to a form of social objectivity.

[4]The four criteria, explored at length in the paper, are (1) recognized avenues for criticism, (2) shared standards, (3) community response, and (4) equality of intellectual authority.

https://doi.org/10.1017/S0269889722000011 Published online by Cambridge University Press

epistemically promising prescriptive elements within rich descriptions of the sciences, and offering ways to bolster or improve these elements. It suggests that objectivity improves as we locate and ameliorate the epistemic practices and components of our sciences that lead to our scientific successes, while abandoning those that inhibit them. While we take no stand on whether her account will be historically satisfying, her idea appears to be in line with a particularist strategy: look at some cases of good scientific practice to extract some norms that obtain, and then consider some of those norms as the ones that make science (more) objective. Of her project, she says,

> My analysis makes no pretense to totality or completeness. It suggests, rather, a framework to be filled-in and developed both by epistemologists whose task is to develop criteria and standards of knowledge, truth, and rational belief and by historians and sociologists whose task is to make visible those historical and institutional features of the practice of science that affect its content. (ibid)

Thus, our paper serves to deploy Longino's analysis of objectivity to a problematic case of bloodstain pattern analysis, in a prescriptive manner, and then to make some friendly amendments to the analysis, as epistemologists do, hoping to expand the descriptive mission.

Bloodstain pattern analysis is a forensic science that purports to provide evidence from spatters of blood at the crime scene. This evidence is to be used in legal contexts for the purpose of rendering judgements, and as a result its practitioners are treated as scientific experts. We use Helen Longino's social-procedural objectivity (1990, 2002) to demonstrate that expertise in bloodstain pattern analysis is not backed by a science that exhibits a level of objectivity consistent with its use in legal decision making.[5] We focus on demonstrating that Bloodstain Pattern Analysis is not structured to succeed in reducing epistemic risks, and therefore cannot be sufficiently objective to be relied upon for legal judgments.

Longino's account of objectivity faces some challenges. Her account leans in part on the idea that the communities that drive increases in objectivity hold to a set of shared standards, among several other important features. The shared standards embed a problem: in order to engage in transformative critique of scientific knowledge, one must use the standards that have been set down by an established and long entrenched set of players. There are three objects that may be in need of transformation by the epistemic agents of a properly structured community: (1) the theories at the core of the science, (2) the standards by which those theories are investigated (investigation standards), and (3) the standards by which the investigation standards are themselves investigated (meta standards). The meta standards include the constraints that determine which voices can join in critique of the science.

One possibility for ensuring that all three objects are open to potential transformation is to open the sciences' doors to much greater participation. Not requiring the preset shared standards (either investigation or meta) for participants in transformative critique would also remove the possibility of an echo chamber effect. This, however, leaves the sciences open to a "cacophony of vulgar democracy," wherein there are few (if any) rules for how to, or who may, engage in a particular science. Thus, any good social-procedural account of objectivity must walk a line between leaving investigation and meta standards un-addressable (in an echo chamber) and leaving the scientists who steward a science's core theories on a par with anyone who seeks to engage those theories (a cacophony).

Longino's own account supposes that increasing diversity of membership in properly structured communities addresses concerns that (2) and (3) will be forever immune to transformative critique and not remain as they were at inception – in an echo chamber. Anna Leuschner (2012) argues that Longino's apparent wishful thinking, that inclusion will address the meta standards

[5]As noted earlier, our arguments focus on (and assume) the legal context of the United States.

https://doi.org/10.1017/S0269889722000011 Published online by Cambridge University Press

echo chamber, leaves a gap in her account. That is, Leuschner does not believe that Longino's shared standards and tempered equality of intellectual authority (2002) walks the line between the cacophony and the genuine possibility of transformative critique of the meta standards. We briefly examine attempts to address this issue offered by Philip Kitcher (2001, 2002, 2011), Anna Leuschner (2012), and Jaana Eigi (2019).

Our own view is that this apparent problem is resolved by recognizing that the insularity (echo chamber) concerns are a result of holding a system view of the sciences, rather than an infrastructural view. Longino focuses on altering the science "from within," wherein the science can be understood as an isolated system.[6] Systems, however, become infrastructures when they are connected to other distinct systems in such a way that that the connections lead to possible alterations (or constraints) on one of the connected systems. We will say more about this distinction later in the paper. That said, we agree with Longino that inclusion drives transformative critique and that a properly structured epistemic community increases the possibility of transformative critique.

The infrastructure concept we work with comes from Starr and Ruhleder (1996), Bowker and Starr (1999), and is furthered by Edwards, et. al. (2007). Our view is that objectivity is a function of a science's infrastructure, and, as a result, some infrastructures are well structured for objectivity of the sort necessary to generate a science that can be relied upon and others are not. Proper attention to and the development of an infrastructure serves to produce the successes necessary for objectivity – purely insular (or near enough) systems cannot be sufficiently objective for legal contexts.

A number of philosophers appear to advocate for this sort of approach without naming it, including Alison Wylie (2015), Saana Jukola (2016), Inkeri Koskinen (2017), and Longino herself (2002). We believe that our account offers a different set of interventions than those proposed by others, which also harmonizes with the impulses of other feminist philosophers of science in addressing echo chamber concerns. Our account is vulnerable to the critique that it provides no way to judge the individual experts who deliver scientific knowledge to the judicial system; this in turn, could falsely marginalize dissenting voices within a science. We address this concern at the end of this paper and, in doing so, offer some novel opportunities for philosophers of science.[7]

As a quick note before we proceed, we are not offering a demarcation criterion for the sciences. Our account is centered on identifying sciences from which experts may be drawn for *legal contexts*,[8] not on what counts as a science simpliciter. As a result, we rely on a weak form of "baptism" to identify the sciences that our account will then address. That is, we allow for lawyers and lawmakers to name the sciences in which they are interested for the purpose of making legal judgements. Our account is then aimed at identifying the objectivity of that science, and determining how to select a scientist from appropriate sciences. With that said, we turn now to the first core component of our account - a deep agreement with Longino regarding the social-procedural criteria that need to be met in order for a scientific community to meet the critical criteria for objectivity.

[6]This "from within" approach has some merit, especially insofar as it avoids calls to tear the sciences down and to start over in order to dismantle problematic background assumptions. It certainly calls to strategies similar to Patricia Hill Collins' "outsider within" (Hill Collins, 1986).

[7]In identifying a set of scientists as stewards for a set of scientific theories, we may also run afoul of a second form of critique. Peschard (2007), for example, offers insight on how lay people may be critical *within* the stewarding group. We do not address this concern in this paper. We believe our framework of "objectivity as a function of the quality of an epistemic infrastructure," can capture lay people both as participants in a science and *as scientists*, but we are open to the possibility that such an analysis may require greater care, as suggested by Preschard and others.

[8]Our aim is to give an account of the objectivity of a science for its use in legal cases, unlike Burch and Furman (2019) who use Koskinen's account of objectivity (2018) to draw a parallel between objectivity in the sciences and what makes certain legal practices objective.

https://doi.org/10.1017/S0269889722000011 Published online by Cambridge University Press

Longino's social and procedural account of objectivity

Longino's social-procedural account of objectivity revolves around effective transformative discourse within a scientific community. Effective transformative discourse enables the possibility of transformative critique; however, it does not ensure it.[9] The degree of objectivity of scientific knowledge is proportional to the amount of potentially transformative critique available to the scientific community in question. Transformative critique functions to limit or decrease the biases of individual scientists and the communities they form, resulting in the production of more objective scientific knowledge. Thus, where there is effective transformative critique, there are the sorts of successes that result from epistemic risk reduction – Koskinen (2018) argues that these successes are the hallmark of objectivity.

Transformative critique is facilitated by effective discursive interactions, which can only occur to the degree to which the following criteria are met: (1) there are venues for critical discourse; (2) there is uptake of critique by the scientific community; (3) there are public shared standards; and (4) a tempered equality of intellectual authority is upheld (Longino 2002, 128-135). It is worth noting that these criteria are necessary but not sufficient for effective discursive interactions, and that effective discursive interactions do not guarantee transformative critique. Furthermore, the criteria are met in degrees, so objectivity, in turn, comes in degrees. We turn now to the four criteria, as they offer the potential for evaluation and provide a minimal basis for objectivity.

The first criterion, "Venues for critical discourse" refers to an epistemic community's public modes of sharing and evaluating research in the field. It also requires granting criticism of research the same interest, emphasis, and number of locales as novel research. An increase in venues allows for more criticism to be shared in the community. The second, "uptake of critique" stresses the importance of paying attention and being responsive to criticism. An increase in uptake ensures that conversations between parties of different positions are reciprocal and encourages the transformative change that strives towards objectivity.

The third criterion, "public shared standards," serves to ensure the quality of critiques, the quality of scientific theories, hypotheses, and practices, and quality communication across participants. The quality of critiques is influenced by the relevance of the criticism. For criticism to be relevant, it must appeal to something, such as shared standards that the criticized hold. The quality of scientific theories, hypotheses, and practices are influenced by the public nature of shared standards. Having public shared standards allows for the science and its practitioners to be held accountable. The quality of communication across participants is influenced by the presence of a shared language. In order for different parties to have a constructive and transformative discourse, they must use the same language (or near enough) to ensure they are evaluating the same phenomenon. Additionally, appealing to shared standards in critiques, scientific theories, hypotheses, practices, and communication furthers the reduction of individual, subjective biases in knowledge production and evaluation.

The limiting nature of public shared standards is pertinent to the fourth criterion, "tempered equality of intellectual authority." This criterion refers to how members of an epistemic community regard others with respect to their capability for quality contribution. The requirement of tempered equality functions to open up discourse to those that are not in positions of power, allow for legitimate consensus based on the arguments and evidence provided (as opposed to social or political standing), and ensure scientific content is exposed "to the broadest range of criticism," from different perspectives (Longino 2002, 132).

As previously stated, transformative critique is not attainable through satisfaction of only one of these criteria. It is the interaction between venues, uptake, shared standards, and tempered equality that allows for new perspectives, interlocutors, and transformative critique. Each criterion

[9]Transformative critique is not ensured by the possibility of transformative critique, because a scientific community with the possibility of transformative critique may not have enough of each criterion, could have already achieved a high degree of objectivity, etc.

https://doi.org/10.1017/S0269889722000011 Published online by Cambridge University Press

is vital to increasing objectivity, and each influences the others. Of particular importance to us are the ways in which criteria number three and four - the public shared standards, and tempered equality – interact with each of the others. Specifically, Longino notes that repeated failure of uptake disqualifies a party from consideration as a tempered equal of intellectual authority. Public shared standards function as restrictions on who should be granted tempered equality of intellectual authority because they limit what counts as relevant criticism. Moreover, public shared standards can set the number, quality, and activity of the venues for critique. Tempered equality of intellectual authority is of special importance to feminist philosophers of science because this criterion allows for and requires cultivation of marginalized voices in the sciences. Cultivating the inclusion of marginalized voices allows for novel critique of the venues and shared standards that have excluded those voices.

This social-procedural account of objectivity provides the groundwork for identifying "sciences" that fail to meet the minimal requirements for objectivity. In the next section, we demonstrate how this account can be used to disqualify Bloodstain Pattern Analysis as an objective science - thus rendering it unsuitable for legal judgements and its experts otiose to judicial decision making. Of course, this method for identifying problematic sciences for judicial decision making can be generalized for use in other cases.

Bloodstain pattern analysis

Bloodstain pattern analysis (BPA) is a forensic science that purports to recreate the events of a crime from spatters of blood found at the scene. According to bloodstain pattern analysts, their methods are reliable enough to convict people of murder, sending them to prison or worse. These high stakes judicial decisions suggest that this science should be held to a high degree of objectivity. However, BPA fails to demonstrate successes in meeting Longino's four criteria for effective transformative discourse and, in turn, objectivity. This explains why our judicial system is currently turning away from BPA, disqualifying it for use in legal contexts according to Longino's social-procedural account of objectivity.

In 2006, Congress provided the National Academy of Sciences (NAS) $1,500,000 with which to conduct a study of forensic sciences within the United States (Gianelli 2012). NAS formed two committees for the task, the Committee on Identifying the Needs of the Forensic Sciences Community and the Committee on Applied and Theoretical Statistics of the National Research Council of the National Academy of Sciences. The committees sponsored eight meetings throughout the three-year period, which consisted of research and testimony from representatives in the various fields of forensic science, laboratory administration, academia, statistics, and law. During the committees' four closed meetings, they deliberated, reviewed, and drafted a report that was released in February 2009: "Strengthening Forensic Science in the United States: A Path Forward" (hereinafter, "the Report").

Within three months of publication, Justice Scalia cited the Report in a United States Supreme Court decision (Gianelli, 2012). He wrote in Melendez-Diaz v Massachusetts (2009): "Forensic evidence is not uniquely immune from the risk of manipulation . . . . Serious deficiencies have been found in the forensic evidence used in criminal trials."[10] Shortly thereafter, Congress held hearings, and multiple law schools held academic conferences, publishing written symposia and legal articles on the criticisms of forensic sciences and the recommendations proposed by the Report (Gianelli 2012).

Since the Report's revelations, the criticism of specific forensic science disciplines has become more pointed within the legal community.[11] Articles and symposia have been hyper-critical of

[10]Melendez-Diaz v. Massachusetts, 557 U.S. 305, 129 S. Ct. 2527, .2536-37, 174 L. Ed. 2d 314.

[11]Many longtime jurists who were unfamiliar with the ins and outs of the forensic disciplines touted by experts in the courtroom found the 2009 report to be a kind of epiphany. As described by Judge Harry Edwards, co-chair of the NAS committee, "I started this project with no preconceived views about the forensic science community. Rather, I simply assumed,

https://doi.org/10.1017/S0269889722000011 Published online by Cambridge University Press

courts' tendency to rely on forensic techniques and testimony that has been historically accepted when, in reality, "effectively no research exists to support the practice" (Beety 2016, 555). In an article from the Ohio State Journal of Criminal Law, Beety suggests that specific disciplines "arose out of crime scene investigations and law enforcement's search for compelling evidence to convict. In this unusual development, forensic results were not tested in a lab but rather in the field. Their reliability and importance were indicated by the rate of convictions for crimes, not by impartial scientific assessments" (Beety 2016, 544). Beety's concern for the origins of forensic sciences, like bloodstain pattern analysis, is indicative of the general sentiment within the legal community, namely that, "forensic science is incredibly useful, but its findings have not only been overstated, they have been procured by poorly trained individuals without the rigor of developing the science in a lab, rather than in a courtroom" (Beety 2016, 547). Expressly included in Beety's criticism of forensic sciences is the discipline of bloodstain pattern analysis.

As so aptly put in an article published in the Mississippi Law Journal, referencing the Report:

> The uncertainties associated with bloodstain pattern analysis are enormous . . . interpreting and integrating bloodstain patterns into a reconstruction requires, at a minimum: an appropriate scientific education; knowledge of the terminology employed (e.g., angle of impact, arterial spurting, back spatter, castoff pattern); an understanding of the limitations of the measurement tools used to make bloodstain pattern measurements (e.g., calculators, software, lasers, protractors); an understanding of applied mathematics and the use of significant figures; an understanding of the physics of fluid transfer. (Meckfessel Taylor et al. 2013, 1302)

The law journal articles referenced in this essay demonstrate that reform of the forensic sciences is strongly supported within the legal academic community. Perhaps more significant than that is the support from within the forensic science establishment. Leaders within this community have conceded the necessity of validating and creating oversight for forensic disciplines. Specifically, the American Academy of Forensic Sciences has embraced the recommendations of the Report, epitomizing the fact that validation of these forensic sciences—like bloodstain pattern analysis—is essential for preservation of the integrity of evidence in the court of law (Risinger 2018). Without validation and oversight, the current trend of law enforcement officers and "experts" testifying without any "scientific theories, methodologies, techniques, or data" in fields like bloodstain pattern identification will continue (Cooley & Oberfield 2007, 289). With this judicial landscape explored, we will now be able to more fully understand this landscape by examining how well BPA fares under scrutiny informed by Longino's four criteria for effective, critical transformation.

Criterion #1: Recognized avenues for criticism

If BPA is to be objective to the degree that it ought in order to be relied upon in legal contexts, it must have a plurality of recognized avenues for criticism - journals, conferences and so on. The International Association of Bloodstain Pattern Analysis (IABPA) does have a journal, but in the last three years, not a single issue of the journal has published a research article. Instead, the content of the Journal of Bloodstain Pattern Analysis has only consisted of information about IABPA conferences (CFPs, "training opportunities," etc.) and lists of IABPA committee members. The fact that the only journal attached to the BPA discipline publishes no original

as I suspect many of my judicial colleagues do, that forensic science disciplines typically are well grounded in scientific methodology and that crime laboratories and forensic science practitioners follow proven practices that ensure the validity and reliability of forensic evidence offered in court. I was surprisingly mistaken in what I assumed. The truth is that the manner in which forensic evidence is presented on television - as invariably valid and reliable - does not correspond with reality" (Gianelli 2012).

https://doi.org/10.1017/S0269889722000011 Published online by Cambridge University Press

research, much less criticism of that research, alone probably disqualifies BPA as a sufficiently objective discipline.

Criterion #2: Uptake of critique from the scientific community

BPA as a discipline was derived from the methods and training of one man: Herbert MacDonell (James 1999). MacDonell created the modern day understanding of BPA through experimentation in his home's basement laboratory, and propagated it in the early 1970s. He then used these experiments to support his manufacturing of BPA textbooks and educational materials. By the end of his career in the early 2000s, MacDonell had educated over 1000 law enforcement officers or scientists. Today, there are over 900 members of the IABPA. If these individuals were not trained by MacDonell himself, then it is highly likely that they were trained by one of MacDonell's students.

These facts pose a serious problem for the objectivity of BPA: the discipline's scientific community is not only incredibly small but deeply insular. When a scientific community is as insular as BPA's, it is unlikely to be an environment that encourages intersubjective criticism, and thus the hypotheses produced within it will likely fail to be challenged. When these hypotheses fail to be challenged, the background assumptions that are incorporated by the individual practitioners are not mitigated and the influence of potential bias on the scientific knowledge remains.

Criterion #3: Shared standards

For Longino, a necessary component of scientific communities, if they are to be objective, is a set of publicly shared standards of practice. Specifically, there are three types of shared standards: the core theories of the science, the standards governing the proper investigation of those theories, and the meta-standards by which the investigation standards are delimited.

The core theories of BPA can be found in its publicly available textbook (James & Eckert 1999). This text has very few references to other scientific literature: in the first four chapters more than one third of the citations are directly to MacDonell. Only one chapter of eight significantly references theories in chemistry and fluid dynamics that supposedly ground BPA's scientific rigor, and even then, the discussion of chemistry is limited only to the detection of blood using luminol and says nothing about the blood patterns themselves. The central theories of BPA are based on chemistry and fluid mechanics, but as the paucity of avenues of criticism and the self-referentiality of this text shows, there is no interaction between these sciences and BPA.

The shared investigation standards of BPA are centralized by the International Association of Bloodstain Pattern Analysts and its training and certification programs. But sources of possible critique are lacking. For example, many BPA analysts work alone, and their hypotheses are not checked by other analysts. Experiments are also nearly impossible to recreate because (1) crime scenes are unique, and (2) ethical scientific standards prevent reconstructing crime scenes with living humans. Because experiments cannot be replicated, BPA analysts may be in the dark about the rest of their communities' methods and practices. We should not be surprised, then, that the methods by which BPA analysts purportedly recreate the events of a crime have not demonstrated accuracy or reliability. Analysts have utilized dubious techniques like substituting human blood with theatrical blood that has neither the same chemical nor fluid dynamic properties. Additionally, analysts have utilized artificial tools that approximate actual crime scene blood patterns, such as liquid droppers and blood-covered sponges (Colloff 2018; Smith 2018). Even the founder of the discipline acknowledged that the "accuracy of his methods could not be quantified" (Smith 2018). Though BPA has its roots in the well-established sciences of chemistry and fluid mechanics, its investigative processes rely heavily on approximation and subjective interpretation. At the level of meta standards, nearly all of the authority in the BPA community continues to stem from Herbert MacDonnell and his students.

https://doi.org/10.1017/S0269889722000011 Published online by Cambridge University Press

Criterion #4: Tempered equality of intellectual authority

The BPA community fails to foster the kind of inclusion that Longino requires. The homogeneity at the top of the community's hierarchy - specifically, its overreliance on MacDonnell and his experiments - represents a failure to foster inclusion. There is no genuine inclusion of marginalized voices who hold epistemic standpoints that are likely to seriously reduce troublesome insularity and unnoticed assumptions. Importantly, this lack of inclusion occurs even as the BPA community allows nearly anyone to join, with qualification requirements that could be considered no more than minor inconveniences. BPA analysts are required to acquire neither significant law enforcement training nor substantial scientific education. All that is required to join their community of practice is the completion of a 40-hour, week-long course (Colloff 2018). Federal Rule of Evidence (702), does not require any further certification to testify as a BPA expert in a court of law. It is this odd arbitrary acceptance of a variety of individuals that draws attention to an important critique of Longino's, which we explore with the aid of Leuschner (2012).

Leuschner's Critique

Anna Leuschner (2012) provides a critique of Longino's account of objectivity that focuses on shared meta-standards,[12] those standards concerning who is able to contribute in potentially transformative discourse. Leuschner is most concerned with the designers and curators of the shared standards: those who construct and agree upon the public shared standards that, in principle, should allow for greater inclusion while at the same time maintaining the boundary between the theories and theorizers and a wider community. However, those who construct these influential shared standards must be those that are already involved and well entrenched in the scientific community. In other words, the biased, already entrenched scientists, who require the transformative critique for which Longino argues, are the same people who construct the standards that will or will not allow for effective transformative critique by way of inclusive practices.

Leuschner's concern can be summarized as follows: (1) the public shared (meta) standards themselves are never held to the procedures that allow for transformative critique, and (2) an assumption that the already entrenched scientists can create unbiased shared standards seems to undermine the purpose of Longino's project. In short, an echo chamber exists within Longino's account that allows scientists to remain untouched by transformative critique when they are setting the conditions for entry to their science (shared meta-standards). Below we provide a brief overview of two responses to Leuschner's concerns.[13]

Philip Kitcher (2001) provides a solution to the echo chamber around shared meta-standards and appeals to deliberative democracy by way of "ideal appropriate experts," representative deliberators, and the general public. Ideal appropriate experts are already established experts who agree on the specific outcomes of research. These experts tutor deliberators who represent relevant perspectives. Behind a veil of ignorance, these deliberators come to agree on which research agendas should be pursued, and relay this information to the broader public. Ideal decisions are produced on a case by case basis through ideal conversations of this sort. The idea is that the pairing of experts and tutored non-expert stakeholders can direct (at least somewhat) the sciences toward questions that are not merely of the result of a scientific echo chamber. In effect, this solution walks the line between the cacophony of vulgar democracy and the insularity of the

[12]It is worth noting here that Longino does not make a distinction between shared investigative standards and shared meta standards. Rather, "shared standards" refers to an amalgamation of the three types of shared standards we have elucidated, which are necessarily dynamic.

[13]A response to Leuschner's critique can be extrapolated from Longino's discussion of shared standards (2002). Longino emphasizes the potential for shared standards to change and be transformed, in addition to stating that there is no act of establishing shared standards, rather they operate by persisting across critique. Despite this potential response, we are inclined to agree with Leuschner about the existence of an echo chamber.

https://doi.org/10.1017/S0269889722000011 Published online by Cambridge University Press

sciences. It, however, does not appear to suggest a means for introducing effective transformative discourse around the meta-standards, it merely suggests a work around.

Leuschner's own solution to Longino's echo chamber is an amendment to Kitcher's solution (Leuschner 2012). She argues that Kitcher's solution is not sufficient because his account is also subject to an echo chamber problem, due to the insulation of the experts who tutor the deliberators when deciding who counts as having a relevant perspective. Moreover, this echo chamber is due to the impossibility of using the ideal deliberative process to choose the experts, because they must already be in place. Leuschner suggests expanding Kitcher's deliberative model with the introduction of political regulation. She argues that regulations brought about through a process of negotiations, which consider both epistemic quality standards and non-epistemic requirements of inclusion and pluralism, ought to be imposed on research projects. Leuschner argues that the question of who is qualified to contribute to any given research project ought to be determined by democratically legitimated political instances. These political bodies would act as a case-by-case system for checking the experts and discursive panels introduced by Kitcher.[14]

We believe that emphasizing the echo chamber that Leuschner indicates, and which she and Kitcher address, is misleading. Rather than resolving the narrow echo chamber puzzle, we suggest that philosophers of science and those who rely on the objectivity of some science instead turn their attention to the science's infrastructure. A science's infrastructure provides critical information about the possibility of transformative critique over its set of core theories. Moreover, attending to the infrastructure and its dynamics provides information about how the core theories are changed, which will include information about bias and bias reduction. That is, we suggest that the echo chamber exists in an extremely pernicious way for some sciences and less so for others. Further, we believe that the focus on specific echo chambers is emblematic of holding that systems are, alone, responsible for ordering their own discourse around shared standards. In our view, the concern that sciences must walk a line between the stifling silence of insularity and the cacophony of vulgar democracy is the result of failing to see how scientific systems connect to other systems (their infrastructure).

Infrastructure and objectivity

Our argument regarding the infrastructural approach to scientific systems is extrapolated from that of Edwards, Jackson, Bowker, and Knobel (2007), whose comprehensive account of the infrastructure framework was designed, specifically, for understanding issues surrounding cyberinfrastructures. In this report, they review several decades worth of theorizing about infrastructures, leaning heavily on an account of infrastructure from Star and Ruhleder (1996, 113), and flirt with the idea that the sciences can be understood using an infrastructure view. We embrace this flirtation, and suggest that understanding the social and dynamic dimensions of scientific epistemology as an infrastructure (1) resolves Leuschner's concerns about echo chambers, though it replaces that concern with some other concerns, (2) provides a distinction between scientists and participants in a science, resolving concerns about vulgar democracy, (3) highlights the need for two kinds of inclusion to increase objectivity (i.e., bringing those with differing standpoints into a science *as scientists* and in other cases *as participants* in the science), and (4) provides new avenues for directing the normative toolkit of philosophers of science.

[14]Jaana Eigi disagrees with Leuschner's solution to Longino's echo chamber problem. In direct response to Leuschner, Eigi claims that while political intrusion is helpful, it is not sufficient to bring about transformative critique. Instead, Eigi appeals to amending the common notion of shared norms, or shared standards, to bypass the worries about an echo chamber, endorsing a notion of shared norms from Isabelle Peschard whereby norms are understood as "shared practice[s] rather than specific shared beliefs and commitments" (Eigi 2019, 1). Understanding norms as practices allows for more flexibility within those shared standards so that Leuschner's problem does not arise. In other words, the criteria for inclusion can be subject to critique. This understanding would also encourage the inclusion of laypeople.

https://doi.org/10.1017/S0269889722000011 Published online by Cambridge University Press

Edwards et. al. (2007) summarize infrastructures as networks rather than systems. The network emerges as various, independently constructed systems that become linked by gateways. It is built in a modular manner, as a series of specialized modules that connect to form a network. As the network becomes more stable, the infrastructure comes to have a number of reasonably consistent features. Infrastructures are not tightly controlled, functioning rather as a structure of coordination among various local systems. Infrastructures are dynamic and social, and face a number of predictable opportunities and challenges. Their dynamics include: (1) reverse salients - structural barriers that prevent or hinder connections to further systems, (2) gateway-orphan dynamics, where new systems are connected to the infrastructure and other systems become orphaned (disconnected) from it, and (3) path dependence, wherein the underlying structure becomes increasingly invisible and constraining to future growth and the possibility of including additional systems.

To illustrate their point, Edwards et. al. offer examples for each of these kinds of dynamics. One phenomenon that serves as a reverse salient in developing a variety of infrastructures, for instance, is intellectual property rights: the ownership of certain ideas or processes may create substantial financial, conceptual, or trust related barriers to connecting systems. The gateway-orphan dynamic is obvious in a number of technologies, of which USB technologies are a prominent example, orphaning numerous other connectors and eventually making it impossible to connect certain devices to others. Path dependence is more difficult to observe, since it involves part of the path becoming invisible, but one reasonably clear example is the inability of other interfaces to unseat the QWERTY keyboard layout. We are so well trained to use this interface that it has become invisible to us as a constraint on other possible keyboard setups (among other possible changes to the interface). Another reasonably obvious example is the virtual impossibility of a transition to the metric system for machine tools and parts; the imperial system is simply "assumed," and constrains certain changes to how mechanics, at minimum, operate in the United States.

The exchange and evaluation of scientific ideas and processes, we argue, is subject to similar issues. For our purpose, of understanding the objectivity of a science, the focus is primarily on the second infrastructure dynamic - gateway-orphan dynamics. However, all three dynamic properties of infrastructures are worthy of attention from philosophers of science.[15]

We propose using Edwards et. al.'s infrastructural framework as a model for science, where a science is baptized in the legal context by the interests of the courts and policy makers. At the center of any science, from which an expert may be drawn, are the scientists who are directly tasked with developing, confirming, and creatively expanding the central set of theories of that science. In physics, for example, these theories might be something like classical mechanics, electricity and magnetism, quantum mechanics, statistical physics, special relativity, and quantum field theory (Stevens 1995). Physicists are the scientists who have facility with these theories, test them, and develop novel hypotheses and alternate accounts within this system of knowledge production. While physicists are the stewards of these theories, building them, manipulating them, and ensuring they are predictively successful, there are many others who participate, though less directly, in the transformative critique and transformation of these theories – they are participants in physics. The infrastructure of each science will be different. For example, physics has a reasonably rich infrastructure, while bloodstain pattern analysis does not, as will be described below.

[15]In this way, we partially agree with Hacking (2015, see especially page 27). Our object of interest is the epistemic flow between various systems - the knowledge to be gained from consulting local knowers is not itself being evaluated for its objectivity. On the other hand, we are assessing the objectivity of a science, as a function of its epistemic infrastructure; being connected to local knowers increases the objectivity of the science in question. Our purpose is to determine whether or not we should rely on experts from a specific science in legal contexts. Thus, we are partially disagreeing with Hacking - the objectivity of at least one underlying science does matter in this context and is being judged.

https://doi.org/10.1017/S0269889722000011 Published online by Cambridge University Press

In general, there are three sorts of gateways that connect a science to opportunities for transformative critique. First, there are gateways to other sciences. Second, there are gateways to practitioners, such as engineers, teachers, and lawyers, who use the theories but are not tasked with their stewardship. Third, there are gateways to other producers of knowledge who offer alternative theories, methods, and accounts of observations that appear to be about the same phenomena. We take indigenous knowledge or revolutionary science, such as heliocentric astronomy in the sixteenth century, to be examples of this third sort of system, to which a received science may open a gateway. These gateways are not "wide open." The non-steward participants in a science do offer opportunities for transformative critique, but because of the stewardship (privileged) position of the science's own scientists, as well as power dynamics, translational difficulties,[16] and path dependence, the flow of epistemic goods is uneven. In what follows, we briefly explore each of these three kinds of gateways, demonstrate that BPA lacks these gateways, and suggest that the study of these gateways is an important job for philosophers of science.[17]

Gateways between sciences offer opportunities for transformative critique. Not only do different sciences often involve facility with the same central theories, they also offer opportunities for what Adrian Currie (2018) calls methodological omnivory. As grounds for epistemic optimism, Currie argues that a science's epistemic circumstances are vastly improved when it can readily "steal" methodologies and concepts from other sciences. In this way, there is a gateway for the flow of methods and ideas from other scientists, who now participate indirectly in the critique and transformation of the science in question. Here we find an opportunity for critiques of both the theories themselves and of the investigative standards of a community (and associated methodological theories). Attending to this sort of gateway may therefore reveal the presence of transformative critique of some shared standards, or opportunities for such critique.

Of course, in the case of BPA, there are no gateways to reveal the presence of transformative critique. As previously discussed, while BPA was grounded using certain principles of chemistry, this relationship has not been maintained. As a result, BPA has failed to entice chemists into further discussion that could lead to transformative critique of the central theories of BPA. Put another way, BPA could increase its objectivity by strengthening its ties to chemistry and physics. Additionally, if BPA analysts were to highlight their role as stewards of their underlying theories, there would be greater opportunity for transformative critique, which in turn would improve the objectivity of their science.[18]

Gateways between sciences and practitioners, such as engineers, lawyers, and teachers, offer opportunities for transformative critique as well. These practitioners use theories and ideas in ways that offer opportunities not just for confirmation of theories, but for transformative critique, as the practitioners bend or break theories against the needs of their respective practices. Poznic (2016) points to an example of this kind of gateway. There are cases where concrete models, built by engineers, in this case an "organ on chip," become available to scientists as novel observations for the development and testing of theories. Moreover, practitioners do not share the same goals as the stewarding theorists, and yet share a language and facility with the central theories - this can generate opportunities for the transformative critique of the meta-standards as well.

Once again, BPA misses opportunities to open and make use of these gateways due to a lack of practitioners. The stewarding theorists are the experts upon whom lawyers depend,

[16]The infrastructure theorists note the need for "pidgin languages" to foster communication between scientists in very different sciences or knowledge production endeavors (see Edwards et. al. 2007).

[17]Other philosophers of science, Wylie (2015), Eigi (2017), and Jukola (2016) to name a few, have noted and advocated for this using other frameworks.

[18]We also note that BPA appears to exhibit path dependence. There has been little to no change in the underlying theories, despite some changes in methods (e.g. the use of computer models). The initial chemistry and physics are hidden behind the computer models. To increase objectivity, BPA could make these assumptions open to transformative critique as well. Path dependence can serve to prevent increases in objectivity by removing or hindering access of theorists to the assumptions of their modeling procedures.

https://doi.org/10.1017/S0269889722000011 Published online by Cambridge University Press

but there is no corresponding facility with the central theories of BPA on the part of the lawyers. As a result, these lawyers are not practitioners in the same way that engineers are in the case of physics, for example.

The third type of gateway for transformative critique, which BPA also fails to demonstrate, comes from engagements with "unorthodox," or extra-academic, communities of knowledge producers, who offer competing accounts of observations and competing theories. These gateways offer the epistemic opportunities suggested by Alison Wylie's "standpoint theory-derived principle" for extending Longino's norm of tempered equality of intellectual authority (Wylie 2015). Wylie argues that "in order to counteract the risks of insularity and the effects of dysfunctional group dynamics that can insulate foundational assumptions and norms of justification from critical scrutiny, well-functioning epistemic communities should actively cultivate collaborations with external communities whose epistemic goals, practices, and beliefs differ from their own in ways that have the potential to mobilize transformative criticism (Wylie 2015, 13). Of course, Wylie notes, these gateways may not always reach the level of dynamic, interactive pluralism. The gateway may be more closed to collaborators, as in the case of what she calls syncretic (tolerant but non-interactive) pluralism, interactions that may open the door for the transformative critique of theories, but not the goals of theorists, and so on.

Opening these gateways provides additional objectivity to any science, just as Wylie suggests. As a result, we agree with the impulse behind Wylie's principle and where sciences should open these gateways. Furthermore, we urge philosophers of science (or legal practitioners) to examine the nature (and presence) of such gateways when assessing the objectivity of a science for legal purposes.

Koskinen (2017) challenges Wylie's extension of tempered equality of intellectual authority, suggesting that when gateways are created other problems may emerge. Koskinen has two worries for the democratization of science as it relates to the objectivity of a science. The first is that the boundaries of a scientific community may not be particularly obvious. The second is that there are difficulties in ensuring that effective transformative discourse flows across potential gateways. Koskinen illustrates these concerns by considering the use of indigenous knowledge about floods and geology, the kind of case Wylie uses to advance her "standpoint theory-derived" principle for inclusion. Koskinen outlines the various ways in which the gateway that leads to the inclusion of extra-academic sources, namely the flood myths of various indigenous people, in turn excludes folklorists' critique of flood myths. Using the language of our framework, the folklorists are excluded, *orphaned*, from the infrastructure of geology. In sum, the boundaries of a community may be unnoticed, even where they would improve the opportunity for transformative critique, and favoring one standpoint may lead to orphaning other contested knowledge production endeavors. Koskinen suggests that these problems are exacerbated because the echo chamber of large transdisciplinary groups is not immune to orphaning relevant communities. As such, it becomes less clear who is to police the creation of gateways and attending to whether transformative critique can flow to the stewarding group.

The infrastructure framework offers a means for structuring both Wylie and Koskinen's insights, and a new set of duties for epistemic experts, such as philosophers of science. Monitoring the dynamics of gateway and orphan creation and the flow of potential for transformative critique across a science's infrastructure is consistent with sometimes applying Wylie's principle to increase objectivity, but also with sometimes ensuring that a research program's orphans (standpoint or otherwise) are attended to. Directing epistemic attention towards casting out to find methods, practitioners, and extra-academic agents of potentially transformative critique requires an asset-based attitude, where the stewards of the science and their collaborators (including epistemic experts, such as philosophers of science), look to non-scientists (or scientists of other sciences) for what they have to offer, rather than what they are lacking or what they can be given. Herein we find the primary novel suggestion of our infrastructural view of objectivity: attending to the gateway-orphan dynamics of the infrastructure cannot fall to the experts

https://doi.org/10.1017/S0269889722000011 Published online by Cambridge University Press

(scientists) of the science in question alone - it is their job to steward the theories and the possibility of transformation.[19] As Leuschner, among others, points out, they are not likely to be able to also monitor the epistemic infrastructure (especially the meta-standards), and are unlikely to be able to see the work of those who may be very different from them in an asset-based manner.

The infrastructure framework suggests, then, that the concerns regarding an echo chamber around meta-standards and investigative standards stems, at least in part, from thinking of sciences as largely isolated. They are not. Furthermore, a cacophony of vulgar democracy is not forthcoming, even if we look to include important, currently orphaned, standpoints. The central community's shared standards and requirement for uptake will not simply be overrun by looking to include currently orphaned epistemic systems. Nevertheless, the dynamics of infrastructures are a double-edged sword - they provide stability and opportunity for transformative critique across theories, investigative standards, and meta-standards, but they risk becoming invisible and subject to orphaning helpful knowledge producing communities. In this way, the echo chamber re-emerges, not as a circle, but as an ongoing obligation to asset-based attention to gateway-orphan dynamics.[20]

In sum, then, our infrastructural account suggests the following are the correct steps in assessing whether an expert's science is sufficiently objective for the purpose of legal judgements:[21]

(1) Identify the science of interest.
(2) Analyze said science's central system's venues for critique, the uptake of critique, the public shared standards (both investigative and meta), and the degree to which it treats its participants with respect to intellectual authority.
(3) Analyze the other systems to which the central system connects, particularly other sciences, practitioners, and extra-academic communities.
(4) Note any identifiable, orphaned (excluded) systems.

These steps should produce judgements about the science underlying some expert's testimony and whether it can be relied upon for legal judgements. A science that may be relied upon will have a wide and diverse infrastructure, wherein the infrastructure plays a role in in eliminating or reducing biases in the theory, investigation standards, and meta-standards and serves to direct the possibility of transformative critique towards its stewarded theories. Furthermore, a science that may be relied upon will have numerous venues for critique; its stewards will demonstrate uptake of critique from within and without, and they will treat participants with (tempered) equality of intellectual authority. Additionally, a science that may be relied upon must be identifiable as a science by a reasonably wide set of participants in legal decision making, otherwise it will not be baptized for judicial decision making. Finally, stewarding scientists (and other experts, such as philosophers of science) should attend to the dynamics of the infrastructure, including reverse salients, orphan-gateway dynamics, and path dependence.

It is also of note that the infrastructural account provides guidance with respect to another concern raised by Longino:

> The tempered equality condition also raises complex questions of community membership. It requires both that scientific communities be inclusive of relevant subgroups within society supporting those communities and that communities attend to criticism originating from

[19]The stewarding scientists are not offering something to others who need it, rather the gateway only works when the scientists recognize the assets of the other groups - a host of literature (e.g. Wylie 2015, Koskinen 2018, and so on) supports the idea that scientists may be fairly myopic in this sort of task.

[20]This ongoing obligation to asset-based inclusion is similar to Eigi's call for accountability and responsiveness, in addition to Longino's tempered equality. Communities must recognize others as having something worth contributing.

[21]And has, as a result, has taken steps to reduce the sexism, racism, and classism of our social world, which infect our theories and our standards for evaluating them.

https://doi.org/10.1017/S0269889722000011 Published online by Cambridge University Press

> "outsiders." It makes us ask what constitutes the "we" for any given group, and what the criteria are for providing an answer. Are "we" those who actively engaged in producing knowledge of a certain kind for a certain aim, as members of a laboratory group, or should "we" encompass also all those potentially impacted by that knowledge? (Longino 2002, 133-134)

Where tempered equality has to walk the line between the potential cacophony of vulgar democracy and participation (inclusion), the infrastructural view provides a structure for answering these questions. Inclusion is critical to the central system, but that system needs to be connected by gateways to other communities. As a result, what appear to be unfinished questions for tempered equality are now questions about the infrastructure, and analyzed in terms of the flow of the potential for transformative critique across the infrastructure's gateways toward the central theories, the investigative standards, and the meta-standards. Tempered equality stands as a standard for how we treat all participants, but not as a standard for how to determine how we include or exclude participants.

All that remains now is to consider the experts who are to deliver these sciences to legal decision makers (in at least U.S. legal contexts). Our account makes the communities that make up the infrastructure responsible for the science's objectivity. As a result, it is possible that individual participants may or may not be well suited for the delivery of testimony regarding the science's core theories and findings.

Objectivity and recalcitrant experts

In our account of objectivity, in legal contexts it is a science's infrastructure that forms the basis for a judgement of its objectivity (i.e. whether a science may be relied upon for the purpose of legal judgements). Where the science is a mere system or is quite isolated from the possibility of transformative critique because it has not reached out or been reached out to by other epistemic communities, it is not sufficiently objective. This account, however, appears to fail to provide guidance on whether or not the objectivity of individual scientists, within a science, can be more or less reliable for legal purposes. We have in mind examples such as S. Fred Singer or the tobacco scientists of years gone by (Tong and Glantz 2007). Assuming that being objective is an aim of any good science, we have indicated that scientists (the stewards of the theories in question) and other participants in the science must assume a certain attitude: an asset-based attitude toward infrastructure dynamics (in particular, gateway-orphan dynamics), seeking out (especially) extra-academic or non-orthodox practitioners. Evidence of this attitude would serve as a way of identifying scientists who take the potential for transformative critique, and as a marker of the degree to which an individual practitioner is a more or less objective member of their community.

Saana Jukola raises this concern regarding science done by "commercialized" researchers in her 2016 paper, "The Commercialization of Research and the Quest for the Objectivity of Science," where she focuses on the particular case of tobacco researchers. In it, she agrees that objectivity is not properly identified by looking at properties of individuals, but rather that the objectivity of an individual is derivative of the properties of the community to which they belong.[22] Communities that are organized around commercial practices suffer several problems (Jukola 2016). Jukola argues that the interests and funding of research for commercial purposes impact research by (1) limiting the critical point of view, (2) restricting or limiting study design options, and

[22]For more on the idea of the objectivity of individuals being derived from the objectivity of the community to which they belong, see Nelson (1993).

https://doi.org/10.1017/S0269889722000011 Published online by Cambridge University Press

(3) restricting publication and data sharing. In our framework, the commercialization of research restricts the opportunities for gateways which increase the possibility of transformative critique.[23]

Jukola's concluding remarks suggest that she does not see the individual as a good target for analysis of objectivity, and that instead groups are responsible for the trustworthiness of a research program. Her central concern is to draw the attention of philosophers of science to the greater context in which research occurs, especially including science policy decisions. Science policy, she argues can directly impact the motivations, attitudes, and attention of scientists, and steer them away from quality self-policing (and away from behaviors that increase the possibility of transformative critique). As a result, in order to retain a dedication to the possibility of transformative critique for investigative and meta standards, researchers must adopt negative attitudes towards isolating behaviors and should assess their communities for troubling motivations.

Longino's 2002 account of objectivity provides a good way of thinking about the concern that Jukola raises about the fact that Longino's uptake criterion and her tempered equality criterion appear to be at odds. How can we cultivate truly dissenting voices while expecting those same dissenters to genuinely meet the uptake criterion on the individual level? Jukola's take on this is as follows: scientists' funding and policy context makes it difficult for them to take certain results or views seriously. Jukola's solution is to suggest that researchers should increase participation (perhaps including philosophers of science to monitor the relation between these contexts and the conditions of research) and to make visible shared standards around the role of funding and policy in research. That is, uptake and dissention do not have to take place in individuals, but rather in well-formed communities. Our solution is similar: sufficiently objective communities will include gateways to other communities that provide transformative critique of the investigation and shared meta-standards of the stewarding group, members of the stewarding group must adopt an attitude of tempered equality toward members of the gatewayed groups, and efforts must be made by members of the stewarding group to seek out orphans of their infrastructure. As a result, we agree that this problem for Longino is one of appearance only - communities, not individuals, must balance dissention, uptake, and the other transformative critique enhancing practices.

The resolution of the apparent problem does leave us with an unresolved issue in legal contexts, though. Since individual scientists, not communities, provide testimony to the courts, individual experts need to be sufficiently objective, not just by way of participation in a community, but also in terms of willingness and ability to present the received view of the stewarding group. This seems to fly in the face of the feminist project to which Longino's conception of objectivity so rightly belongs. Experts must expressly dissent from stewarded views when those views are not sufficiently objective (especially insofar as they may be sexist, racist, and so on). As a result, we believe that in legal contexts the science itself should be judged for sufficient objectivity in the ways we have argued, but the individual providing the testimony must also reflect the same good making features of the community - the individual expert must also demonstrate the attitudes that align with increasing the possibility of transformative critique. That is, the individuals may not be mere dissenters *when they provide testimony in legal contexts*. If they dissent from the stewarding group's received view, they must also display uptake (an ability to express the received view in shared terms) and an asset-based attitude toward gateway-orphan dynamics (i.e. they must be able to attend to other communities in the infrastructure and have some sensitivity to the orphaning of other communities). Of course, these attitudes are required of those presenting the received view as well. As a result, not just any scientist can offer testimony in a way in which it may be relied upon for legal judgement - only some scientists are capable of properly expressing the science and its objectivity. Additionally, this is not at all to say that sciences should not include dissenting scientists for the purpose of increasing objectivity.

[23]It is no great leap to see a parallel between Jukola's concerns about commercialized research and the concerns we raised about the behavior of the BPA community. There is an entire training and insular publication industry at stake for some BPA practitioners.

https://doi.org/10.1017/S0269889722000011 Published online by Cambridge University Press

We suggest that individual experts can be evaluated based on their epistemic attitudes that align with increasing (or at least not thwarting) the possibility for transformative critique. This attitude allows us to judge individual scientists on the basis of the role they can (and are willing to play) for the purpose of making legal decisions. Also, in agreement with Jukola, we hold that scientists must have appropriate content knowledge (facility with the confirmed theories of their science), and, as a result, it is for the stewarding scientists to provide testimony, not just any participant in the science.[24]

Conclusion

We set out to offer a framework through which to expand our understanding of (good) scientific expertise for legal contexts. We have argued that in order to provide testimony in U.S. legal contexts, especially the forensic sciences, an expert must be drawn from the core science, having facility with the theories in question. Additionally, said expert should mirror that science's openness to transformative critique and show attentiveness to infrastructural dynamics that are required for the its objectivity. During our investigation, we have suggested that communities of scientists are in need of partners in attending to infrastructural dynamics, especially if new gateways are to be asset-based and seeking of new participants. We have also noted that, though interventions may be required, they are not as straightforward as Kitcher (2001) or Wylie (2015) suggest, but also rest on a different structure than Eigi's (2017, 2019) interventions. That said, we do not argue that we are providing a better account than those mentioned here, merely an alternative.

Additionally, we have shown that a social-procedural account of objectivity can illuminate and justify the turn away from bloodstain pattern analysis in the U.S. legal context. BPA lacks, or fails to maintain or enhance, gateways between itself and other sciences, other practitioners, and other communities of knowledge producers. BPA quite simply fails to generate a community of practitioners who can sustain or generate transformative critique, and in doing so, isolates itself as a disconnected system. We have set a reasonably high bar for sciences in legal contexts, which in turn suggests that (1) new, exploratory methodologies are not well suited for legal decision making, and (2) old, entrenched, and insular practices are equally suspect.

In the end, we have not provided a complete account of the concept of objectivity, but rather a novel take on how such a conception may be used to determine if a science is one from which experts may be relied upon in legal contexts. In line with Hacking (2015), we argue that invoking objectivity is unlikely to resolve disputes. Rather, we believe that noticing the epistemic goods that give rise to a judgement of objectivity is a necessary first step in the selection of experts, especially in high stakes judicial decisions, for the purpose of resolving (legal) disputes.

Acknowledgements. We would like to thank Collin Lucken for his extremely helpful (and transformative) critique of several sections of this paper. We are also indebted to a number of communities who received us kindly as we worked out our view. We owe our serendipitous introduction to the infrastructure literature to Stephanie Hall. And, many thanks to several excellent editors at *Science in Context* and a pair of anonymous referees. Thank you all.

References

Beety, Valena E. 2016. "Cops in Lab Coats and Forensics in the Courtroom." *Ohio State Journal of Criminal Law* **13**:543–65.

Bowker, Geoffry C. and Lorraine Star. 1999. *Sorting Things Out: Classification and Its Consequences*. Cambridge, MA: MIT Press.

Burch, Matthew and Katherine Furman. 2019. "Objectivity in Science and Law: A Shared Rescue Strategy." *International Journal of Law and Psychiatry*. **64**:60–70.

[24]We recognize this does little to answer questions regarding who counts as an expert when a science itself is in question, as appears to be the case, for example, in McLean vs Arkansas in 1981. We imagine that the objectivity of the sciences in question would matter (contra Haking 2015), but, as to how, we leave as a future project.

https://doi.org/10.1017/S0269889722000011 Published online by Cambridge University Press

Colloff, Pamela. 2018. "Blood Will Tell, Part I." https://features.propublica.org/blood-spatter/mickey-bryan-murder-blood-spatter-forensic-evidence/ (last accessed April 18, 2022).
Cooley, Craig M. and Gabriel S. Oberfield. 2007. "Increasing Forensic Evidence's Reliability and Minimizing Wrongful Convictions: Applying Daubert Isn't the Only Problem." *Tulsa Law Review* **43**:285.
Currie, Adrian. 2018. *Rock, Bone, and Ruin*. Cambridge, MA: The MIT Press.
Daston, Lorraine and Peter Galison. 2007. *Objectivity*. New York: Zone Books.
Douglas, Heather. 2004. "The Irreducible Complexity of Objectivity." *Synthese* **138**:453–473.
Eigi, Jaana. 2017. "Different Motivations, Similar Proposals: Objectivity in Scientific Community and Democratic Science Policy." *Synthese* **194**:4657–4669.
Eigi, Jaana. 2019. "How to Think about Shared Norms and Pluralism without Circularity: A Reply to Anna Leuschner." *Studies in History and Philosophy of Science*. **75**:51–56.
Edwards, Paul N., Steven J. Jackson, Geoffrey C. Bowker, Cory P. Knobel. 2007. "Understanding infrastructure: Dynamics, tensions, and design." Report, History and Theory of Infrastructure: Lessons for New Scientific Cyberinfrastructure workshop, University of Michigan, Ann Arbor.
Gianelli, Paul C. 2012. "The 2009 NAS Forensic Science Report: A Literature Review." *Faculty Publications* **48** (2):378–93.
Hacking, Ian. 2015. "Let's Not Talk About Objectivity." In *Objectivity in Science*, edited by Flavia Padovani, Alan Richardson, and Jonathan Y. Tsou, 19–33. New York: Springer.
Hicks, Daniel. 2011. "Is Longino's Conception of Objectivity Feminist?" *Hypatia* **26** (2): 333–351.
Hill Collins, Patricia. 1986. "Learning from the Outsider Within: The Sociological Significance of Black Feminist Thought." *Social Problems* **33**:14–32.
James, Stuart H. 1999. *Scientific and Legal Applications of Bloodstain Pattern Interpretation*. Boca Raton: CRC Press.
James, StuartH. and William G. Eckert. 1999. *Interpretation of Bloodstain Evidence at Crime Scenes*. Boca Raton: CRC Press.
Jukola, Saana. 2016. "The Commercialization of Research and the Quest for Objectivity of Science." *Foundations of Science*. **21**:89–103.
Kitcher, Philip. 2001. *Science, Truth, and Democracy*. Oxford: Oxford University Press.
Kitcher, Philip. 2002. "The Third Way: Reflections on Helen Longino's The Fate of Knowledge." *Philosophy of Science* **69** (4):549–559.
Kitcher, Philip. 2011. *Science in a Democratic Society*. New York: Prometheus Books.
Koskinen, Inkeri. 2017. "Where is the Epistemic Community? On Democratization of Science and Social Accounts of Objectivity." *Synthese* **194**:4671–4686.
Koskinen, Inkeri. 2018. "Defending a Risk Account of Scientific Objectivity." *The British Journal of Philosophy of Science*.
Kuhn, Thomas S. 1962. *The Structure of Scientific Revolutions*. Chicago: University of Chicago Press.
Leuschner, Anna. 2012. "Pluralism and Objectivity: Exposing and Breaking a Circle." *Studies in the History and Philosophy of Science* **43**:191–198.
Longino, Helen. 1990. *Science as Social Knowledge. Values and Objectivity in Scientific Inquiry*. Princeton: Princeton University Press.
Longino, Helen. 2002. *The Fate of Knowledge*. Princeton: Princeton University Press.
Meckfessel Taylor, K.C., Mariette Elisabet Dirkx, William McIntosh and W. Tucker Carrington. 2013. *CSI Mississippi: The Cautionary Tale of Mississippi's Medico-Legal History*. Available at SSRN 2269446.
National Research Council. 2009. *Strengthening Forensic Science in the United States: A Path Forward*. National Academies Press.
Nelson, Lynn Hankinson. 1993. "Epistemological Communities." In *Feminist Epistemologies*, edited by Linda Alcoff and Elizabeth Potter, 121–159. New York: Routledge.
Peschard, Isabelle. 2007. "Participation of the Public in Science: Towards a New Kind of Scientific Practice." *Human Affairs* **17**:38–153.
Poznic, Michael. 2016. "Modeling Organs with Organs on Chips: Scientific Representation and Engineering Design as Modeling Relations." *Philosophy & Technology* **29** (4): 357–371.
Procter, Robert. 1991. *Value-Free Science?: Purity and Power in Modern Knowledge*. Cambridge, MA: Harvard University Press.
Risinger, D. Michael. 2018. "The Five Functions of Forensic Science and the Validation Issues They Raise: A Piece to Incite Discussion on Validation." *Seton Hall Law Review* **48**:719–32.
Sober, Elliott, and Peter Hylton. 2011. "Quine." *Proceedings of the Aristotelian Society*, Supplementary Volumes, **74**:237–299.
Smith, Leora. 2018. "How a Dubious Forensic Science Spread Like a Virus." https://features.propublica.org/blood-spatter-analysis/herbert-macdonell-forensic-evidence-judges-and-courts/ (last accessed April 18, 2022).
Stevens, Charles. 1995. *The Six Core Theories of Modern Physics*. Cambridge, MA: The MIT Press.
Star, Susan Leigh, and Karen Ruhleder. 1996. "Steps Toward an Ecology of Infrastructure: Design and Access for Large Information Spaces." *Information Systems Research* **7** (1): 111–134.
Tong, Elisa K., and Stanton A. Glantz. 2007. "Tobacco Industry Efforts Undermining Evidence Linking Secondhand Smoke with Cardiovascular Disease." *Circulation* **116** (16): 1845–1854.

Wylie, Alison. 2015. "A Plurality of Pluralisms: Collaborative Practice in Archaeology." In *Objectivity in Science*, edited by Flavia Padovani, Alan Richardson, and Jonathan Y. Tsou, 19–33. New York: Springer.

W. John Koolage is a professor of philosophy and the Director of General Education at Eastern Michigan University. His current research interests are general and feminist philosophy of science, philosophy of psychology, as well as teaching and learning.

Lauren Williams is an adjunct professor at Eastern Michigan University. Her current research interests include philosophy of science (objectivity, theory production and selection), feminist theory (oppression and privilege), social epistemology, and disability justice.

Morgen Barroso is a law student at the University of Connecticut School of Law. She is expected to receive her Juris Doctorate in May 2022 and is Editor-in-Chief of the Connecticut Public Interest Law Journal. Her current research interests cover the fields of legal philosophy, the disproportionate impact of legislation on marginalized populations, human rights and post-conflict justice, and philosophy of science.

Cite this article: Koolage, W. John, Lauren M. Williams, and Morgen L. Barroso. 2021. "An Infrastructural Account of Scientific Objectivity for Legal Contexts and Bloodstain Pattern Analysis," *Science in Context* **34**:101–119. doi:10.1017/S0269889722000011