Engaging Science, Artistically

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ABSTRACT: *In this discussion I show that philosophy of science concepts, especially where examples and thought experiments are limiting, can be enriched with artistic examples. I argue that artistic examples show abstract components and relations that can then be used to engage with philosophical concepts. First, I discuss a useful representational model for thinking about the process of science as analogous to the process of art. I set up philosophy of science as not only open, but also closely connected to art by using Giere's (2006) and van Fraassen's (2008) discussions of the connection between scientific and artistic perspectives. Second, I show how artistic examples can be engaging and informative for teaching philosophy of science concepts. I apply two artistic examples to the concept of quantum measurement 'indeterminacy': Jackson Pollock's artistic process and Mark Dior's fallen hemlock. Finally, I use anecdotal experience of creating art with a philosophy of science class in order to apply indeterminacy to social properties.*

Introduction

Pragmatic choices about how to teach a philosophical subject are guided by the concepts and corresponding examples. When teaching Kant's concept of the 'sublime' in philosophy of art, visual displays can push the boundaries of the concept. One can use examples such as Horace Vernet's "Stormy Coast Scene after a Shipwreck", to explore the role of fear in the 'sublime'.[1] Likewise, one could use Albert Bierstadt's "In the Mountains" to explore the same concept without any analysis of the role of fear. In philosophy of art, such examples engage by providing instantaneous and rich content. But in philosophy of science the role of engaging examples is of a different sort. The concepts in philosophy of science are rooted in the axiomatic tradition where logical structure sets the boundaries between theory and data. The tradition has transformed, leaving the hypothetico-deductive method for more pluralistic explorations in model-building and experiment. The way those abstract concepts are taught can be enriched by visualization techniques for clarifying technical arguments. For example, Chang (2007) has used three visual models[2] of argumentation in order to understand how students structure arguments. Teaching philosophy of science concepts through empirical examples can also provide lively applications. In philosophy of physics one can explore error analysis applied to the case study of so-called "faster-than-light neutrinos" (Amelino-Camelia, 2011). In philosophy of biology, one can explore how populations change epigenetically due to the presence of chemicals—e.g., mice change their mating dances in response to vinclozolin (Blocker et al. 2013). These kinds of examples are complex, interesting, and push the boundaries of philosophy of science concepts. However, sometimes such examples are not straightforward, overcomplicate the picture, or carry their own *biases*. One such example is Schrödinger's cat:

> One can even set up quite ridiculous cases. A cat is penned up in a steel chamber, along with the following device (which must be secured against direct interference by the cat): in

> a Geiger counter there is a tiny bit of radioactive substance, so small, that perhaps in the course of the hour one of the atoms decays, but also, with equal probability, perhaps none; if it happens, the counter tube discharges and through a relay releases a hammer which shatters a small flask of hydrocyanic acid. If one has left this entire system to itself for an hour, one would say that the cat still lives if meanwhile no atom has decayed. The psi-function of the entire system would express this by having in it the living and dead cat (pardon the expression) mixed or smeared out in equal parts. (Schrödinger 1935, §5)

Originally, variations of this example by Schrödinger as well as Einstein were composed as a *critique* of the Copenhagen interpretation. In popular culture it has become a catching demonstration of quantum measurement.[3] When teaching quantum measurement and quantum interpretations in undergraduate upper division philosophy of science, students will often use the parameters set by pop cultural interpretation of the example as a framework for new interpretations. In the pop cultural example, the cat is in a superposition of states, both dead and alive, and it only collapses on to one of those states when…the box is *opened*. This prompts a *faulty* assumption that quantum measurement is necessarily mediated by conscious activity.[4] But this interpretation is not representative of more common interpretations of quantum measurement, and furthermore, it limits student exploration of new philosophical views on quantum measurement. The issue is that when attempting to explain the process of quantum measurement in a different way, one is limited either to modifying the cat example or to simply drawing diagrams of photon guns and interference patterns. The cat example is simplistic and becomes tedious to students, and the measurement set-up diagrams are informative but not engaging. In fact, the question is often, "What else does this apply to?" I take there to be two questions here: 1) What other physical systems does this apply to? 2) What are the important components in this system that I can abstract out and apply to other things? I take (2) to be the more difficult question; and I think that the generation of interesting examples can help teach (2) as well as (1).

In this discussion, I suggest that philosophy of science concepts, especially where examples and thought experiments are limiting, can be enriched with artistic examples. Specifically, I argue that artistic examples show *abstract components and relations* that can then be used to engage with philosophical concepts. I apply two artistic examples to the concept of 'indeterminacy': Pollock's artistic process and Dior's fallen hemlock.

My discussion is outlined as follows. In Section 2, I discuss a useful representational model for thinking about the process of science as analogous to the process of art. This section is supposed to set up philosophy of science as not only open, but also closely connected to art. Recent work by Giere (2006) and van Fraassen (2008) make use of art as an analogy for science because of the perspectival and representational similarities. Just like works of art, scientific models and measurements *represent reality* to respects and degrees. I suggest that understanding the relation opens philosophy of science concepts to parallel artistic examples. In this section I use artistic examples to draw analogies between science and art.

In Sections 3, I show how artistic examples can be engaging and informative for teaching philosophy of science concepts. Interestingly, the examples that I use are from *non-representational* art. Here, I not only use famous art examples but I also use anecdotal experience where I have created art with a philosophy of science class in order to engage the material. In Section 3.2, I discuss a specific interpretation of quantum indeterminacy in relation to Pollock's process of making art. In Section 3.3, I use Dior's project on a fallen hemlock as a technical example for measurement interaction. In Section 3.4, I discuss pedagogical extrapolation where an artistic example that was made with the help of student collaboration prompted further exploration of indeterminacy and social properties.

Perspective and Representation: Art and Science

Van Fraassen (2008) and Giere (2006) converge on at least three features of perspective, which transfer from visual/artistic perspective to scientific perspective.

1) The distinction between what things look like vs. what they are like
2) The intersubjective objectivity of a perspective
3) The selective input involved in a perspective.

I discuss these features to show the close relation between science and art. Understanding the relation opens philosophy of science concepts to parallel artistic examples. In short, both scientific and artistic practices share (1)-(3), and so examples can be exchanged between the two disciplines.

Features of a perspective: What things look like vs. what things are like

According to van Fraassen, art and scientific measurement tell us what things look like from a vantage point. Van Fraassen says, "The painter's eye is located with respect to the content of the painting in a way that he himself can express with "this is how it looks to me from here""(2008, 59). In order to demonstrate the perspectival nature of measurement van Fraassen uses an example of two moving cars and a painter as the measurer.

Suppose that two cars are moving in parallel, with the same velocity. Van Fraassen asks us to imagine a spatial frame of reference that has the left border of the road as the Y-axis and an orthogonal X-axis. There is a series of horizontal lines, parallel with the X-axis. The painter sets up his easel at the beginning of the road on the Y-axis. The cars begin to move. They reach each horizontal line simultaneously. But from the painter's point of view the right-hand car is moving along the hypotenuse of a *perceived* triangle and covers a larger *perceived* distance (in the same time interval) than the left-hand car (2008, 69).

Van Fraassen says,

> Within the painter's perspective, the right hand car is moving faster than the car on the left. If he were making a motion picture, or simply taking notes of where in his visual field the cars are at t = 1, t = 2, etc. he would be making a *measurement* of the velocities, but the content of

> his measurement would be *what the motions look like* and not *what they are like*. (2008, 68, my emphasis)

On this view, what measurement and perspectival art have in common is they both provide a vantage point on a phenomenon. Information gathered during measurement will tell us what something *looks like* from a vantage point, rather than *what something is like*.

Giere (2006) uses visual perspective in vision (rather than art). In using this example, Giere draws the distinction between what we *perceive as colors* (our trichromatic visual perspective) and the physical properties that interact to produce that perception (e.g. the incident light and the molecular makeup of the surface). Giere distinguishes our experience (perspective) of color and the physical properties that produce the perspective. In this sense, color properties are perspectival properties that depend on the evolutionary story of our visual system as well as physical properties of wavelengths of light. This perspectival feature shows why differences in perspective can be real in art as well as science. A dichromatic vs. trichromatic person looking at a painting has a difference in perspective similar to two measurement instruments sensitive to different wavelengths of gamma radiation.[5]

Features of a perspective: Intersubjective objectivity

Giere brings up an important point about visual perspective—namely, the "intersubjective objectivity" of a given perspective. In common parlance, perspective indicates a different point of view. Giere says this may, misleadingly, suggest that each perspective "is as good as any other" (2006, 13), thereby suggesting some sort of relativism. According to Giere, a perspective should not indicate something that is merely subjective. That is, there is "roughly a way something looks from a particular location for most normal viewers"—e.g. the Washington monument from far away vs. from the base (2006, 13).

In discussing how things "appear" during measurement, van Fraassen also cites intersubjective objectivity of a measurement perspective: "How an observable object or process (phenomenon) appears in the outcomes of the measurement is itself an objective fact, a public, intersubjectively accessible fact" (2008, 284). According to van Fraassen, sometimes appearances are deceiving. He uses the example of rainbows to indicate "public hallucinations"—appearances that are intersubjective but do not correspond to real physical objects.[6] The point about intersubjectivity is important. Often, examples from art are taken to have a subjective component or totality. But since art is a matter of perspective, and that perspective can be recreated, it indicates that the interaction between the viewer and the work of art is relational rather than subjective. Van Fraassen's and Giere's views emphasize support for this relational view by emphasizing that perspective can be recreated given the position of perspective.

Features of a perspective: Selectivity to input

Visual perspective and scientific perspective both involve selective sensitivity to input. According to Giere, with the use of a visual vantage point we can emphasize certain details of our target while ignoring others (e.g. emphasizing the height of the Washington Monument by making a painting, photo, or video looking up[7]). Likewise, with the use of a scientific perspective we can select and emphasize certain aspects of the phenomena. Giere's perspectival view can be contrasted to a strong realist view, which I call 'reflective realism'. The difference can be usefully taught, using an art analogy because it draws on the concept of 'reflection', which I discuss by referencing the work of Ron Mueck.

For the reflective realist (reflectivist), scientific practice *reveals* or *reflects* properties that objects, events, and processes really have. For example, a value V in a given measurement reflects property P of the actual object of measurement. Terminology such as "discover", "reveal", and "reflect" are used in strong "realist" characterizations of measurement.[8] If we set up a parallel to visual or artistic perspective, we see that no visual reflection is perfect—e.g. think about a "reflection" from the lake and the skewed image it produces. But realists use the term to indicate *perfect* reflection.

We can compare the reflective realist view of measurement with hyperrealism in art. Hyperrealist works of art, like those of Ron Mueck, have an eerie quality of accuracy to them. Mueck focuses on details like wrinkles, skin pigmentation, uneven fat distribution, arm and leg hairs, sweat particles, etc. The goal of these works of art is to get the *relation between the subject of the art and the art* as close as possible. The properties in the work of art are intended to closely correspond to properties of the subject, even though in reality this is impossible. It is up to the artist to make sure that the process of reflection goes smoothly.

In the contrasting perspectival view of scientific practice, the product of a given measurement or theory of some phenomenon is a *representation* of that phenomenon to respects and degrees. Van Fraassen uses the analogy of art to contrast representation with resemblance. He says, "Successful representation may require deliberate departures from resemblance" (2009, 13). Sometimes, distortion in the form of representation is used in order to successfully represent:

> Misrepresentation is a species of representation after all: a caricature of Mrs. Thatcher may represent her as draconian, but it certainly does represent her, and not her sister or her pet dragon... Yet even if we take the caricature to represent her because of some carefully introduced resemblance there, we can declare it a misrepresentation by insisting that it represents her as *something she is not*. (2009, 14)

In art, visual *accuracy* is not required for a successful representation. Certain features of the target are *selectively* represented. In this sense, because there is incompleteness, there is a departure from accuracy. This is applicable to scientific measurement activities that selectively focus on specific properties, while excluding others. The artist can also sacrifice visual accuracy for a distortion of the target in order to represent some aspect of that target, which I will shortly describe using the work of Bellows.

One of the most important aspects of looking at science and art as representational is that a representation *does not represent* on its own. For both van Fraassen and Giere, a representation is *used by someone* to represent some thing for some purposes. For example, the distortion of Mrs. Thatcher as a draconian only "makes sense" if we understand the artist's representational *purpose*. Similarly, the success of a distortion in representing a target depends on the purposes of the scientist. Because the scientist selects the respects in which a representation represents a target, a two-place relation between the representation and the target (Y is represented as F) is substituted by a four-place relation between user, representation, and target: X represents Y as F, for purposes P.

To illustrate selective representation in art, take the example of George Wesley Bellows's painting depicting the legendary boxing match between Dempsey and Firpo. Bellows' painting selectively represents visual and circumstantial elements of the actual boxing match (the target of representation). The circumstantial ones are more interesting to focus on. First, in the historical event, as Dempsey went through the ropes his head clashed with a writing machine, leaving a cut on his head. Second, the boxing event was controversial because of the notoriously slow count of the referee. (In fact, many argue that if it was not for the slow count, and individuals physically helping Dempsey get back in the ring, the fight would have been ruled in favor of Firpo.) But if you look at the painting, the referee is already counting before Dempsey makes full contact with the ringside surface. Dempsey's head does not clash with the writing machine. For the *purpose* of the artist's representation, these physical inaccuracies (or distortions) do not matter. According to Wood (2010), Bellows painting represented a more complex phenomenon—the juxtaposition between the American hero and the alien fighter; and 'the fragility of power' (2010, 5). Even though Dempsey won the fight, Bellows chose to highlight the temporary, heroic moment of the hated foreign fighter, Firpo. The success of Bellows' representation of Firpo only makes sense if the viewer understands the political context of the boxing match and Bellows' interest in the concept of the foreign fighter. Bellows had demonstrated interest in the concept of the alien fighter in 1921 with his painting "Introducing Georges Carpentier" (Wood 2010, 4). He continued this theme with Firpo. Wood remarks:

> The exoticism of this Argentinean challenger is reflected in the tanned contours of his body and the richness of his purple trunks; Dempsey's coldness, in contrast, is encapsulated in his white trunks and pale body. Firpo's handsome face betrays no emotion as he watches a faceless Dempsey fall through the ropes; a facelessness that finds its echo in that of the owner of the arm supporting his fall. (5)

Without knowing the purpose of the distortion in the Bellows' work it would be very difficult to figure out what aspects of the Dempsey/Firpo fight the painting represents.[9]

Art and Science: The analogy falls apart

What we have gathered so far is that representation in art and science is related in the following ways:

1) The representation selectively represents the target in terms of selectivity to respects/aspects and to degrees.
2) A representation does not represent on its own. Both the artist and the scientist select the respects and degrees to which a representation represents a target. A two-place relation between the representation and the target (Y is represented as F) is substituted by a four-place relation between user, representation, and target: X represents Y as F, for purposes P.

However, the analogy between representation in art and in science falls apart. Paintings only represent/depict things as they *appear to us in perception*. But, according to van Fraassen, scientific theories (and maybe scientific measurements) represent/depict things *as they are*.[10] Van Frassen writes:

> If science offers a representation of nature, what precisely does it represent? Paintings and photos depict things as they appear to us in perception. In contrast a scientific theory may be said to depict things as they are. The differences between how things appear to us and how they are depicted by a scientific theory can certainly be striking. (2009, 269)

I think that the representational discrepancy between science and art is exactly where art becomes even more useful for scientific practice. If one is, for example, teaching representationalism vs. realism in philosophy of science, works like those of Mueck or Bellows are demonstratively clear. But if one is teaching specific scientific concepts like quantum measurement, which describe processes that we *do not encounter in our daily perceptual experience*, how can artistic examples even apply? This is where non-representationalist art provides the proper analogy. In the next section I show that artistic examples are useful even for discussing complex concepts like 'indeterminacy'; and the use of artistic examples is to show *unique components and relations* that can be abstracted and made to engage with the scientific concept.

Indeterminacy, Numbered Paintings, and a Fallen Hemlock

In this section I focus on specifying an interpretation of 'indeterminacy' using two artistic examples. I spell out Barad's (2007) concept in Section 3.1. In Section 3.2, I use Pollock's artistic process to illustrate *non-representational emergence of new things*, which is parallel to the emergence of new properties through quantum measurement interactions. In Section 3.3, I use Dior's example of the manipulation of conditions to illustrate that *how conditions are manipulated within an interaction* (or "intra-action") matters in scientific practice.

'Indeterminacy'

To discuss a specific characterization of 'indeterminacy' I use Barad's (2007) interpretation of quantum measurement. Barad refers to traditional scientific views where:

1) The world is composed of separate objects with definite and determinate properties; and
2) Our scientific practices reveal these properties (and quantity values) without disturbing the world.

Barad says, "Classical epistemological and ontological assumptions, such as the ones found to underlie Newtonian physics, include the existence of individual objects with determinate properties that are independent of our experimental investigations of them" (ibid, 106). But quantum measurement seems to "smear" this simple realist picture of scientific practice of revealing determinate properties.

I give a brief description of non-controversial aspects of quantum measurement in order to set up Barad's use of 'indeterminacy' (DeWitt 2004). It is important to note that Barad's interpretation is one of many, but I have chosen it because it is difficult to structure using examples. First, it is necessary to characterize particle and wave phenomena and their relation to scientific measurement.

Particles are:

Discrete, that is, they are separate objects with particular properties;
Determinate, i.e., they have well-defined and precise location in space-time; and *Interactive*: they interact with other particles.

Waves are:

Spread out over a large region of space-time; and
Interact as waves (changing magnitude, cancelling magnitude, and no-effect interaction).

According to DeWitt (2004), the fact that particle patterns and wave patterns appear in measurement settings is not debated. Firing a photon gun through two slits results in wavelike interference patterns. But when particle detectors are added to the measurement set-up, particle-like interference patterns result. The metaphysical interpretations of these results are debated. Depending on the view we take we can ask if presence of particle detectors *alters* certain intrinsic properties of the photon? There are various interpretations that focus on measurement-dependence; and there are other controversial interpretations that posit consciousness-dependence (See Dewitt 2004).[11] Recently, Barad (2007) proposed an interpretation of 'indeterminacy' that focuses on measurement interaction ('intra-action'). This interpretation is difficult to understand because it posits an unusual framework for pre-measurement and post-measurement properties.

For Barad, there is a puzzle if the nature of light is both particle and wave: "The dual nature of light and matter presented a quandary of the first order: an object is either localized or extended; it can't be both" (2007, 100). To avoid a contradictory nature to a single object, one can posit that pre-measurement properties differ from post-measurement properties. Barad's view radically changes the picture of pre-measurement and post-measurement properties. According to her picture, a given property cannot be separated from an experimental arrangement, which is composed of a set of conditions that constitute measurement apparatuses. In other words, the role of the apparatuses cannot be abstracted to find out what pre-measurement properties *really* are. Barad posits that properties *only emerge* from arrangements. One cannot split the arrangements into *interacting* parts that are self-contained and determinate. Rather, arrangements are "intra-actions", which cannot be separated: "Since individually determinate entities do not exist, measurements do not entail an interaction between separate entities; rather, determinate entities emerge from their intra-action" (ibid, 128). This means that different objects and properties become determinate through different intra-actions. This also implies that objects are *indeterminate independent of intra-action*. Barad says:

> So the question of what constitutes the object of measurement is not fixed: as Bohr says, there is no inherently determinate Cartesian cut. *The boundary between the "object of observation" and the "agencies of observation" is indeterminate in the absence of a specific physical arrangement of the apparatus*. What constitutes the object of observation and what constitutes the agencies of observation are determinable only on the condition that the measurement apparatus is specified. *The apparatus enacts a cut delineating the object from the agencies of observation*. Clearly, then, as we have noted, *observations do not refer to properties of observation-independent objects (since they don't preexist as such)*. (ibid, 114)

For Barad, 'indeterminacy' is rooted in a *metaphysical account* rather than epistemological one. Objects are not determinate *unless* there is an intra-action (i.e. an arrangement of conditions). This implies that *determinacy can only occur within a given arrangement of conditions*. That is, once there is a given arrangement then determinacy emerges. So the next question is, how does one teach Barad's 'indeterminacy'? One can focus on the fact that things are not determinate prior to measurement, but this is puzzling. The usual question is, "what are things prior to measurement?" "Don't they still exist as objects?" Schrödinger's cat does not help much as a teaching tool. How does one characterize interaction vs. "intra-action" in the case of the cat? It seems like the example would generate the same pre-measurement picture.

In order to provide useful examples, it is important to selectively focus on certain features of the concept that an example should *represent*. It turns out that an adequate way to represent Barad's example is through non-representational works of art. I use two examples. One focuses on the non-representational *emergence of new things* from their interactions. The other example focuses on the fact that *interactions matter*—that is, for any kind of measurement it can't be just *any* interaction. In quantum measurement as well as other physical sciences, conditions must be *carefully manipulated* to produce new things.

Pollock and non-representational art

The representational art analogy from Section 2 emphasizes measurement as a passive process: Just as the subject is represented on the canvas, the phenomenon is represented as a measurement result or theoretical variable. This is why representational art examples do not capture 'indeterminacy'. Rather, we have to find some example that focuses on the interacting elements of the measurement set-up that are relevant to the emergence of new things. I will use the example of Jackson Pollock's art in order to illustrate the emergence of new things from interaction. The focus here is on Pollock's total process of making art.

Pollock numbered his paintings so that people would look at them without searching for representational elements in the names of his paintings (Karmel and Varnedoe 1999). For Pollock, the work of art is *not* a representation of a phenomenon (ibid, 68-69). Rather, it *is* the phenomenon, which is produced by the interactions that take place in the painting set-up (ibid, 99).[12] Pollock's local painting set-up[13] and the interaction (intra-action) that occurred *within* this set-up can be summarized as follows: First, paint was carefully selected to have the proper viscosity. Pollock used gloss enamel paint rather than oil-based paint. The paint was sometimes diluted to have little textural effect, and at other times thickened. He used sticks, worn out brushes, and basting devices that looked like giant fountain pens. Pollock also used raw, unstretched canvas in order to be able to perform full-body painting (ibid, 72). The painting resulted from the interaction that took place within the painting set-up. Moreover, it is fair to say that it is difficult to appreciate the work of art *without* looking at this process of interaction. As *part of* the painting set-up, Pollock is interacting with other elements of the set-up to produce the phenomenon. This means that Pollock is *not separate* from the measurement interaction, he is *working as part of it*. This is why the term "intra-action" applies nicely—one cannot separate the elements of the artistic set-up without losing the thing that is being produced. In interviews Pollock describes being "in" his painting when making it (ibid, 17). The quality of interacting from *within* importantly shows students the transition from 'interaction' to 'intra-action'. I teach that both terms signify the importance of elements causally intersecting to produce the new phenomenon. However, there is a major difference in metaphysical *views* between 'interaction' and 'intra-action'. 'Interaction' signifies that we can *step outside* of our measurement practices to view measurement-independent properties. 'Intra-action' signifies the opposite—that we cannot separate the elements without losing the phenomenon that emerges. Students follow this conceptual progression by thinking about traditional representationalist art, where the painter is outside of the work and also the object being represented. In Pollock's case, everything is entangled, and the thing produced is not a representation, but rather a product of the intra-actions.

Hemlock and careful conditions

The Pollock analogy effectively captures how new things emerge as a product of intra-actions; but it misses the fact that measurement intra-action must be *carefully maintained*. That is, *how* conditions are manipulated in the scientific context matters, and there is regularity to the manipulation/stabilization of conditions.

On February 8th, 1996 in Seattle, a hemlock tree fell over. The tree fell in a protected watershed area and because of other fallen trees it did not touch the ground. This prevented the tree from rotting quickly. Mark Dior took an interest in this tree for a work of art. But the work was not a painting, a sculpture, or a photograph—it was not a representation of the tree—rather, the work of art was the tree. Dior's goal was to take the tree out of its natural setting and place it in a gallery context. According to Dior:

> We're taking a tree that is an ecosystem—a dead tree, but a living system—and we are re-contextualizing it and taking it to another site. We're putting it in a sort of Sleeping Beauty coffin, a greenhouse we're building around it. And we're pumping it up with a life support system—an incredibly complex system of air, humidity, water, and soil enhancement—to keep it going. (Art:21 interview[14])

The importance of this project is preserving the *ecosystem* as the *art system*. In other words, Dior's aim was to preserve the macro and micro interactions that have been occurring in this hemlock tree ecosystem. In order to preserve bacterial, fungal, plant, insect, and soil profiles; and in order to replicate the forest ecosystem's pattern of decay and renewal, Dior carefully planned "a life-support system" for the tree. First, the tree was transplanted to Seattle, carrying all of its biosystems (including, a hummingbird nest). Teams were in charge of preserving specific systems of the tree (e.g. fungi, insects, etc.). Second, once transplanted to Olympic Sculpture Park, a greenhouse was built around the tree in order to replicate conditions similar to those found in the watershed area forty-five miles outside Seattle. Biologists, soil scientists, and architects were involved. The greenhouse comes equipped with water systems, irrigation systems, cooling systems, panels to control the light levels, the glass to replicate the color spectrum of the canopy in the original forest. These greenhouse systems are carefully timed for execution.

I teach Dior's project as a project that is dedicated to *carefully manipulating conditions*. This means that within an intra-action, conditions cannot be manipulated any which way. They have to be manipulated in order to get a *repeatable, re-producible*, and *reliable* phenomenon. I call this 'stabilization of conditions'. According to Dior, this reconstruction (or, the stabilization) is ultimately doomed. He says,

> We're putting it in a sort of Sleeping Beauty coffin, a greenhouse we're building around it. And we're pumping it up with a life support system—an incredibly complex system of air, humidity, water, and soil enhancement—to keep it going. All those things are substituting what nature does—emphasizing how, once that's gone, it's incredibly difficult, expensive, and technological to approximate that system—to take this tree and to build the next generation of forests on it. So this piece is in some way perverse. It shows that, despite all of our technology and money, when we destroy a natural system it's virtually impossible to get it back. In a sense we're building a failure.

Dior clarifies why it is a failure:

> I want to show how difficult it is for us to grasp—not just conceptually, but also practically. How difficult it is for us to figure in all of the variables that you would need to replicate a forest. We're trying but we can never do it perfectly.

In Dior's 5-year project, he carefully set up forest conditions in a sculpture park to stabilize a phenomenon. Researchers are doing something similar: they are setting measurement conditions in order to get repeatable, re-producible, reliable phenomena. This teaches the students how to understand condition manipulation. But condition manipulation/stabilization is not merely reserved for quantum measurement. In fact, I show that once we *abstract out the importance of condition manipulation/stabilization*, we can easily *apply* it to many types of physical measurement. For example, when measuring the boiling point of water it is not accurate to say that we just put a thermometer in a sample and get a reading of the *true* temperature. Rather, the boiling point of water is a process of stabilization of conditions. Chang (2004) offers an account of the history of thermometry where he describes that to get a sample of water to have the same temperature value, conditions like atmospheric pressure and dissolved gas must be manipulated. Chang presents an anecdote about how De Luc walked, slept, ate, etc. for 4 weeks straight all while shaking a tube of water to purge it of the dissolved air. De Luc's dedication to manipulating the conditions of measurement serves as a good illustration of the care with which the conditions of measurement have to be carefully stabilized.

Once students understand the importance of, 1) Measurement *intra-action and the emergences of new things* from Pollock, 2) The careful *manipulation/stabilization of measurement conditions* through Dior, and 3) The application of (1) and (2) to other sciences, this is where student creativity and collaboration can take exciting form. I describe an activity that spontaneously emerged in a unit on quantum measurement to briefly discuss the extrapolation of concepts.

The Measurement Problem of Internet Mechanics

One day a student conversation emerged about digital communication. I thought about a scenario, which happens frequently: Two people are digitally chatting, when one cuts out. After some time, the person comes back and says, "Sorry I disappeared, the WI-FI went out." An interesting symbolic question emerges: If the WI-FI goes out, do we "disappear"? Not physically, of course; but rather in a social sense. Students agreed that digital spaces are integral to certain complex social properties, like identity, social connections, and social communication. That is, digital spaces provide intra-actions that can *determine* our identities and connections; and for some, if the digital intra-action disappears, so does a large part of the person's *social properties*. This conversation sparked an unusual application of the concept of 'intra-action'. The students liked the example so much that they prompted the development of a small animation. We storyboarded it together and then I animated the piece, using stop motion animation. The piece depicts two agents communicating when the WI-FI goes out. Both agents disappear—one into particles and the other into waves. They reach out for one final connection, before becoming indeterminate: https://www.youtube.com/watch?v=s5iCemTc6kg

Simple examples can open new areas of exploration. In this philosophy of science course, a simple animation began a conversation about to what extent social properties become determinate with measurement context. But because of this exercise, I created an essay question as part of the final exam that asked students to apply various quantum interpretations to social phenomena. This then became a structured presentation in the philosophy of science class for the next term. In both terms students have focused on things like the determining function of the media. Does the media merely expose limited information (epistemic limitation) or does it actually change how new things emerge? Students and I discussed that it can be the former as well as the latter because *information exposure can function as a causal property that influence other properties*. That is, the kind of information that we are exposed to prompts what we do about actual events. This is commonly referred to as a type of 'endogeneity': where there is a loop between two variables. In this case the loop would be between information sources and social states of affairs.[15] While this falls outside of Barad's interpretation, it is still worth noting as an important example of the measurement-dependence of social properties, which has both epistemic and metaphysical components. The progression of examples from Pollock to Dior to an oddball animation has prompted an application of quantum measurement to social properties. This shows that sometimes the examples that we use in teaching can have unpredicted pedagogical consequences. Not only do examples push conceptual boundaries but they also push *new applications*. Extrapolating concepts is a continuous endeavor. It may be that the application of 'indeterminacy' falls apart in interesting ways when applied to specific social properties—after all, some social properties may remain invariant over different measurement contexts. But it may also be that such application produces interesting relations between physical and social measurement. Either way, it prompts for active application on the part of the total class, where key features of concepts are abstracted and applied.

Concluding Remarks

In this discussion, I have suggested that philosophy of science concepts, especially where examples and thought experiments are limiting, can be enriched with artistic examples. Specifically, I have argued that artistic examples show *abstract components and relations* that can then be used to engage with philosophical concepts.

I discussed a useful representational model for thinking about the process of science as analogous to the process of art. I set up philosophy of science as not only open, but also closely connected to art by using Giere's (2006) and van Fraassen's (2008) discussions of the connection between scientific and artistic perspectives. Then, I showed how artistic examples could be engaging and informative for teaching philosophy of science concepts. I applied two artistic examples to the concept of 'indeterminacy': Pollock's artistic process and Dior's fallen hemlock. I also described anecdotal experience where I have created art with a philosophy of science class in order to engage the material. This act of student engagement prompted a new application of 'indeterminacy' to social properties. This shows that examples aren't merely illustrations—they push concept and application boundaries. The use of artistic examples offers more than just a visual display of some concept. It provides avenues to new applications.

Endnotes

[1] Kant seems to suggest that we are both powerless and yet have the feeling of separation from nature, which gives us a sense of power (See Hacket 1987 §28, 261–262).
[2] Toulmin's model (Toulmin 1958), Means and Voss's model (Means & Voss 1996) and Lakatos's scientific research programmes model (Chang 2007).
[3] In popular terms, we can think of Schrödinger and Einstein as "trolling" on the Copenhagen interpretation. So, the example is about as robust of a demonstration of a view as a caricature is of some person.
[4] Schrödinger's use of "direct observation" may be blamed for the limiting interpretation of measurement: "It is typical of these cases that an indeterminacy originally restricted to the atomic domain becomes transformed into macroscopic indeterminacy, which can then be *resolved* by direct observation" (Schrödinger 1935, §).
[5] See Giere's discussion on COMPTEL and OSSE, where two instruments produce images of different sorts based on their sensitivity ranges (2006, 47).
[6] He says, "if the rainbow were a real thing then all of the various observations and photos would locate it at the same place at a given time (2008, 102)".
[7] The triggering of vertigo-like symptoms would serve as good emphasis.
[8] Swoyer (1988) provides a good example for such terminology: "Even a fairly small group of objects can be ordered in a good many ways, and it is difficult to see why vastly different operations would so frequently yield quite similar orderings if they weren't *reflecting* the same facts about the world. According to the realist, there *are* objective facts about length that transcend the particular methods of measuring it, and the reason why different measurement procedures so often yield similar results is that they are sensitive to the same facts" (239).
[9] An interesting point about the Bellows episode is that he distorts in order to tell a particular story. While scientists distort to emphasize certain details, they do not distort to produce a desired outcome.
[10] An objection can be made that both visual representation and scientific theory are based on observation.
[11] Still others are more controversial and posit many worlds. There are some interpretations that stick to the point that measurement does not change intrinsic properties and there are merely hidden variables.
[12] Pollock was resistant to representation in art. He was also resistant to the view that artists should paint things "out in nature": "When asked whether he painted from nature, Pollock replied: "I *am* nature"" (ibid, 253).
[13] What I mean by 'local painting set-up' is the conditions for making art. This is analogous terminology to the 'measurement set-up' and the conditions for measurement interaction ("intra-action").
[14]See http://www.pbs.org/show/art-21/
[15] See Weijers and Keyser (2016) for a discussion of a complex endogeneity problem in ethical and technological contexts, where information used to make predictions determines the predicted

likelihood of a given event, which, in turn, can affect the morality of using the information to make the bet.

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