Contextualizing Science for Value-Conscious Communication

by

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Abstract

Democracy hinges on the personal and civic decision-making capabilities of publics. In our increasingly technoscientific world, being well-informed requires an understanding of science. Despite acknowledging public understanding of science as an important part of being well-informed, publics' engagement with science remains limited. I argue that part of publics' disengagement with science is because information transmitted about science, like science itself, has been decontextualized.

Though there are many ways to decontextualize information, obscuring values in science is a popular means of doing so. Due to the ubiquitous nature of values, science misrepresented as 'value-free' will be the focus of my decontextualization critique. Epistemic values (intrinsically important for connecting scientific observations to reality) and non-epistemic values (linked to ethical, social, political and personal concerns) are the sorts of values that have been misrepresented by views like the value-free ideal (VFI). The VFI is the idea

that non-epistemic values should not play a role in the evaluation of evidence and has been heavily criticized on practical and normative grounds. This has led to alternatives to the VFI being proposed, including ways for non-epistemic values to be included in the evaluation of evidence.

In a yet to be explored implication of the VFI, I argue that models of science education and communication that accommodate the VFI have been popularized as a way to reinforce decontextualization. These models describe science and publics with only a minimal account of values, leading me to challenge them on practical and normative grounds since communicating science as 'value-free' is misrepresentative, and from a normative perspective undesirable, especially as including values can help engage publics. In response, I advocate for value-conscious descriptions of science instead.

To catalyze this contextualization, I introduce **k**ey **a**spects for **u**nderstanding **v**alues **i**n **s**cience (based on alternatives to the VFI) and call them the 'KAUVIS'. By using a basis of transparency between scientists and publics, the KAUVIS provides a means to describe how values interact with science without dictating which values are the correct ones. The KAUVIS includes descriptions of the roles values take on, how values relate to the goals of research, and considers epistemic and ethical (non-epistemic) values. Hence, the KAUVIS can more accurately represent science than the VFI, and in so doing, contextualizes information about science in relation to research goals and social needs, making science more engaging.

By developing the KAUVIS to describe values, I also show that traditional information transmission models are maladapted to conveying the true value-laden nature of science. As a consequence, I examine more value-conscious communication models which I show to be enhanced by the descriptive detail of the KAUVIS.

However, unveiling the inner workings of values in science may also have negative consequences for how publics interpret and engage with science. After all, exposing values in science can lead to further dispute about science. Hence, the KAUVIS opens up questions like, what (if anything) is lost by divulging values in science? My initiatory examination of the drawbacks of being explicit about values will uncover that even though there is a risk that publics may reject scientific claims, an understanding of values in science is desirable for decision-making and deliberation. In other words, a description of values can serve to clarify how they are being used, and help define what it is we are in disagreement about. Thus, by more accurately representing science and values, we might strengthen democracy by providing publics the contextualized information they need for science to be of service.

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I take you with me to this last one.

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Chapter 1

Introduction

In order to accurately and effectively engage publics about science, communicators must overcome descriptive and normative challenges including stemming from how to accurately represent science. Sources of misrepresentation stem in part from the value-free ideal that science operates under. Though criticisms of these ideals for science are well documented, there is a gap in the literature regarding how values in science are represented in the communication of science – so how should values in science be communicated? To answer this question, I will first layout how science is misrepresented as insular and free of values (as opposed to a contextualized enterprise immersed in values). I will then show how a value-free vision of science has influenced the use of models in education and communication, specifically selecting for decontextualizing models. I use decontextualization to mean the minimizing of values in science either by subtracting the values of scientists from science or underestimating the importance of publics' values towards science. This leads me to argue that decontextualization plays an underlying role linking a value-free ideal for science to science education and science communication – an ensemble that has yet to be investigated conjointly.

In response to the misrepresentation decontextualization produces, contextualized (value-conscious) approaches to transmitting science will be shown to better address pedagogical and democratic concerns. Value-conscious information is able to more accurately represent science and socially-situate science, making it more memorable for publics. However, by acknowledging values in science (and how they are transmitted), publics will come to science without a universal (value-free) basis of scientific knowledge, opening up new research questions at the intersection of values, science and democracy.

As it stands, the communication consequences of values in science have mostly been discussed in terms of science policy as opposed to science education and communication in the philosophy of science literature (Den Hoed & Keizer, 2009; Douglas, 2009; Elliott & Resnik, 2014). Though science policy is not the focus of this dissertation, it lies at the crossroads of science, society and democracy as does science education and communication. Furthermore, how science is communicated is inherently interwoven into developing policy as information is processed for civic consumption and application. Hence, it is worth examining traditional science policy models for what issues may be important for transmitting science and to see how values can be involved as a starting point.

1.1 The Linear Model for Science Policy

The standard view of science policy in the 20th century is the linear model.[1] The model's legacy continues to the point that discussions about science still rely on terms like 'basic' and 'applied' that were coined for the model (Pielke Jr, 2007, p.84-88). The model also represents a prime illustration of decontextualization. Designed as a way to semi-situate science in society by describing who should engage with science, the linear model proposes a unidirectional three step process of investment, resource accumulation and social benefit (commu-

[1] Other similar accounts include the 'assembly line' (Kline, 1985) and 'linked-chain' (Wise, 1985) models.

nications occur here at this last step). Beginning with funding basic scientific research (an investment independent of social interests), scientific knowledge is then pooled to become a resource to draw from (resource accumulation), in order to create applications for society (social benefit).

According to Pielke (2007), the linear model can take on one of two forms that emphasize either the autonomy of scientists or the application of research – though both describe science moving unidirectionally from scientists to publics. The first version highlights the importance of basic research but how research is applied goes beyond the purview of scientists and becomes the responsibility of politicians and society more broadly. This version decontextualizes science by stressing the autonomy of scientists through the removal of political accountability. The second version of the linear model offers specific guidance in the context of actual decision-making. It proposes that scientific consensus be followed by political consensus and policy decisions. However, this version fails to take into account the sometimes fraught ways in which publics' values towards science can impact policy decisions.[2]

[2]Consider the scientific consensus over anthropocentric climate change (an example I will return to in Chapter 3). 97% of scientists support the finding that Earth is unequivocally warming and this is extremely likely to be caused by humans (Anderegg, Prall, Harold & Schneider, 2010; Cook et al., 2013; Oreskes, 2004). Under a strong account of the linear model, government action on this issue would be mandatory given the consensus. However,

As an example of how under a linear model even unassuming basic research done in isolation can have significant unintended societal consequences, consider the now ubiquitous use of quartz crystals in timekeeping devices. Quartz crystals were first discovered to respond to mechanical stress by accumulating electric charge - known as being piezoelectric - by Pierre and Jacques Curie (1880).[3] By 1927, Bell Telephone Laboratories had produced the first quartz clocks (Horton & Marrison, 1928). But, it was not until after Issac Koga's (1936) unrelated development of a crystal cut method that generated oscillation frequencies via mechanical stress (independent of temperature variations) that a reliable time standard could be manufactured. As a result of Koga's method, quartz crystals were reliable enough to use extensively throughout WWII - most notably for communications (Thompson Jr., 2011, p. 175). Koga had not considered the potential uses of the crystal cut method, but it dramatically altered society through technology used in the war and afterwards. For instance, the popularity and reliability of quartz prompted manufacturers (like Texas Instruments and Seiko) to use it in watchmaking which lead to the

due to public skepticism about climate science (Bulkeley & Kern, 2006; Limon, 2009; Lutsey & Sperling, 2008), policy action would likely be met by resistance.

[3] A somewhat similar phenomena of electrical charge induced by temperature change - pyroelectricity - had been studied by Carl Linnaeus (1747) and Franz Aepinus (1756) in the mid-18th century.

'Quartz Crisis'. As a result, Swiss manufactures nearly saw the mechanical watchmaking industry they dominated and valued as part of their global identity go extinct (Frei, 2009; Tushman & O'Reilly III, 1996).[4] In this example we see how Koga's basic research on crystal isolation, pursued without interest in application, became an influential aspect of modern society. Therefore, although basic research can be carried out in isolation and harnessed for social good as the linear model predicts, it can also have unintended social repercussions offering reason to reconsider the linear model and its decontextualized approach to research.

1.1.1 Criticisms of the Linear Model for Science Policy

As a consequence of reconsidering the linear model, three major challenges have come forward. First, the linear model has been criticized for describing science as isolated from society – an explicit means of decontextualization. Second, it assumes that applications of science do not inform scientific research. And third, it is unable to address society's desires directly, a further separation of science from society's values. Combined, these challenges have resulted in

[4]Were it not for the development of the Swatch company, and their cheap plastic quartz watch first marketed in 1983, Swiss watchmaking may have ceased all-together. Now, Swatch is the largest watch manufacturer in the world (Anwar, 2012; Glasmeier, 1991).

the linear model being considered an impractical oversimplification (Balconi, Brusoni & Orsenigo, 2010; Dosi, Orsenigo & Sylos Labini, 2005).[5] Because details of these criticisms (like whether science should consider society's needs) involve understanding values, they are worth reviewing.

First, science and scientific communities do not operate autonomously. Science operates in value-laden social contexts like the educational system (Miller, Eagly & Linn, 2015) and research institutions (Coupé, 2003; Covaleski & Dirsmith, 1988). These are both influenced by value-laden personal relationships (Kraut, Galegher & Egido, 1987) which influence how we do science and who is supported in doing science. Hence, the linear model utilizes an unrealistic decontextualized view of science by describing scientific research as autonomous of the personal and social factors that go into science (Pielke Jr, 2007).

Second, the linear model also faces criticisms based on the order in which science is actually carried out. The linear model suggests that science policy ought to be developed by funding basic research that is then used to search out applications for science. In terms of how science is realistically practiced, the inverse can also occur where scientists use the applications and findings of

[5] Although, Balconi et al. (2010) respond that the criticisms of the linear model itself are also an oversimplification.

science to inform basic research. For example, take the accidental discovery of the cosmic microwave background by Arno Penzias and Robert Woodrow Wilson at the Crawford Hill location of Bell Telephone Laboratories in New Jersey. They had built a Dicke radiometer for radio astronomy but routinely got excess antenna temperature readings of 4.2K which they could not explain. After isolating from additional radar, radio and heat interference,[6] a residual noise was still measurable and believed to come from outside the Milky Way (Penzias & Wilson, 1965). In this case, it was the technological development of the Dicke radiometer that allowed for basic research about the microwave background to advance. Hence, it is difficult to claim that application (or technological development) must always happen after research, as per the linear model's outline.

Third, the linear model also faces challenges by separating science from society's evolving expectations even as science struggles to meet these expectations (Pielke Jr, 2007). This tension can be seen in how science may disappoint in some respects, even while exceeding expectations in others. For example, the discovery of gravitational waves in astrophysics is powerful for

[6]Not to mention removing the nesting pigeons from their equipment.

helping to understand the universe (Collins, 2010). Knowing this, the National Science Foundation has spent 1.1 billion dollars of American taxpayer money on the project over the past 40 years (National Science Foundation, 2017). Some might find this cost exorbitant, yet others may think it a bargain.[7] So therein lies the issue, when crafting science policy, because the linear model separates research from society, it is unable to know society's desires by just encouraging basic research broadly and will continue to fail to meet the expectations of publics. Though this might be seen as further reason for why science should remain autonomous (since it cannot predict publics' desires), alternative models for science policy might be better able to cultivate science so that it is attuned to society.

In summary, the linear model describes science in society as unidirectional and isolated. This misrepresents science as a decontextualized (the first challenge), oversimplifies how science actually works (the second challenge), and ultimately struggles to meet publics' expectations (the third challenge). Despite these issues, the linear model remains popular (see Greenberg (2001, p. 45) and Sarewitz (1996)). For example, scientists who do basic research often

[7]For comparison, the U.S. spends almost a thousand times that much on defence every year (Horgan, 2016).

support the model because they benefit professionally from the reinforcing relationship between them, policy makers, and special interest groups (Pielke Jr, 2007). This affords these scientists a relatively lax social responsibility in relation to their work but continued funding. In addition, the linear model supports the impression that science is somehow above or disconnected from the messiness of politics - reinforcing science's privileged position. Hence, by considering societal concerns only at the end, the linear model contributes to the idea that science can exist separate from society's values (Douglas, 2010), decontextualizing science further.

1.2 Connecting the Linear Model to How Science is Transmitted

Certain information transmission models also imagine science to operate apart from society, similar to the linear model.[8] Here scientists are envisioned to preform research independent of social concerns, the results of their research then turns into a pool of scientific knowledge, after which translators (science

[8]The models themselves will be described more in Chapter 3.

educators and communicators) convey the information to publics for their personal and civic use. The difference between the linear model for science policy compared to how information about science is transmitted, is that in the end, the final goods for publics differ. In science policy, a public mandate or product becomes available, whereas in communication, understanding and improving science literacy are usually the goal.

1.3 Chapter Conclusion

Frameworks like the linear model can influence how science is done and policy written because of how it views science (i.e. as independent from society's concerns). Similarly, I will show that science is transmitted linearly (or uni-directionally) in science education and communication in part because science is described as decontextualized from values. However, science is an inherently contextualized endeavour, requiring scientists who themselves are also socially situated. As a result, decontextualizing science actually misrepresents science in both the linear model and information transmissions, contributing to poor public understanding of science. I will argue that decontextualizing science by removing values in particular is related to poor public engagement with science, and can have negative consequences for democracy as uninformed publics are unable to adequately utilize science for personal (e.g. healthcare, living environment and future prospects) and civic (i.e. policy) decision-making. Hence, scientists and science communicators ought to adopt a value-conscious approach to science in order to adequately prepare publics for democratic decision-making in this new age of innovation.

1.4 Dissertation Overview

I begin this dissertation by explaining how the prevalence of the value-free ideal serves to decontextualize science. The value-free ideal is roughly the idea that science can and should be devoid of personal and social values, specifically when judging evidence. As the ideal hinges on the type of value being used and when in the scientific process, I begin by breaking down how the ideal applies to different phases of science (the 'context of discovery' or 'context of justification'),[9] then I examine the types of values the value-free ideal is concerned about (epistemic and non-epistemic values). However, several critiques

[9] While I discuss the criticisms of the distinction in the literature, and acknowledge that this categorization has its flaws, I find it to be a useful heuristic for unpacking how values influence science and use it to frame subsequent discussions.

of the feasibility and desirability of the value-free ideal have been raised in recent decades (Douglas, 2009; Fausto-Sterling, 1985; J. Leach, 1968; Longino, 1995). I consider three major critiques: the descriptive, boundary, and normative challenges. Given that the normative challenge critiques the ideal qua ideal, I consider four alternatives that stem from the normative challenge to show how personal and social values can be desirable when evaluating evidence. These alternatives are Douglas' direct/indirect role distinction, Elliott's Multiple Goal Criterion, Steel and Whyte's Values-in-Science standard as well as Kourany's Socially Responsible Science. These alternatives are important because they show why values are integral to science, and as a result, I use them in Chapter 4 to develop what publics need to know about values to engage with science.

In Chapter 3, I will examine the influence the value-free ideal has had on science education (from kindergarten to high school) and science communication (post-schooling). Both aim to improve science literacy. Science literacy is defined broadly as the ability to critically engage with information about science in an informed way. Though science education and communication are naturally tied to the idea of life-long science literacy (Dierking, Falk, Rennie, Anderson & Ellenbogen, 2003; Liu, 2009), they are usually considered independently. Instead, I will consider both domains and the decontextualizating features they share as both support science literacy and public understanding of science. Beginning with science education, arguments for what content to communicate often results in a desire to teach elements of the 'nature of science' around which there is agreement by scientists, philosophers, as well as science and technology scholars – this is known as the consensus view (Irzik & Nola, 2011). But, as there is limited consensus around values in the evaluation of evidence where findings are generated, values are omitted from these transmissions. After publics leave the formal educational system, they still need information about science for personal and civic decision-making, requiring them to supplement their school-based levels of science literacy with additional information. Informal science communication is all information taken-up outside the classroom (post-schooling) such as in museums, from documentaries, and newspapers. However, information provided informally to publics usually depicts scientists and communicators as knowers and publics as deficient of scientific knowledge. This view of publics is known as the deficit model (Trench, 2006), where public deficiency of scientific knowledge is imagined to be the source of low levels of science literacy and the reason for public disagreement about science. This is despite the fact that publics are diverse, can have varying levels of interest towards different sciences, as well as justified value-laden concerns about science. For the deficit model, the nuanced differences amongst publics are misrepresented as identically deficient, allowing science to exist decontextualized from publics. Hence, in both the consensus view and deficit models of communication, values in science and the values of publics are rarely acknowledged and instead expunged. Thus, I develop the literature by proposing that the sustained popularity of the value-free ideal has influenced the presentation of science as decontextualized by encouraging the use of the consensus view that omits values in science education, and supports the use of the deficit model to be used in science communication, hiding the values of publics.

Were the value-free misrepresentation of science not enough, the deficit model and consensus view have also been found to be ineffective at helping communicators and scientists increase public understanding of science (S. Rosenberg, Vedlitz, Cowman & Zahran, 2010). Part of their ineffectiveness stems from their misrepresentation of science as devoid of values which in turn makes the information less socially-situated and memorable. Here I contribute to the literature once again by going beyond initial questions of which values ought to go into science, instead focusing on what publics need to know about values to engage with science. Chapter 4 explores value-conscious communication options based on the value-free ideal alternatives presented in Chapter 2. By highlighting **k**ey **a**spects for **u**nderstanding **v**alues **i**n **s**cience (or the 'KAUVIS') I propose that publics require a description of values to engage with science as opposed to the value-free decontextualized account of science presented. The KAUVIS presents a more transparent value-conscious account of science that includes describing how values are used directly and indirectly, the goals scientists have for including certain values, and a balance between ethical and epistemic values. Though elucidating these values will be tricky, having value-conscious descriptions can better represent how values influence science than in a value-free account and help engage publics in science by contextualizing information. Given the degree of value-consciousness required for the KAUVIS' account of science to be transmitted effectively, I also consider the adoption of more contextualizing models. Starting with the dialogue model (where information is transmitted back and forth between scientists and publics (Trench, 2008)), it is a first step towards exploring bidirectional communication, but turns out to be insufficient in terms of public engagement. This leads me to propose the participation model for science communication, which permits publics to set the aims and agendas for research, as a better way to maximize public interest in science by engaging publics in the research process and recognizing them as legitimate sources of knowledge (Trench, 2008). A particular version of the participation model called the Analytic-Deliberative Process (ADP) is further highlighted as a particularly compatible template for value-conscious communication because it is able to incorporate some of the most important features of the alternatives to the value-free ideal and as a result, cultivate a more authentic public understanding of science.

Chapter 5 contextualizes the KAUVIS itself based on potential implications of using it to cultivate value-conscious science. I will begin by reflecting on how some knowledge of science is often required for personal and civic decision-making and how 'good' decisions can be taken to be 'well-informed' (Dietz, 2013). To make well-informed decisions, publics need to be aware of values in science which the KAUVIS can help to describe. Plus, even alternate accounts of what is required for decision-making, like the scientific reasoning skills (Drummond & Fischhoff, 2015), will be shown to also rely on an appreciation of values in science - providing even further reason for the KAUVIS. To then contextualize decision-making within democratic societies, I examine direct, representative and deliberative democracy. The KAUVIS will be shown to help publics better understand values in science as they vote on issues themselves (direct democracy), evaluate science used by elected officials (representative democracy), and negotiate with others (deliberative democracy). Of these types of democracy, I will also show that deliberative democracy offers a more value-conscious decision-making framework to engage values in science and recognize the values of publics. Lastly, I reflect on potential consequences of acknowledging values in science (and the values of publics) in terms of the basic scientific knowledge decision-makers are envisioned to have. In other words, what questions open up if we accept that not everyone will come to decision-making with the same default information about science because of values. Even amidst this uncertainty, I conclude optimistically that at least with tools such as the KAUVIS, we can more aptly define how values interact with science (and information about science) to better understand its capabilities.

In sum, given that science is value-laden, it should be carried out with an awareness of values and described as such. Transmitting decontextualized information about science has obscured values in science, contributing to a misrepresentation of science. Because publics do not have relevant value-based information about science, it hinders their ability to make informed-decisions, and in turn, compromises informed decision-making in democracy. By explaining how values are routinely masked in the consensus view for science education and the deficit model for science communication, I add to the literature by connecting these models to the value-free ideal through decontextualization. In response to this decontextualization, I turn to alternatives to the value-free ideal that reveal the ideal's unattainability and undesirability. Considerations based on a transparent account of values in terms of whether they should play a direct or indirect role, how values can be appropriate for particular goals, as well as weighing epistemic and ethical goals equally, are all more value-conscious and lead me to form the KAUVIS. As applied to science education, I explain that using the KAUVIS would require adopting new models that can convey aspects of science beyond simply its 'value-free' findings, even if this means presenting controversy. For science communication, adopting the KAUVIS requires open discussions around values in science while reflecting on the values of publics. Through describing values, I contextualize science creating a more accurate and memorable account of science. Thus, by laying out what parameters to use to describe values in science, I hope to generate value-conscious feedback loops in education and communication for more open dialogue at the interface of science and democracy.

Chapter 2

The Value-Free Ideal

In order to understand popular models for communicating science we must first understand the prominent ideal for carrying out science: the value-free ideal. Values are "...something desirable or worthy of pursuit..." (Elliott, 2017, p. 11) that help to structure our goals. But, the value-free ideal (VFI) for science is restrictive by claiming that social, ethical and political concerns (i.e. values) should have no influence over the reasoning of scientists, and that scientists should do research with as little interest in these concerns as possible (Douglas, 2009, p. 1). In this chapter I will explain when values are allowed to take part in science under the VFI, what types of values are permitted, major challenges to the VFI and alternatives to the ideal. Detailing the VFI and the motivations for its alternatives will help to elucidate why science is transmitted in certain ways and what communicating science might look like if a different ideal for science were adopted.

2.1 The Values-in-Science Landscape

The VFI elucidates when in the scientific process values should be used and what types of values. In terms of when, the VFI considers whether values should be used during the 'context of discovery' or 'context of justification' phases. With regard to type, the VFI distinguishes between epistemic and non-epistemic values. Overall, the VFI expects epistemic values to play a role in both phases of science, but limits non-epistemic values to the 'context of discovery' phase as a way to decontextualize science from its social, political and personal surroundings. Though the demarcation of discovery/justification and epistemic/non-epistemic have been criticized, they help to define the VFI, alternatives to the VFI and form part of the ways in which scientists and publics can come to understand the ubiquity of values in science.

2.1.1 The Discovery and Justification Phases of Science

The VFI relies on a distinction between different phases of science in order to deter the use of non-epistemic values when evaluating evidence. For this, science operates in two phases, the 'context of discovery' phase and the 'context of justification' phase (Reichenbach, 1938). The 'context of discovery' phase is where research questions and methods are decided on. The 'context of justification' phase is where research takes place and scientists are forced to evaluate their evidence to come to conclusions about their findings.

It has generally been accepted by philosophers of science, including those who support the VFI and those that do not, that values can and do play a role in the 'context of discovery' phase by shaping the direction of research (Douglas, 2016). However, during the 'context of justification' phase, scholars in support of the VFI have insisted that social and ethical values should not play any part in evaluating evidence (Jeffrey, 1956; Levi, 1960, 1962). Motivations for not allowing values to play a role in science revolve primarily around the worry that permitting non-epistemic values to influence the interpretation of evidence might hinder figuring out the true nature of the world.

There are several challenges to the discovery/justification categorization. For instance, there is the question of whether the phases are temporally distinct processes (Arabatzis, 2006; Steinle, 2006) or overlapping stages (Salmon, 1970). Further challenges come from whether there is only one distinction or a set of intermingled distinctions (Hoyningen-Huene, 2006). The consequence of these challenges is that it forces us to reflect on which elements of a historical process count for science, and inevitably which phases these elements should be considered a part of. Despite these uncertainties, the discovery/justification phase distinction still serves as a helpful heuristic even though the phases may not be entirely separate or linearly ordered. Hence, the 'context of discovery' and 'context of justification' phase distinction is useful for the VFI by facilitating discussions of when in the scientific process values should be used and ultimately helps to decontextualize values from science when evaluating evidence.

2.1.2 Epistemic and Non-Epistemic Values

Traditionally scholars have tried to categorize values as epistemic or non-epistemic (Levi, 1960; McMullin, 1982). The distinction between which values are and which are not epistemic matters because it sets limitations on what values are acceptable under the VFI during the ‘context of justification’.

As an example of epistemic values, consider the following five that Kuhn (1977) believes to be collectively sufficient, though perhaps not exhaustive, for the assessment of scientific theories. These values are accuracy, (internal and external) consistency, scope, simplicity and fruitfulness. Accuracy refers to whether or not the consequences of a theory agree with the results of existing experiments and observations in the domain. Internal consistency means that there should be no paradoxical claims within a theory, whereas external consistency entails that the theory in question agrees with other currently accepted theories. Scope outlines the breadth with which a theory can be applied beyond what it was designed to explain. Simplicity is the ease with which a theory can be understood and applied to ‘bring order’ to phenomena. Lastly, fruitfulness – which Kuhn (1977, p. 357) admits to be the least obvious – is the benefit the theory has to generating new research questions, relationships and general interest. Combined, these values serve as criteria for evaluating the adequacy of a theory and provide a, “...shared basis for theory choice” (Kuhn, 1977, p. 359) which is vital for scientists trying to decide between adopting a new theory or continuing on with an established one.

Kuhn acknowledges that though these values are features of ‘good’ scientific theories, some of them may be more important in particular circumstances than others. He also recognizes that deciding between ‘good’ theories can be challenging because theories can have any combination of these five values to varying degrees (Kuhn, 1977). According to Kuhn, it is often the case that features such as scope and accuracy are at odds (Kuhn, 1977), so is a theory with more scope better than one with more predictive accuracy or vice versa? Furthermore, even within a value like accuracy, scientists can disagree in terms of what is most important to represent with a theory.[1] Hence, some theories may seem more appealing than others based on the degree to which they have these values, but a standard criteria of choice cannot be established since scientists can weigh the importance of different values dissimilarly.

In addition to type of value (epistemic/non-epistemic) and when they occur (discovery/justification), Kuhn also explains that scientists are personal

[1] As an example of competing features within a particular value, take for instance Kuhn’s (1977) retelling of the debate between the oxygen theory and the phlogiston theory. According to Kuhn, the oxygen theory could account for weight relations in chemical reactions but the phlogiston theory could alternatively account for the similarity between metals compared to the ores they were derived from (Kuhn, 1977, p. 357). Both theories are accurate but with regards to different features thus adding to the challenge of deciding which is better overall.

actors that also utilize non-epistemic values. As employers of epistemic values, personal preference and personal values become a part of how science is done. Personal values are values which can be social, political and pragmatic while influencing research in multiple ways. On this he explains, "... the choices scientists make between competing theories depend not only on shared criteria – those my critics call objective – but also on idiosyncratic factors dependent on individual biography and personality." (Kuhn, 1977, p. 361) Here we see that even if it were possible to describe certain values as epistemic, there is still the potential for disagreement amongst scientists within the boundaries of communal norms. Hence, in terms of which values to adopt, non-epistemic values form part of a larger landscape of context relevant values that can influence science.

When Kuhn selects certain epistemic values as criteria for scientists to use in evaluating theories, though he acknowledges that there can be other relevant values, he is demarcating which are adequate to distinguish a viable theory and is not the only one to do so. Steel (2010) also characterizes epistemic values as intrinsic and extrinsic. Intrinsic epistemic values are necessary for truth and are intrinsic in principle. For example, a value like internal consistency is indicative of truth and determined by the theory itself and independent of scientists. However, Kuhn rightfully notes that although intrinsic epistemic values might be epistemic in principle, when actually used and evaluated by scientists, context (as value-laden and biased) is a relevant feature. This means that even epistemic values thought to be worthwhile for their intrinsic features are susceptible to extrinsic factors. Extrinsic epistemic values (like simplicity) are truth-promoting in particular contexts (Steel, 2010). Hence, the concept of epistemic values still affords us the ability to debate the plausibility and desirability of the VFI in its consummate form, and thus remains attractive to describe a romanticized view of science.

Overall, the 'context of discovery' and 'context of justification' phases and the epistemic versus non-epistemic categorization offer distinctions crucial to formulating how values can manifest in science and allow publics and scientists to theorize how they want values to be involved in science. For VFI supporters, their emphasis on removing non-epistemic values from the 'context of justification' phase is paramount. Though these two axes of categorization do not cover all the ways of describing values, they cover the broadest ways of comprehending values in science which several alternatives draw on. Hence, the context of discovery/justification and epistemic/non-epistemic delineations are ultimately useful for describing values in science (a theme to be revisited in Chapter 3 for how best to contextualize values in science).

2.2 Challenges to the Value-Free Ideal

Due to the epistemic/non-epistemic nature values can have and when they can be applied, challenges to the VFI have erupted. The most developed are the descriptive challenge, the boundary challenge and the normative challenge (Douglas, 2016). All three have in common the acceptance of a range of epistemic and non-epistemic values throughout science but for different reasons. The descriptive challenge points out that even science thought to be 'good' is rich with non-epistemic values. The boundary challenge shows how porous the line is between which values are, and are not, epistemic. Lastly, the normative challenge shows that based on risk assessment, in certain circumstances, explicit use of non-epistemic values is required for responsible and rational inferences. Ultimately, I will consider the normative challenge in greatest depth as it attacks the ideal qua ideal and offers rich value-conscious alternatives for how to acknowledge values in science.

2.2.1 Descriptive Challenge

According to Douglas' (2016) summary of challenges to the VFI, even science thought to be exemplary (based on epistemic values) and recognized as reputable (compared to pseudoscience) has been criticized as being problematic. Feminist scholars (see Fausto-Sterling (1985), Solomon (Solomon, 2001) and Harding (1986; 1991)) found that the traditional practice of making scientific inferences (e.g. how results from research on one sex could be translated to others) can produce results that are blatantly sexist and can blind science to alternative explanations because of faulty background assumptions. Background assumptions rely on information collected in a certain context and reflects what research was acknowledged as reputable in accordance with norms at the time. This can overlook important perspectives and experiences by valourizing the contributions of select knowers. The reliance on context specific background assumptions provides further reason to view science as value-laden.

Helen Longino (1990) argues that the scientific method is value-laden with respect to the interpretation of evidence. Since the interpretation of evidence relies on inference, scientists are forced to use value-laden background assumptions while testing their theories (Longino, 1990). Values underlying background assumptions (including personal beliefs) help scientists determine what evidence is relevant and the selection of evidence. For example, based on the popular ‘damsel-in-distress’ narrative relying on sexist assumptions about women, language describing the role of the egg in reproduction has been described as ‘passive’ (Campo-Engelstein & Johnson, 2014; Martin, 1991). As a consequence of assumptions such as this, different interpretations of what constitutes appropriate evidence, or even contradicting interpretations of the same evidence are possible. Longino also clarifies that while some philosophers may call background beliefs part of the ‘principles of inference’, these principles cannot, “... be abstracted from the sequence of reason for believing and belief.” (Longino, 1990, p. 44). For Longino, beliefs are connections, whether actual, presumed, correlational or causal, between states of affairs. Most importantly, in the absence of background beliefs, no state of affairs would be taken as evidence of another (Longino, 1990).

One proposed solution to acknowledging background assumptions by feminists has been to increase diversity in science.[2] Diversity is believed to facilit-

[2]Harding (1991) and Solomon (2001) also advocate for diversity. Harding explains how women’s social experiences, along with those of minorities, can illuminate male biases in research. Whereas Solomon describes decision-vectors that use a wide array of factors

ate better scrutiny of science by improving epistemic effectiveness through critical engagement with hypotheses in order to prevent background assumptions from blinding homogenous scientific communities (Longino, 2002).[3] Furthermore, Longino introduces the idea of transformative criticism as a means to harness the reflective capabilities of diverse communities. Transformative criticism requires a dialogue between members of scientific communities founded on avenues for critique, shared standards, community response, and shared intellectual authority (Longino, 1990, p. 76). Hence, individuals are envisioned to interact with theories and hypotheses creating a process of public scrutiny, collaborative knowledge and social epistemology. Longino's definition of social epistemology is described as the practice of examining the social conditions of knowledge production and what social conditions we should consider for generating reliable knowledge (Longino, 1990). To facilitate this, Longino recommends the creation of public forums, instituting equality among intellectual authorities, developing responsiveness and establishing common values. So while individuals can make claims, it is the community as a whole that trans-

(social, cognitive, ideological etc.) which can influence the choices that scientists make and the outcomes of their decisions.

[3]While there can be multiple ways to construe diversity, Intemann emphasizes the need for diverse experiences among community members (Intemann, 2011).

forms theories into knowledge via critical engagement as a norm (Longino, 2002). As a result, scientists have a better chance of catching biased values in the background assumptions that populate the 'gap' between evidence and theory (Longino, 1990).

VFI supporters respond that it is possible to determine when there is enough evidence without using values or background assumptions by instead relying on probability thresholds. Jeffrey (1956) argues that scientists do not need to accept or reject hypotheses themselves, but rather they can assign probabilities to results instead. Rudner (1953) anticipates this response but notes that either someone or some group would then have to decide that a probability assessment is warranted over other assessments, and determine what probability is significant enough to support a conclusion. Plus, any type of assessment will inevitably end up being a value-based assessment because someone at some stage must perform it. Because inference cannot occur independent of values, and science cannot proceed without inference, science cannot function without values. In other words, values serve to help cross the 'gap' between evidence and theory, although the 'gap' can never fully be filled since it is impossible to collect and assess all relevant evidence (Intemann, 2005). As a result, feminists are rightfully concerned that the 'gap' is an area where sexist assumptions and values can seep into science. Hence, the probability proposal is not actually a value-free one and represents part of the struggle that VFI supporters have had in regulating values in the 'context of justification' phase.

In sum, Longino in taking a social epistemological approach, forces us to reflect on the 'gap' between evidence and theory. The social structures of science under the VFI have to hide certain values because the VFI prevents them from being recognized or reported as it precludes non-epistemic values from playing a role. If non-epistemic values are presumed not to be involved in the 'context of justification', then scientists attempting to adhere to the VFI may lack the tools to unearth these values, communicate them, and address them in relation to background assumptions despite the influence values have on science. However, the descriptive challenge alone is insufficient to destroy the VFI qua ideal and nor does it provide a replacement. On the contrary, what social structures tell us about values in science could actually be used by VFI supporters as further motivation to get rid of values in science. After all, if scientists are so susceptible to social values when 'jumping the gap', then VFI supporters might be tempted to fight even harder for the exclusion of values from science (Collins, 2009), even if success remains elusive for them. Hence, it is here when making inferences that contextualizing background assumptions and the social structures that science operates in become apparent. As a consequence, the values motivating background assumptions and those running through social structures need to be communicated for a full understanding of science, even under the VFI.

2.2.2 Boundary Challenge

In its present form, the VFI necessitates that a clear boundary between epistemic and non-epistemic values. If values cannot be clearly sorted as either epistemic or non-epistemic, then the VFI fails (Douglas, 2016). Proponents of the VFI (Jeffrey, 1956; Levi, 1960) encourage epistemic values to influence scientific inference, but insist that non-epistemic values (related to ethics, society, justice etc.) be removed. When practicing science, values can have a mix of epistemic and non-epistemic features. For instance, imagine an environmental study that values preservation. An overarching value like preservation can be motivated by epistemic concerns such as protecting ecosystems for future research or non-epistemic factors like desiring to safeguard local communities that rely on intersecting waterways. Therefore, epistemic and non-epistemic values can create complex social, political, and pragmatic influences on science that challenge whether a clear boundary between epistemic and non-epistemic values is even possible. Phyllis Rooney (1992) and Helen Longino (1995) offer among the most well-known criticisms of the epistemic/non-epistemic distinction from two different angles. Rooney (1992) approaches the boundary from a historical lens whereas Longino (1995) denounces it using a feminist critique.

Through a look at the history of physics, specifically Bohr and Einstein's debate around the acceptability of quantum theory, Rooney (1992) demonstrates how values can prompt the acceptance or rejection of a theory for non-epistemic reasons. During McMullin's (1982) presidential address at the biennial meeting of the Philosophy of Science Association (PSA), he claimed that Bohr was more concerned with the predictive success of quantum theory than Einstein who worried about quantum's consistency and coherence. Rooney points out that what McMullin overlooks are Einstein and Bohr's "substantive metaphysical beliefs" in terms of the organization of the universe (Rooney, 1992, p. 16). She argues that for Bohr and Einstein, whether the universe had an essential coherence or order influenced their opinion of quantum theory. This means that their personal (non-epistemic) beliefs played a key role during the 'context of justification' phase in weighing the evidence. This debate shows how non-epistemic values can influence scientific opinion on whether or not evidence is adequate, perhaps especially in newly emerging fields where scientists have to rely more heavily on 'background assumptions' as opposed to communally established (but still value-laden) standards. Hence, Rooney concludes that the epistemic-sociological border is "continuously being redefined" (Rooney, 1992, p. 16).

Longino (1995) argues against the selection of epistemic values presented by Kuhn via alternative values introduced by feminist philosophy of science. Recall that Kuhn's traditional list is comprised of accuracy, (internal and external) consistency, simplicity, scope and fruitfulness. Ordered as closely as possible to Kuhn's five epistemic values are Longino's feminist values: empirical adequacy, novelty, ontological heterogeneity, complexity of interaction, diffusion of power, and applicability to current human needs. So let us consider how these features vary from Kuhn's sufficient five.

Empirical adequacy refers to the agreement between a theory or model and actual observable claims. A failure to have agreement provides, "...grounds for rejection of the hypothesis or theory in question." (Longino, 1996, p. 45) Longino (1995) points out that feminist scholars have shown how faulty research design or improper statistical methodology fail even basic minimal standards for empirical adequacy (see Haraway (1989, p. 80)), leading to criticisms of Kuhnian accuracy. If prior experiments are biased then these biases can translate to current research and reinforce already problematic research standards. Hence, scientists can be blind to the inadequacies that remain buried in the Kuhnian account of accuracy based on how new theories fit with previous experiments and 'background assumptions'. Alternatively, a feminist account of empirical adequacy is useful for revealing gender, race and class biases based on contrasting claims grounded in 'background assumptions' with actual observations.

Novelty refers to models that differ significantly from current theories either by virtue of their processes, principles or by what they are investigating. According to Longino, since traditional science is marked by faulty assumptions of male superiority and androcentrism, including novelty in our value framework might be a better way to address the needs of diverse publics more than traditional science. As Kuhn's take on consistency (and accuracy) may reinforce experimental bias, a departure from that requirement towards accepting novel models can be a helpful tool for correcting for previous epistemic oversights within our theories.

Ontological heterogeneity gives equal weighting to features of individuals within a group compared to the group as a whole. These individual differences, according to Longino, are important not to abstract or idealize away. Accounting for individuality thus preempts the need for establishing a single standard and granting priority to a single type (Longino, 1995). This means valuing micro-level differences that can help deter theories of inferiority. Though Kuhn might not envision scope as anything beyond the breadth of application of the theory outside its domain, this can come at the expense of the depth anticipated when focusing on individuals. In fact, it is unclear whether there is a good reason to prioritize scope over depth since there can be unique interactions that, if overlooked or idealized, may pose a serious epistemic loss.

Related to ontological heterogeneity, which encourages considering multiple perspectives, is how the complexity of interactions is appreciated by pluralist theories. Complexity encourages interactions between processes and theories to be bidirectional as opposed to unidirectional. The movement away from single factor models to multi-factor interaction networks becomes increasingly necessary in fields like bioinformatics as we attempt to chart complex pathways that are unable to be accurately described as unidirectional (Chaisson et al., 2015; Phan, Gao, Tran & Vo, 2015). Compared to Kuhn's value of simplicity, accounting for complex interactions may appear undesirable. However, a pluralist perspective may be required for complexity (as well as epistemic diversity) to offer a more nuanced and comprehensive description of phenomena.

The diffusion of power relates to the accessibility of science. For Longino, research programs that do not require expertise mastered by only a very select group of people, or research methods that do not demand very expensive equipment are preferable because it opens up science to a broader range of participants. For instance, Longino gives the example of medicine that encourages women to have the ability to make individual choices about their bodies (Longino, 1995) because the knowledge produced is accessible and relevant.

Lastly, in terms of applicability to human needs, Longino departs substantially from the values outlined by Kuhn (and draws further perhaps on the notion of the diffusion of power). Applicability focuses on research programs that generate useful knowledge for improving the living conditions of publics. In practice, this means prioritizing research that looks at reducing hunger, health promotion, and environmental sustainability over science intended for 'defence' or knowledge for its own sake. Applicability compared to Kuhn's value of fruitfulness can be contrasted based on target audience. While Longino advocates for producing science specifically to address societal concerns, Kuhn's goal of generating new research questions is much more aligned with a linear model for science production. By valuing fruitfulness, Kuhn supports investing in producing basic research that can go on to generate more research. Under a fruitfulness approach, society might or might not reap the scientific benefits of science. In contrast, a stakeholder model for science focuses on funding science research that has the most potential to address society's needs (Pielke Jr, 2007). In such a case, science research could be more applicable to human needs under a stakeholder model than by valuing theories for fruitfulness.

To understand the different implications of adopting certain values over others, consider how Kuhn and Longino contrast over scope. Kuhn believes that a theory is epistemically valuable if it has a broad scope and can be applied beyond its domain. Longino might argue instead for a theory that is accountable to a wide array of differences within a domain. For example, consider the case of orphan drugs used to treat rare medical conditions. They are costly to manufacture because development and production expenses must be offset by low volume sales, and they can be pricey to buy because manufacturers end up having a monopoly on the treatment (Burls, Austin & Moore, 2005). Those valuing the intended scope of a theory might hardly be interested in theories and applications that are so limited, after all, there is less assurance that orphan drug research can have other applications compared to drugs designed to address more popular issues (even though there is a chance that an orphan drug might have some mass applicability down the line). Yet, others that value ontological heterogeneity, might justify such research as intrinsically worthy depending on how people suffer from the disease. Evidence of the importance of ontological heterogeneity can be seen in the realization that enhanced sharing and dissemination of knowledge related to orphan drug development is recognized as epistemically worthwhile even while in its early research stages (pre-competition for patents and licensing) (Coté, Xu & Pariser, 2010).[4] Hence, adopting a value like scope would limit research on unique cases like developing orphan drugs, but valuing ontological heterogeneity could justify research into these rare cases.

In sum, Longino's proposed values, some resembling more closely Kuhn's list of epistemic values than others, are a challenge to how we define which values are acceptable under the VFI. The boundary challenge suggests that there does not seem to be a consistently applicable set of epistemic values, and in future there may even be other relevant ones. Hence, there are numerous values which could be used to perform and evaluate science with no absolute reason for adopting one set over another. Because of this inability to select a discrete, universal set of epistemic values, the VFI fails.

2.2.3 Normative Challenge

The normative challenge focuses on inductive risk as an unavoidable part of science. In science, we never have all possible evidence for our hypotheses as there is always another test that could be run or more data that could be gathered. Similarly, we never have conclusive proof for our scientific theories

[4]Plus, because of the very personal nature of orphan drug research, patient-parent advocacy groups represent one of the most prominent examples of publics engaging directly with science to guide research (Wästfelt, Fadeel & Henter, 2006).

- there is no one trial (or even set of trials) that can tell us definitively that we have it right, or wrong for that matter. As a result of the perpetual uncertainty between evidence and theory causing an 'inductive gap', there is always an 'inductive risk' when making scientific claims. Inductive risk is two-fold. Scientists can either fail to make an accurate claim or make an inaccurate one (Hempel, 1965). The cost and consequence of either failing depends on context, which can be scientific and/or social. In response, some scholars (Levi, 1960, 1962; McMullin, 1982) think that only epistemic values should play a role in crossing the 'inductive gap' whereas others (Douglas, 2000, 2009; Elliott, 2011b, 2011a; Kourany, 2010, 2013; Steel & Whyte, 2012) believe non-epistemic values can play a part as well.

As a consequence of this degree of uncertainty within science, there is concern as to whether evidence 'reveals' itself unbiasedly and if scientists are able to interpret this information objectively.[5] As a way to try and reveal or interpret evidence without bias, some scientists (and publics) valourize the VFI as a lighthouse - or guide - for performing science under the assumption that value-free objectivity is possible and/or desirable. In many cases, we assign

[5]There are various types of objectivity in terms of how humans interact with the world, individual reasoning processes and social processes (Douglas, 2004), but I will focus on (the impossible to achieve) value-free objectivity.

scientists a high degree of authority because we believe them not only to be using a reliable method of investigation, but because they claim to use robust epistemic values (acceptable under the VFI and intended to be objective). This is despite the fact that epistemic and non-epistemic values both inevitably play a role in science. After all, science we think to be 'good' based on epistemic values is often biased because of our background assumptions (the descriptive challenge), and we struggle to differentiate epistemic from non-epistemic values (the boundary challenge).

As experts in their field, when scientists speak, they are generally believed (Douglas, 2016). Yet before speaking, scientists must decide on whether or not they have sufficient evidence.[6] According to the normative challenge, scientists ought to decide if they have enough evidence in the context of how their research will be used and what the consequences of a false-positive or false-negative error might be (Douglas, 2016).[7] Due to these potential consequences, social, political and ethical factors cannot be avoided. For instance,

[6]Part of assessing evidence comes in terms of characterizing data where scientists must decide on ambiguous events and whether to sort them into a predefined category, mark them as outliers, or discard them from their data set. See Douglas (2000) and her study of scientists forced to sort ambiguous rat liver slides based on potential carcinogenic changes or Miller's (2014) example of how smokers can find the same evidence about the dangers of smoking less persuasive than non-smokers.

[7]The alternative, conducting research detached from the social consequences of false positives and negatives, is reminiscent of the linear model.

consider Douglas' (2016) example of thresholds for sufficient evidence for new treatments of diseases versus requirements for high-energy physics. In terms of disease treatment, if there is no alternative treatment for a deadly disease then the threshold for sufficient evidence could reasonably be set quite low because in this case, almost anything is better than nothing. A milder disease, with already existing treatment, would require a higher threshold of evidence, forcing the new treatment to perform at least as well as the existing treatment or have more preferable side effects. Alternatively, in a field with fewer social impacts like high-energy particle physics, very high thresholds of evidence can be used to avoid premature claims from later having to be reversed. In this example, there are three different thresholds being set for evidential sufficiency based on both non-epistemic and epistemic values in relation to context. Because in some cases we may want to utilize non-epistemic values when deciding if there is sufficient evidence, the VFI fails.

The normative challenge illustrates not only that non-epistemic values are necessary in the evaluation of evidence, but also that they can be desirable by combining the endemic uncertainty of science with the 'inductive risk' argument. Since scientists wield epistemic authority, their responsibility to publics is evaluated in part in terms of their intentions and duty to not act recklessly or negligently (Douglas, 2003). This connects the epistemic authority of scientists to society's well-being, a non-epistemic value. However, if models for science like the VFI that aim to separate scientists from society are the norm, then the non-epistemic values needed to guide inferences may be harder to source and describe.

Conclusion

As the descriptive, boundary and normative challenges show, the VFI fails for being impractical and undesirable. The descriptive challenge questions the use of epistemic values thought to be uncontroversial and uncovers biases based on non-epistemic background assumptions. The boundary challenge suggests that determining which values ought to be considered the definitive epistemic set for science is subjective. Lastly, the normative challenge, tying the endemic uncertainty of science with the inductive risk argument, explains how not only do non-epistemic values have to be used in the assessment of evidence, but that it can be desirable to do so because of the social implications of making false positives or negatives. By confronting the VFI qua ideal, the normative challenge delivers the most compelling criticism of the VFI and as such, will inspire my consideration of normative-challenge based alternatives as a way to describe epistemic and non-epistemic values.

2.3 Alternatives to the Value-Free Ideal

All three of the major challenges I have summarized include the admission of non-epistemic values in science. As a result, the epistemic and normative undesirability of the VFI qua ideal has stimulated discussion about what alternatives to the VFI should look like. This section examines four alternative accounts for values in science.[8] The first proposal, by Heather Douglas (2009, 2016), puts forward that different values should take on different roles. In response, Kevin Elliott (2011a) asks for clarification regarding the logical basis and potential consequences of the role distinction and develops a Multiple Goals Criterion to guide research. Daniel Steel and Kyle Powys Whyte (2012) are concerned about non-epistemic values conflicting with epistemic values. And Janet Kourany (2013) emphasizes ethical and epistemic values in relation

[8]These alternatives do not resolve the challenge of distinguishing between the discovery and justification phases of science or issues demarcating epistemic from non-epistemic values, but nor do they need to. Instead by acknowledging these points, the alternatives map out ways to accommodate values in response to these features of science.

to the needs of publics. These alternatives only represent a slice of the options available to philosophers and scientists for how to incorporate values in science but help to outline the considerations needed to transmit information about values in science. As each alternative offers a useful contribution in terms of how to elucidate values in science, outlining them next in detail will serve as primer for considering what features of values stakeholders should know (Chapter 4).

2.3.1 Douglas' alternative: A Direct/Indirect Role for Values

Douglas' alternative to the VFI hinges on a distinction between a direct and indirect role for values in science which will later on be used to discuss what publics' need to understand science. In general, values can act as a motivator or deterrent for either proceeding with a methodology or weighing evidence. Douglas (2009, 2016) allows epistemic and non-epistemic values to play a direct or indirect role during the 'context of discovery' phase but only allows epistemic values to play a direct role during the 'context of justification' phase, limiting non-epistemic values to an indirect role.[9] Although the distinction does not overcome challenges with respect to demarcating the phases of science or delimiting epistemic from non-epistemic values, it does provide a way to describe values which is why it will prove useful in answering how to communicate science.

In accordance with the standard view of philosophy of science and the VFI itself, Douglas (2016) agrees that it is acceptable to allow epistemic and non-epistemic values to play a direct role when deciding on research questions and methods during the 'context of discovery'. This is because we believe that there are legitimate reasons for pursuing knowledge via some avenues and not others. These values serve as reasons in themselves (direct) or supporting reasons (indirect) to adopt a methodology, accept a funding opportunity, collaborate with certain researchers etc. To illustrate how values in a direct role can influence science during the 'context of discovery', Douglas imagines how when determining methodology, a scientist may reject a method that could cause distress to subjects (Douglas, 2016). For example, consider our current

[9]To decide using non-epistemic values in an indirect role, first the evidence must be reliable as collected and evaluated using epistemic values. Furthermore, Douglas does not define a list of epistemic values always believed to be appropriate in a direct role, so values are examined on a case by case basis.

methods for drug testing. In a world where ethical/social values mattered little, scientists could employ some fairly unethical methods in the name of research. If values like patient autonomy were not important, then scientists could theoretically isolate drug trial participants from their loved ones (to avoid confounding factors), conduct harmful and dangerous tests on them (if they may lead to more efficient or accurate results), and claim that it was all for the sake of knowledge. However, because this style of research is unethical, deciding not to conduct research on moral grounds is reason enough not to pursue it. Hence, an ethical (non-epistemic) value like respect for patient autonomy should play a direct role in how experiments are designed.

In the 'context of justification' during evidence characterization or interpretation, non-epistemic values should not play a direct role according to Douglas (2009). Instead, non-epistemic values should only be used indirectly when scientists are, "...characterizing phenomena and assessing hypotheses with respect to evidence." (Douglas, 2016, p. 618) The concern is that if non-epistemic values are able to play a direct role when assessing evidence, those non-epistemic values could become a reason in themselves for accepting or rejecting a theory. Instead, a non-epistemic value in an indirect role should be in tandem with epistemic values that judge whether the evidence (considering inductive risk) is sufficiently robust.

For comparison, a value like fruitfulness should not play a direct role during the 'context of justification' phase because it is not necessarily indicative of the truth of the theory. Instead, internal consistency is more than a supporting reason for accepting a theory - in fact, it is a mandatory feature of reliable theories and should play a direct role (Douglas, 2009). Therefore, Douglas allows for an indirect and direct role for epistemic and non-epistemic values during the 'context of discovery' phase but limits non-epistemic values from playing a direct role during the 'context of justification' phase, permitting only a narrow group of intrinsic epistemic values instead. Combined, the direct and indirect roles Douglas proposes for science give good reason for embracing values in science but showcase how these values should play different roles at different times.[10]

[10]Douglas also differentiates cognitive values from epistemic values, though I will not use this distinction here. Cognitive values are features of the theory that make it easier to use whereas epistemic values provide reliable guides for inference (Douglas, 2016). In practice this means that cognitive values can make a theory more productive but, should not play a direct role for accepting a theory. Whereas epistemic values, such as empirical accuracy, can serve as reliable guides for inference in a direct role (Douglas, 2016).

2.3.2 Elliott's alternative: The Multiple Goals Criterion

Pushing non-epistemic values to an indirect role during the 'context of justification' phase of science but allowing them to play a direct role in the 'context of discovery' phase has opened Douglas up to criticism from Elliott (2011a, 2013). Elliott's critique of the direct/indirect role distinction claims that it has limited effectiveness in terms of managing how values influence science and lacks the clarification to be a fully formed normative alternative, especially with regard to publics (Elliott, 2011a, p. 322). Elliott asks precisely what the direct/indirect distinction refers to, either a logical point based on a distinction between epistemic attitudes or different consequences that result from accepting certain scientific claims (Elliott, 2011a). According to Elliott, the direct role in terms of logical understanding, specifically using the "stand-alone reason" for choice that Douglas presents (Douglas, 2009, p. 96), uses 'the reason' to discuss both motives for accepting hypotheses and choosing methodologies where the consequence of the risk associated with this degree of uncertainty can manifest as false positives or negatives (Elliott, 2013). And so, while recognizing Douglas (2009) for her broadening of inductive risk to include phases of science beyond accepting and rejecting hypotheses, Elliott (2011a, p. 306) argues that the relationship between values playing an indirect role yet having direct consequences is unclear in relation to the scientists' intentions.

To explain this further, Elliott (2011a) provides a case of scientists that accept a hypothesis that ultimately turns out to be false. In his example, a pesticide that scientists deem safe actually leads to public exposure of a harmful substance. Here the scientists make a mistake in accepting the hypothesis that the pesticide is safe and ultimately contribute to a significant increase in local incidences of cancer. Elliott states that what is unique about Douglas' idea of 'direct' is that it is not direct in the causal sense, but in regard to the consequences that scientists intend by accepting a hypothesis. Here, the scientists did not intend to put public health at risk but did so inadvertently.

Douglas responds that the distinction is predominantly about the logical role for values given the uncertainty that comes with evaluating evidence and with respect to erroneous or unintended consequences (Douglas, 2016). Furthermore, Hicks (2018) suggests that the logical distinction can also be a helpful one, especially compared to the limits that come with adopting the VFI. When considering the consequences of risk under the VFI, scientists are limited to reflections only on the implications of using epistemic values for justification, likely just part of what is required to assess evidence with respect to social consequences. Therefore, the logical distinction might in some ways be able to show us the varied implications that value selection can have in terms of evaluating risks associated with false positive and negative social impacts.

In response to addressing how to decide on values for science, Elliott agrees with Douglas that there is a benefit to using forums for deliberation to investigate what values scientists and publics desire (Douglas, 2005).[11] In more detail, Elliott believes forums might be able to help determine which non-epistemic values should (or should not) influence science, ultimately making the role of values in science more transparent. Within these forums, Elliott (2013) elaborates that a focus on scientists' goals can help determine which values are relevant to research and argues that these goals should be communicated to publics. He calls this the Multiple Goals Criterion (Elliott, 2013). The Mul-

[11] Brown also questions the source, status and where exactly ethical and epistemic values are intended to be incorporated, but Douglas and Elliott together are able to cover Brown's concerns regarding the source of values and where they should intervene so it will be discussed no further here.

tiple Goals Criterion uses specific goal-oriented values to, "... appropriately influence a scientist's reasoning in a particular context only to the extent that the value advances the goals that are prioritized in that context." (Elliott, 2013, p. 381) In other words, scientists can evaluate evidence using select values (based on practical goals) so long as they maintain appropriate cognitive attitudes about their conclusions. However, determining which values are befitting of the goals remains a challenge.

A strength of the Multiple Goals Criterion is that it offers guidance for regulating values in assessing scientific models, evaluating evidence etc. But, unlike Douglas' direct/indirect roles distinction, non-epistemic values are allowed to play a direct role when weighing evidence and offer reasons to accept a theory so long as they promote the goals of the assessment. For example, if the goal is to minimize social harms, when deciding on whether or not to accept a dose-response model, ethical and pragmatic values (e.g. whether the results are realized fast enough) are the sorts of non-epistemic values that are fair to include under the Multiple Goals Criterion. In contrast, selecting a dose-response model based based on non-epistemic values, like augmenting a scientist's prestige, would not be an appropriate to adopt (Elliott, 2013).

Though skeptics might try and argue that the Multiple Goals Criterion does not offer enough bite to criticize the complex array of values that go into research, Elliott emphasizes that the Multiple Goals Criterion evaluates the legitimacy of values used in light of the goals prioritized which will be relevant in our discussion of making information about science more engaging later on.

2.3.3 Steel and Whyte's alternative: The Values-in-Science Standard

Like Elliott, Steel and Whyte (2012) also criticize the purpose of the direct/indirect distinction and the position of non-epistemic values in relation to epistemic ones. Based on concerns regarding how non-epistemic values in science can play a negative role,[12] Steel and Whyte (2012) use environmental justice to show the practical limitations of Douglas' direct/indirect role distinction. Their concerns come from the fact that the actual reasoning of scientists is not always transparent, even to the scientists themselves, which can hinder attempts to regulate values in science (especially non-epistemic ones) (Steel

[12] Hicks (2014) agrees with Steel and Whyte that utilizing non-epistemic values leads to an intersection between epistemological and ethical aspects of problems, projects and hypotheses in science.

& Whyte, 2012). Douglas might respond that when using (non-epistemic) values in an indirect role, scientists' values can be revealed through public forums of deliberation, but this is not necessarily a transparency standard.[13] Thus, as transparency is an unattainable ideal, Steel and Whyte argue that non-epistemic values should not be allowed to conflict with epistemic values (except in terms of moral permissibility), independent of whether they occur in the direct or indirect role.

Based on the risk that scientists may not always be transparent about values, non-epistemic ones in particular, Steel and Whyte advocate for prioritizing epistemic values over non-epistemic values; they call this the values-in-science standard. Steel and Whyte focus on the type of value being used more so than the role the value is playing because according to them, epistemic values (or values that encourage the attainment of truth) are the values scientists ought to use when evaluating evidence. According to the authors, epistemic values are distinguishable from non-epistemic values based on their effects.[14] In con-

[13]From a practical standpoint, I suspect that there is no guarantee that scientists can reliably recognize all the values that go into research or what role the values play, especially in large collaborative research network.

[14]Steel and Whyte's consequentialist emphasis on the effects of values, as the determinant of if the values were appropriate to use, resembles the linear model in that it stresses post-research implications.

trast, Steel and Whyte worry that non-epistemic values are more likely to lead to negative effects and the particular effects they want to avoid relate to social and environmental injustices.[15] To avoid negative effects, Steel and Whyte specify that non-epistemic values used in science must not conflict with epistemic values in, "... the design, interpretation, or dissemination of scientific research that is practically feasible and ethically permissible..."(Steel & Whyte, 2012, p. 169). By encouraging truth-promoting epistemic values, Steel and Whyte place a degree of importance on the causal relationship between values and outcomes, meaning that in certain circumstances particular values might be more desirable than others. For example, epistemic accuracy is almost always useful for the attainment of truth and therefore considered 'robust' (Steel, 2010), compared to simplicity which might fail in complex cases and therefore be less desirable to use (Steel & Whyte, 2012).

To understand how prioritizing non-epistemic can occur, consider Steel and Whyte's pharmaceutical example. Imagine that a pharmaceutical company

[15]For example, race is a better predictor of living in communities with commercial hazardous treatment, storage, and disposal facilities – which are known to have harmful health consequences (Jennings & Gaither, 2015) – than any other variable such as income. This is theorized to be because organizations that decide on the location of these facilities act on racist beliefs founded on non-epistemic values (Steel, 2010; Commission for Racial Justice, United Church of Christ, 1987)).

demands higher standards of evidence from their scientists before allowing them to publish studies with negative results. By setting disproportionally high standards for negative results – failing the values-in-science standard he company is able to bury unfavourable evidence and obscure the truth based on non-epistemic values (Steel & Whyte, 2012, p. 171).

In response to Steel and Whyte's values-in-science standard, Elliott and Douglas have raised several concerns (Elliott, 2011a; Douglas, 2016). They argue that because Steel and Whyte hold epistemic values to be truth-promoting, the selection of values depends on knowing what the truth is. However, these values would not be evident until after the assessment of research's effects, so how could scientists decide on what values to use beforehand; put another way, Steel and Whyte may want to avoid negative (unjust) effects by adopting certain truths, but without knowing what the truth is, scientists (and publics) may be hard-pressed to select the right values to influence research. Steel and Whyte try and work around the lack of a clear 'truth-beacon' by insisting that epistemic values take precedence over non-epistemic ones in hopes that the epistemic values are more apt at uncovering the truth. Douglas (2016) categorizes testability, external consistency and open discourse in science as additional examples of epistemic values that are truth promoting so Steel and Whyte are not alone here. As a preview of how features of the alternatives may be combined, Elliott's Multiple Goals Criterion, if aligned with the truth, could be helpful in selecting the right values. However, how to determine if the Multiple Goals Criterion is aligned seems again to be a retrospective undertaking. In sum, Steel and Whyte's major concern is the negative effect that non-epistemic values can have on the truth by corrupting scientific integrity, an approach that compensates for the lack of transparency in science – itself a worthwhile aim.

2.3.4 Kourany's alternative: Socially Responsible Science

In Janet Kourany's 2010 *Philosophy of Science after Feminism*, she outlines a new normative ideal for science to replace the VFI. Her replacement for the VFI is based on new ethical and epistemic standards for science, specifically from feminist philosophy of science. It has two main points: first, that philosophers of science recognize science as a social enterprise within a larger societal context; and second, that as part of this societal context, philosophy of science's aim should be an understanding of the rationality of science in order to integrate ethics and epistemology into science. Provided these goals, Kourany's alternative to the VFI is the creation of socially responsible science (SRS) that considers ethics and epistemology jointly and equally.[16] More specifically, SRS aims to use these otherwise independent values in parallel to control the scientific process (Kourany, 2010, 2013). If both sets of guiding values are equal, then this means that epistemically sound but ethically poor science could not be undertaken and vice versa. As a result, neither ethical nor epistemic values are meant to take priority over the other (a stark contradiction with Steel and Whyte (2012)) .

This socially contextualized approach is not without its critics. Brown raises concern of what happens when competing values arise (M. J. Brown, 2013a), Lacey worries about the abilities of scientists to decide what social values should inform their research (Lacey, 2013), and Potter is concerned about irreducible conflict and pluralism (Potter, 2013). To address these critiques, Kourany (2013) suggests a highly interdisciplinary approach based on inform-

[16]Like Kourany, Anderson (2011) as well as Cole and Stewart (Cole & Stewart, 2001), argue that value judgements can play a valid role in evaluating hypotheses and their applications. The authors agree that in a democratic society, publics have a right to criticize scientific theories for not adequately taking non-epistemic ideas into account, or for incorporating bad values.

ation from within the field and those potentially affected by it. As a result, Brown's worry regarding how competing values might be reconciled is soothed (in theory) by Kourany's suggestion for engaged discourse between stakeholders and the humble realization that no one code of ethics can be comprehensive. Lacey's desire to revamp the VFI for technoscience is done from the perspective of restoring the ideal of science 'neutrality', where science is 'inclusive' and 'evenhanded' (Lacey, 2013).[17] However, Kourany argues that 'neutral' science actually stands to reinforce the disenfranchisement of those who cannot readily access science (either through medicine, environmental perks, or technological resources). Finally, Potter's plurality problem, which seems to necessitate an exclusion of the interests of at least some stakeholders, may have a few of its concerns mitigated by Kourany's supporting examples from green chemistry where all stakeholders appear to benefit (Kourany, 2013, p. 96). So given the increasing need for science to address society's challenges, a more inclusive, multi-stakeholder approach can be appealing, especially since there need not

[17]Lacey defines 'neutrality' as scientific theories, which in principle, serve all viable values in attempt to prevent science from only accommodating special interests at the expense of others (Lacey, 2013). This means that although there may be social values trying to steer research, science itself should not be swayed. The idea that science should be impervious to non-epistemic social values that would favour particular research interests and conclusions is how the revamped 'neutrality' reflects the VFI.

be exclusion when diverse stakeholders interact. Thus, Kourany's alternative account for values in science is purposely engaged and accessible to publics in its embrace of values in science which will be important for my discussion of how to engage publics with science.

Conclusion

The alternatives presented here acknowledge how and why epistemic and non-epistemic values are (and should remain) integrated in science. Douglas does so by limiting epistemic and non-epistemic values to direct and/or indirect roles, Elliott via a Multiple Goal Criterion to guide values, Steel and Whyte by correcting for a lack of transparency by forbidding non-epistemic values to take priority over epistemic values, and Kourany through an ethical and epistemic value-based socially responsible account of science. All of these alternatives highlight the limitations of the VFI, especially in terms of recognizing science as a contextualized value-rich endeavour. After investing implications of the VFI, in Chapter 4 I will use components of each of the alternatives to develop more accurate, engaging, value-conscious descriptions of science.

2.4 Chapter Conclusion

As agreed upon by most philosophers of science, there are both epistemic and non-epistemic values present in the 'context of discovery' phase. The tension as to what types of values and how values should be involved in the 'context of justification' phase remains. But, given that criticisms of the VFI offer reasons to believe that even 'good' science seems to be problematically biased (the descriptive challenge), and it is impossible to distinguish epistemic from non-epistemic values (the boundary challenge), plus in some cases we want non-epistemic values to play a role (the normative challenge), I will take the VFI to be an undesirable ideal for science.

Keeping the challenges and alternatives to the VFI in mind, I will add to the discourse by building on these to argue that the VFI has greatly influenced how information about science is transmitted. The implications of adopting the VFI for science in terms of transmitting information about science has yet to be properly attended to in the literature, even though scholars have insisted on a need for more value explicit models of communication (Dietz, 2013). Provided this, I will explore how the VFI encourages particular types of transmissions that will be shown to misrepresent science as value-free and decontextualize science, ultimately making it less memorable. Thus, I will offer another reason to discard the VFI but this time, for the sake of science literacy and democracy.

Chapter 3

The Value-Free Ideal, Science Education and Science Communication

The value-free ideal (VFI) has been shown to be inherently problematic for epistemic as well as pragmatic reasons. This is partially because decontextualizing the evaluation of scientific evidence from non-epistemic values separates scientific judgement from its societal implications. As science still often operates under the VFI, I argue decontextualization has had negative consequences for science literacy and science communication in terms of accurately presenting science and making it memorable. Misrepresentation and criticism of information retention are serious challenges for science because these affect how future scientists develop an interest in science and how publics relate to science. It is here at the intersection of science, education and communication that conversations in the philosophy of science have yet to reach, and where the implications of the VFI need to be mapped out.

As I link value-free decontextualization to the VFI, science education and science communication in this chapter, it may be tempting to ask why scholars missed the connection before. As outlined in Chapter 2, philosophers have been engrossed in debates about the VFI since the 1950s, and communication scholars have been reflecting on public understanding of science since the 1980s (M. W. Bauer, 2009). But have these scholars been communicating with each other? Philosophers have only on occasion turned their attention to popular science[1] – a domain that shares enough characteristics with professional science communication that it makes it hard to separate the two (Turney, 2008). Likewise, sociologists of science have offered few marginal entries on public science communication compared to notable contributions from social psychology, linguistics and media studies (Bucchi, 2008). In bringing together

[1]See Curtis' (1994) analysis of 'Baconian' narratives in popular science as encoding an implicit epistemology, and Shermer's (2002) content analysis of Gould's popular and professional writing with respect to the history and philosophy of science.

discourse from philosophy, education and communication, I recognize the pervasive problem of decontextualization which will be shown to misrepresent core features of science (e.g. endemic uncertainty) and leach context from science, making it less memorable.

Though it might have been easier to consider the VFI with respect to science education or science communication individually, it would over-simplify the ways in which the VFI is embedded in the larger relationship between science and society. In brief, scientists come to understand science from science education and communication based on research described by scientists using the VFI. Hence, new scientists risk framing science as value-free and as a result describing its findings as value-free for science education and communication – a cyclic relationship. Thus, a value-free decontextualized account of science must be critiqued by investigating ideals in science education *and* communication if science is to be presented honestly.

To elucidate the decontextualization in science education and communication, I will start by reviewing definitions of science literacy as their common objective (DeBoer, 2000; DeHart Hurd, 1958; Marsick & Watkins, 2001).[2] Sci-

[2] They also aim to educate, engage and entertain. While there is a relationship between popularizing science (under the goal of entertainment) and encouraging public understanding of science, I will focus on the latter because it is an understanding of science required for

ence education attempts to improve science literacy through teaching, whereas science communication uses public engagement (Baram-Tsabari & Osborne, 2015). How education could be a form of communication/engagement is not the focus of the forthcoming analysis.[3] This is because being able to completely separate education from communication is unnecessary for describing how we transmit information about science under the VFI. So instead of delving into discourse that attempts to cleave science communication from science education, I will instead use their imperfect (but viable) frameworks, to argue that the decontextualization nestled in the VFI has had a negative influence on science literacy and in turn science education and science communication because it is contextualized information instead that is more accurately representative of science and has been shown to aid in information retention (Bouillion & Gomez, 2001) as well as improve academic performance (Rivet & Krajcik, 2008).

Science education is an institutionally organized and highly structured form

democracy. Popularizing science can be a relevant consideration for the uptake of science (Ziman, 1992), but being entertained by science is not enough to utilize science, which is why understanding will remain our focus.

[3] Although, I recognize that there are semantic and psychological discussions surrounding their relationship in terms of concepts (P. Scott, Asoko & Leach, 2007; R. J. Osborne & Wittrock, 1983) and methods of assessment (Siemens & J.d Baker, 2012).

of ‘formal learning’ motivated by the economic argument for teaching the findings of science. I will consider science education from elementary through to secondary school (K-12) because in many countries publics are required to be enrolled in these forms of schooling.[4] As evidence, science literacy tests are usually held during these formative years (Meyer & Benavot, 2013; Sellar & Lingard, 2014). Thus, what is taught during this time frame is indicative of the science society sees as relevant to teach.

I will continue by surveying what it is social scientists, philosophers and pedagogy scholars believe positively contributes to public understanding of science, and as a consequence, what ought to be taught in the classroom. Their recommendations led to curriculums designed to teach the Nature of Science (NOS) (McComas & Olson, 1998). Broadly, the NOS is the practice, findings and social features of science (Clough, 2011), or in other words:

[4] Brunello et al. (2013) found that the expansion of compulsory schooling in Western countries has significantly affected educational attainment reflecting the desire for a skilled labour force for an increasingly globalized/techno-scientific world (Murtin & Viarengo, 2011). However, others like Reid and Young (2012) point out that instituting new school-leaving age policies without consulting publics misses out on relevant dimensions like gender, ethnicity and ability as students compete for resources (Reid & Young, 2012). Similarly, Schlicht et al. (2010) found that compulsory education has varying effects on educational inequality between western and post-communist countries based on factors like the availability of preschool education, an all-day school tradition, tracking during secondary education, a large private school sector, average class size and education expenditures (Schlicht et al., 2010).

what science consists of, how that knowledge is discovered, and the values that go with it. However, the consensus view – a popular model of science education – argues for teaching information with the most agreement around it (Abd-El-Khalick, Bell & Lederman, 1998). Since the appropriate place for non-epistemic values in science remains under debate (see Chapter 2), discussions about non-epistemic values in science are not included in this information. Omitting non-epistemic values from science education through models like the consensus view situates science outside society and decontextualizes science in the process. The consequence of this decontextualization is that it misrepresents science as free of non-epistemic values and makes it inevitably less memorable because the information then lacks context.

As new discoveries and technologies become available, publics need both reinforcement of the science they know, and updated information in order to maintain a functional degree of science literacy throughout their lifetime (Dierking et al., 2003; Liu, 2009). Learning outside the classroom is known as 'informal learning', is less directed than formal learning (Marsick & Watkins, 2001), and is based on science communication. During informal learning, what is learned is, "...determined by the individuals and groups who choose to engage in it." (Livingstone, 1999, p. 50) making it a significant contribution to science literacy because of the large amount of time spent learning outside the classroom.[5]

The deficit model of science communication denies the relevance of the knowledges and attitudes of publics as well as their potential contributions to science (Trench, 2006). Thus, I add to the literature by showing how by cultivating science literacy through use of science education and science communication models like the consensus view and deficit model, they reinforce the misrepresentation of science championed by the VFI, making science seem decontextualized and separate from society.

I finish this chapter by showing how the VFI, science education and communication share similar chronological trajectories. Combined with the conceptual similarities the three have, I propose that the decontextualization running through the VFI contributes to the use of science education and communication models which minimize non-epistemic values in science. By unravelling

[5]For instance, Tough (1978) found that the average number of hours devoted to informal learning was about 500 a year. In the same vein, a survey in the UK showed that (informal) time spent on Information and Communications Technology in the home (through the use of cellphones, computers etc. but excluding gaming) now greatly exceeds time spent in formal learning environments (Harrison et al., 2002). Plus, with the advent of mobile learning, there has been a marked increase in informal science learning particularly due to its ability to elucidate real-world connections (Crompton, Burke, Gregory & Gräbe, 2016).

the decontextualization threaded through science education, communication and the VFI together, we can see they share misrepresentations of science and ultimately make it less engaging – justifying my consideration of alternatives in Chapter 4.

3.1 Science Literacy

At the intersection of science communication and science education lies science literacy.[6] Science literacy is the knowledge people need to, "...understand, and respond critically..." to science in order to, "...feel empowered to hold and express a personal point of view on issues with a science component."(Millar & Osborne, 1998, p. 12) Levels of science literacy are evaluated semi-regularly in school via standardized testing,[7] and maintaining adequate levels of science literacy is recognized as a lifelong affair (Dierking et al., 2003; Liu, 2009).

[6]For clarification, in many cases authors use the terms 'science literacy' and 'scientific literacy' interchangeably. However, others such as Roberts (2014), make a useful distinction. Like Roberts, I will use 'science literacy' to refer to literacy with regard to science and 'scientific literacy' for the scientific study of literacy in all disciplines.

[7]Standardized testing has had mixed reviews from teachers because of how it can influence instructional and assessment practices in ways that are counter to the learning goals promoted by science education reformists (Aydeniz & Southerland, 2012). It forces educators to 'teach-to-the-test' as opposed to generating an understanding of the NOS (Bhattacharyya, Junot & Clark, 2013). In addition, many of these tests have been criticized for being unfair to certain minority groups (Knoester & Au, 2015) which likely contributes to publics' eroding faith in state-run education (Rhodes, 2015).

However, the details of what to convey in school to produce science literacy are rarely articulated in detail. Furthermore, student levels of science literacy are rarely connected to informal science communication in terms of how people will engage with science personally and civically as adults (Ryder, 2001). In other words, it is unclear what aspects of school-based science literacy are required for adult publics' science literacy later on in life.

The lack of a clear connection between school-based science literacy and adult science literacy may partly be because of the difficulty in defining science literacy. According to DeBoer's (2000) historical account, the term 'science literacy' has been in regular usage since the 1950s despite there not being a universally accepted definition (Roberts, 2014). Early on, industry representatives like Richard McCurdy (1958)[8] and research commissioned by the Rockefeller Brothers Fund (1958)[9] used the term to describe a desired familiarity between science and publics for the overall welfare and prosperity of

[8]McCurdy (1958) uses the term 'science literacy' to contrast with 'technological literacy' and argues that because of the staggering changes happening in science at the time (such as the splitting of the atom), science education should move away from its applied focus to one that examines the principles of science (DeBoer, 2000).

[9]In June of 1958, a report (1 of 5) on the state of education in the U.S was issued by the Rockefeller Brothers Fund. It outlined how the U.S. could respond to rapid developments in science and technology as evidenced by changes at the time in nuclear energy, space exploration, cellular biology and neural physiology. The report argued that there was a shortage of technically trained individuals who would be crucial for future science and technology endeavours (DeBoer, 2000), and so more science literate students were needed.

individuals and the state. But, what exactly that familiarity entailed was left open.

Around the same time, Paul DeHart Hurd (1958) recognized the desperate need for longterm changes to science education because of political concerns, namely the space race.[10] Given these political concerns, he recognized the limitations of a liberal (arts) education in comparison with national goals of building a technically trained workforce. This prompted DeHart Hurd to identify a need for balance between arts and science so that students could develop an appreciation for science and use that as a driving cultural force for informed decision-making. As a result, DeHart Hurd imagined science literacy as something developed in formal learning environments based on the procedures of science but recounted as an imaginative endeavour, filled with 'joys and sorrows' - in other words, contextualizing values. As a direct implication of this definition, DeHart Hurd conceptualized science as a discipline to be taught and situated amongst the social sciences (even the humanities), with the aim being to help address humanity's problems (DeHart Hurd, 1958). However, what McCurdy, the Rockefeller report, and DeHart Hurd failed to

[10] The link between realizing the need to cultivate science literacy and political events is well documented. For example, there was also a concerted effort to increase science literacy to encourage the next generation of scientists during the cold war (Mayer, 2002, p. 38).

do is actually elucidate what science literacy consists of in detail and how to translate science education based science literacy to adult science literacy needs.

In this section, I review several contemporary definitions of science literacy. Based on Xiufeng's (2009) survey of the field, first I inspect Shen's summary on the elements of science literacy that lead to different types of science literacy. Then I look at Miller's more simplified account, and contrast it with the National Academy of the Science's definition. Combined, these three accounts cover a majority of the features science literacy is believed to have and as a result, can be used to gather insight into what science education and communication are meant to convey. I present these definitions to show their conceptual similarities and differences, but in the following sections, ultimately contrast them with how information about science is actually transmitted to show how decontextualization (and the VFI) has a pervasive role motivating a value-free approach to science.

3.1.1 Current Definitions of Science Literacy

To understand decontextualization in science education and communication, let me point to Shen's (1975) six features of science literacy as their shared goal. The features are: basic science concepts; the nature of science (NOS); the ethics guiding scientists' work; the interrelationships between science and society; the relationship between science and the humanities; and, the nature of science and technology. As a result of these features and their uses, Shen proposes three different sorts of science literacy: practical, civic, and cultural.[11] Practical science literacy is used for personal problem-solving (e.g. being able to fix one's car - this is also a part of the utilitarian argument for science education to come). Civic science literacy is enough knowledge for citizens to participate in democracy (a theme to be revisited in Chapter 5). And cultural science literacy, or the appreciation of science as a human achievement.

[11] Shamos (1995) offers a very similar description of the types of science literacy possible, listing them as: cultural, functional and true literacy. Xiufeng (2009) summarizes Shamos' cultural science literacy as concerning the sociopolitical background information associated with science; functional science literacy as the ability to write and read scientific terms coherently in non-technical contexts; and, true science literacy as an understanding of major conceptual schemas along with specific elements of empirical investigation. An overlap can be seen most notably in Shamos' and Shen's accounts of cultural science literacy. Furthermore, Shamos emphasizes the human achievement framing of science less than Shen, though it can be weaved into Shamos' definition of 'sociopolitical background information'.

Alternatively, in a more simplified version of what science literacy should entail, Miller[12] describes it as having four elements: basic textbook facts, an understanding of methods, an appreciation of the positive outcomes of science with technology for society; and the rejection of superstition (J. D. Miller, 1983, 1992). For publics, this means having enough basic vocabulary of scientific constructs to do three main things: read (and ideally understand) competing views in a newspaper or magazine, have an understanding of the process or nature of scientific inquiry, and have some understanding of the impact of science and technology on individuals and society (J. D. Miller, 1998).

From a critical perspective, taking only the positive outcomes of science in society appears biased and can be misrepresentative of science, skewing publics' opinions of science.[13] This is why descriptions of science literacy like Shen's, which can consider both positive and negative features of science and society, are more appealing and will be accounted for in the alternative I

[12]Technically, Miller (1983) recognizes science literacy as having two different definitions: a 'learned' one and a 'public' one. The learned definition questions persons with training in letters (Arts), but lacking knowledge of science. Miller questions whether or not such individuals could actually be considered learned without knowing science and although an interesting (and perhaps controversial) question, I will not delve any further into this since the definition of public science literacy is my focus.

[13]This focus exclusively on the positive may be a relic from the linear model's insistence on bad outcomes of science as the result of how society applies science as opposed to being a problem with science itself (see Pielke (2007)).

propose for how science should be communicated in the following chapter.

The National Academy of the Sciences (NAS) defines science literacy as, "...understandings of scientific processes and practices, familiarity with how science and scientists work, a capacity to weigh and evaluate the products of science, and an ability to engage in civic decisions about the value of science." (National Academy of the Sciences, 2016, S-1) This definition also draws heavily on Shen's idea of creating civic science literacy, though it lacks explicit mention of the embedded nature of science *in* society as opposed to *for* society.

Based on Shen, Miller and the NAS' definitions, science literacy appears comprised of several features such as a description of the empirical findings of science, the methods of investigation used, as well as a socio-cultural account of the relationship between scientists, their research and society. Many of these features are shared with descriptions of the NOS. However, different definitions stress different aspects of the NOS and none of these popular definitions clarify what science literacy at the student level means for adult levels. Therefore, it is worth examining how science education and science communication are described and performed for insight into how science literacy actually manifests as opposed to just relying on definitions of science literacy which do not detail the actual practices aiming at it.

3.2 Science Education

Science education serves as one solution to improving science literacy but can be supported by decontextualizing arguments. The most common are the utilitarian, economic, cultural and democratic arguments. The cultural and democratic arguments provide the best opportunity to describe values in science, but as we will see, it is the least value-conscious 'economic argument' that is most frequently used. Furthermore, these arguments do not dictate what the content of science education should be, only that we need to teach science (unidirectionally). To address the content of teaching, many curriculums mention the NOS. But despite the many features of science that make-up the NOS, I will show why the socially-contextualizing elements end up being left out, thus aligning science education with the VFI by decontextualizing science.

3.2.1 Arguments for Science Education

Some critics claim that science literacy is simply a 'rallying cry' for teaching science (J. Osborne, 2007). If this were true, then that means that advocating for science literacy simply means supporting science education (DeBoer, 2000). Yet, it is worthwhile to recognize science literacy as a concept distinct from science education because we need a way to describe the personal and social outcomes we want for beyond formal schooling, to develop a lifetime of engagement with science.

Livingstone (1999) describes formal science education as,

> ...an age-graded, hierarchically organized, formally constituted system; it often includes compulsory attendance until at least mid-adolescence; and it provides the major credentialing programs to certify one's knowledge competencies for starting one's adult lives – these programs extend increasingly into the adult years with university and postgraduate schooling. (p. 50)

Effectively within these 'formally constituted systems' or classrooms, educators frame the truth of what students should learn (as knowledge competencies) in terms of "what science says" and "how scientists do things" (Baram-Tsabari & Osborne, 2015).

DeBoer (1991, 2000) writes from a historical perspective, that in the nineteenth century it was scientists like Thomas Huxley, Herbert Spencer, Charles Lyell, Michael Faraday, John Tyndall, and Charles Eliot who championed teaching science to encourage science literacy. However, they had to insist the intellectual training that science provided learners was valuable in comparison to humanities disciplines, which at the time, were believed to produce the most honourable and worthy educational outcomes (DeBoer, 1991, 2000). Towards the end of the nineteenth century, and due to writing by scholars like John Dewey (1916) in the early twentieth,[14] over time there came to be at least four main arguments for why science education and science literacy are worthwhile. According to Osborne and Hennessy (2003) these are the utilitarian argument, the ever popular economic argument, the cultural argument, and the democratic argument.[15]

The utilitarian argument posits that science education is important for everyday life which is made easier by an understanding of science (e.g. like being able to fix one's car). Here important knowledge of science is comprised of some appreciation of the logical processes of science as well as teaching the findings of science. It assumes concepts like 'rational thinking' (or the ability to

[14]See Dewey's *Democracy and education* (1916), the Commission on the Reorganization of Secondary Education (CRSE) of the National Education Association's (NEA) report, *Cardinal Principles of Secondary Education* in 1918, and the 1920 the science committee of the NEA's report titled, *Reorganization of Science in Secondary Schools*.

[15]Thomas and Durant (1987) separate out a social argument from the cultural argument, giving it its own category. But, since society inevitably forms a part of the economic, democratic and cultural arguments anyway, I, like Osborne and Hennessy (2003), will discuss society in relation to these other four arguments.

demarcate relevant information, analyze it and use it to draw a conclusion),[16] to be desirable teaching topics and favours refining 'practical problem-solving abilities'. There are problems with the utilitarian approach however. First, there is little evidence to suggest that scientists are more or less rational than their non-scientist peers (Millar, 1996) - meaning that more knowledge of science does not necessarily translate to 'practical problem-solving abilities' or 'rational thinking'. Second, we arguably have less individual need to understand the details of how science works than in earlier times. For example, as technology becomes more user-friendly and intuitive, persons have less need to know how the flow of electrons charges their devices, but rather just that their devices need charging. Effectively, as technology becomes easier to use, people are able to utilize technology without having to understand its intricacies, thus reducing the necessity to learn 'basic' science and justify science education by the utilitarian argument.

The economic argument has historically been the dominant argument for science education and highly influential on how curriculums have been designed (J. Osborne & Hennessy, 2003). The economic argument is that be-

[16] Millar et al. (1996), describe the lowest-level of rational thinking (i.e. reasoning) as one grounded in phenomena compared to the highest-level of reasoning as one grounded in models.

cause science, technology, engineering and math (STEM) are relatively lucrative fields for both the individuals who take them up and for society as a whole (Macilwain, 2010), public education should provide pre-professional training for those entering careers in these fields. Though it is acknowledged that the majority of students who partake in science education will not go into STEM careers, everyone is theorized to still benefit from a STEM education based on the developments made by the few that do. Furthermore, the economic argument assumes that the dominant skills needed by STEM workers are primarily those taught in science classrooms which focus on the findings of science (with the methods to be learned later in professional education) (Baram-Tsabari & Osborne, 2015). Yet, in analyses of those that identify science as being a significant part of their job (e.g. nurses), for many, the findings of science were only one component of what was needed, though not necessarily a sufficient one. Much of what was actually found to be required was highly context specific and not taught in schools (J. Osborne & Hennessy, 2003), providing further reason to aim for presenting contextualized as opposed to decontextualized information to students.[17]

[17] Beyond the 'basic' science content, many people that use science in their work identified needing data analysis and interpretation skills, a willingness to cooperate, and the ability to communicate clearly among other talents (Bancino & Zevalkink, 2007).

The cultural argument states that as science is one of humanity's great achievements, and serves as an undercurrent for much of public life and discourse, people ought to be educated about science in relation to its cultural impact (J. Osborne & Hennessy, 2003). Advocates for this argument stress that in order to enhance public participation in science, publics must be able to engage scientific cultures and understand all the social avenues science intersects with. Scholastically, this may mean reframing science courses to be more about an appreciation of science in terms of its successes, failures and struggles, as opposed to just the 'successful' findings of science. As such, understanding science's role in culture requires a fuller account of science (especially historically) with more emphasis on the human dimension of science. Millar and Osborne (1998) call this the 'explanatory themes' or 'explanatory stories' of science that lead to understanding a 'range-of-ideas' about science. Explanatory themes rely on sharing narratives around major scientific ideas (e.g. like the development of germ theory, or the particle model of chemical reactions) and situate science in society (J. Osborne & Hennessy, 2003). However, there are at least two risks with using the cultural argument. First, communicators must be careful to select sufficiently diverse narratives to prevent only certain epistemic contributions to science being transmitted and not others. This means that educators must be aware of the potential background assumptions they can bring into their teaching through narrative selection. But, concerns over narrative can be overcome with attention to how the narratives are sourced.[18] Second, by focusing on situating science, we may not transmit enough of the findings of science (e.g. like teaching that adrenaline can be a life-saving compound to combat acute allergic reactions as opposed to explaining how this was discovered). This concern can be avoided by making sure to highlight the relevant outcomes of science as well as how it relates to society.

The democratic argument considers the moral and political consequences of living in a socio-technological society. The predominance of science has resulted in more reliance on experts, and as mentioned in Chapter 2, we afford scientists a high degree of epistemic authority by being experts. As a result of this imbalance in epistemic authority, there is the concern that by deferring to scientists we undermine some basic democratic tenets of citizens who,

[18]See Harvey Siegel's (1997) work on embracing multicultural science education (where varied agents and methods are recognized as legitimate ways of knowing). He argues that it is not required that we reject traditional western characterizations of science, but that we recognize multicultural science education as a universal imperative to avoid perpetuating domination and hegemony.

in order to participate in informed decision-making, must rely on scientists and communication experts. Hence under the democratic argument, though we need not turn everyone into experts, publics need to be able to play an 'enlightened role' (European Union Commission, 1995) to carry-out informed decision-making (Kolstø, 2001). This enlightened role requires publics to take-up and engage with reliable information about science, but under traditional models for science (like the linear model), publics are limited to receiving information about science (not contributing to it). Better suited communication models for techno-scientific democracies will also be considered in the discussion of alternatives to current models (Chapter 4) and how science communication works within different types of democracy (Chapter 5).

By comparing the arguments, we see that the utilitarian argument and the economic argument face conceptual and practical challenges. These challenges come from the false belief that 'practical problem-solving skills' are easily transferable and from assumptions about the knowledge needed for careers in science – not to mention an overly optimistic interpretation of who benefits from science in the classroom, the workforce, and society. With both arguments, it is the findings of science that are stressed for problem-solving or for careers in science, though a more diverse set of knowledge is needed. Furthermore, both arguments have almost 'linear model' motivations for teaching science: by investing in science education, we can train scientists (economic argument), who in turn create basic research, which if appropriately funded will generate a pool of knowledge, of which socially beneficial applications can be crafted (utilitarian argument). Conscious of the problems with the linear model, I suggest that this be taken as another warning for why these arguments for science education are misguided. After all, if the linear model oversimplifies science by making it appear unidirectional and problematically decontextualizes science from society, should our motivations for science education imagine science the same way? Thus, the utilitarian and economic arguments present an overly-simplistic decontextualized view of why science education is needed in much the same way that the linear model presents an oversimplified account of science policy, forcing us to look to the cultural and democratic arguments instead.

The cultural and democratic arguments overlap by contextualizing science education in society. The cultural argument recognizes that science is socially situated in historical developments and the democratic argument acknowledges the societal need to engage with science for personal and civic decision-making. These motivations are thus more charitable to understanding science as a multidirectional process, with different external and internal forces influencing science at various stages - in other words, a more value-conscious contextualized account. However, communicators using the cultural and democratic arguments must be aware of biasing background assumptions and social norms when framing what is taught in a way that is different from the findings-focused selections of the utilitarian and economic arguments. Despite these concerns, the cultural and democratic arguments provide us the best means for acknowledging values in science, as a way to more accurately represent science, and make science education more compelling.

3.2.2 Science Education & the Nature of Science

The aforementioned arguments for science education provide different motivations for teaching science with the overall goal of improving science literacy. However, they only give a general outline of what aspects of science to teach (Ryder, 2001). The struggle surrounding the decision about what to teach students in order to enable them to engage with science, and perhaps even go on to have careers in science, remains fraught partially because the different arguments promote teaching different aspects of science. The utilitarian argument places an emphasis on 'rational thinking' despite there appearing to be no correlation between being able to 'think rationally' about science and 'act rationally' in real life. The economic argument is minimally informative because it supports teaching primarily the findings of science, though the methods of science are important for burgeoning scientists as well, while which findings and for what careers remains to be seen. The cultural argument's historical narrative uses explanatory themes to situate science but it chances excluding minority epistemic narratives or not stressing the findings of science enough. Finally, the democratic argument advocates for teaching the strengths and weaknesses of science along with its ideological commitments, but it is unclear which ideological commitments should be the defining ones.

In an attempt to explore the implications of these arguments for science education in terms of how decontextualization is taught, I will reflect on Hodson and Wong's (2017) review of science curriculums. Here they found a strong emphasis in curriculums on teaching the NOS. I will take the NOS to describe, "... the epistemology of science, science as a way of knowing, or the values and beliefs inherent to the development of scientific knowledge." (Abd-El-Khalick et al., 1998, p. 418) where values are what Lederman (1986a) describes as the, "... assumptions inherent to scientific knowledge (e.g. tentativeness, parsimony, empirically based, amoral etc.)" (p.3) This account of the NOS will help to evaluate how values are taught in science education.

Hodson and Wong amassed a compilation of research supporting earlier investigations by McComas and Olson (1998) along with Dagher and Boujaoude (2005), showing that the NOS is a well-established part of science curriculums for many countries. For instance, science curriculum reform documents from Canada, Australia, New Zealand, the United Kingdom and the United States all agree that the NOS should be included in science education (McComas & Olson, 1998), but do not necessarily agree on what the NOS is. Analysis of these curriculum reform documents found that NOS statements could be grouped into four different types based on their conceptual origin (1998). The majority were philosophy of science based, followed by the history of science, sociological statements about scientists and lastly psychological statements about the characteristics of scientists. An updated inspection of the 4 main types of NOS statements by McComas et al. (1998), resulted in a list contain-ing 14 key features of NOS stating that:

1. Scientific knowledge is tentative
2. Science relies heavily but not completely on observation, experimental evidence, rational arguments and skepticism
3. There are multiple ways to do science
4. Science's goal is to explain natural phenomena
5. Laws and theories serve different roles in science
6. All cultures contribute to science
7. New knowledge must be reported transparently
8. Scientists require accurate record keeping, peer review and replicability
9. Observations are theory laden
10. Scientists are creative
11. History shows science's evolutionary and revolutionary character
12. Science is part of social and cultural traditions
13. Science and technology impact each other
14. Scientific ideas are affected by their social and historical milieus

Within this list there are NOS features that reflect particular arguments for science education. For instance, the cultural and democratic arguments for science education would likely stress that 'Science is part of social and cultural traditions' or that 'Scientific ideas are affected by their social and historical milieus'. Alternatively, the utilitarian argument suggests that publics need to know the experimental evidence science produces and so would emphasize how ‘Science relies on experimental evidence, rational arguments and skepticism’. Lastly, the economic argument might underline how ‘Science and technology impact each other’ to connect the need to learn science to developing products from science. And, since the economic argument has historically been the dominant one (J. Osborne & Hennessy, 2003), I put forward that it is the findings portion of the NOS that comes through the most in the classroom, especially in terms of selecting decontextualizing science education models as I will show in the next section.

3.2.3 The Consensus View on Science Literacy

The NOS has become embedded in science education, emerging as a staple in science curriculums and recognized as a key element in defining science literacy (Dagher & Boujaoude, 2005). However, busy educators rarely have the time or the means to evaluate all the aspects of the NOS in their classrooms (Hodson & Wong, 2017; Lederman, Abd-El-Khalick, Bell & Schwartz, 2002).[19] Recog-

[19] Additional external factors like standardized testing that stress teaching quantitative information which can be readily assessed, such as the findings of science as opposed to other NOS features that are better evaluated by qualitative measures (Aydeniz & Southerland, 2012), likely also play a role.

nizing that the list of NOS features is long and class time is limited, pedagogy scholars tried to determine which parts of the NOS should be a teaching priority (Alters, 1997; Stanley & Brickhouse, 2001). Priority teaching topics were determined by selecting those aspects of the NOS that were believed to have the most agreement around them among historians, philosophers and science educators (Abd-El-Khalick et al., 1998). This group of NOS features came to be known as the 'consensus view'.

According to McComas' (1998) overview, agreement around aspects of the NOS have been recognized by scholars like Ennis (1979), Duschl (1988), and Robinson (1968) as well as organizations like the National Science Teachers Association (1982). But, the consensus view is recognizable in its current form because of work by Lederman (1986b). Subsequent research by Lederman (Lederman, 2004; Lederman et al., 2002) and colleagues (Abd-El-Khalick, 2006; R. L. Bell, 2006; Cobern & Loving, 2001; Flick & Lederman, 2004) resulted in the the consensus view becoming very influential, and much like NOS, gaining acceptance in many countries throughout the world (Hodson & Wong, 2017).

In terms of which NOS features there are consensus around, Abd-El-

Khalick et al. (1998) claim the following aspects of the NOS have agreement around them,[20]

> ...that scientific knowledge is tentative (subject to change); empirically based (based on and/or derived from observations of the natural world); subjective (theory-laden); partly the product of human inference, imagination, and creativity (involves the invention of explanation); and socially and culturally embedded... (p.418)

In terms of the aspects of the NOS that do not have agreement, the authors give the example of the debate over whether there is an objective reality or only mental constructs but bypass this controversy by assuming such disagreements to be too esoteric and irrelevant for students' daily lives (Abd-El-Khalick et al., 1998). However, let me critique this list of NOS aspects that apparently have agreement around them, specifically the 'human inference' and 'socially and culturally embedded' components of science. Values reside heavily in the socio-personal aspects of science and here I think Abd-El-Khalick et al. are too optimistic, perhaps as a result of focusing on the use of epistemic values in science. By pointing to the ongoing controversy over how to include non-epistemic values in science as part of 'the product of human inference' and

[20] Abd-El-Khalick et al. (1998) add two additional aspects to their list of NOS features: the distinction between observations and inferences, and the functions of, and relationships between scientific theories and laws.

science being embedded in society, philosophers, STS scholars and historians of science continue to debate which non-epistemic values to use in science and how (as described in Chapter 2). Hence, although there are aspects of the NOS with agreement around them, technically due to the lack of consensus about how non-epistemic values should be used in science, they would get left out of science education under the consensus view.

The emphasis on consensus around aspects of the NOS can also relate to the arguments used for science education. The cultural and democratic arguments for science education recognize controversy as a normal part of science because situating science in society requires an acknowledgement of alternative viewpoints in science. Although the NOS purports to have agreement around science as a product of 'human inference', peering deeper shows that there remains disagreement around values in science which might dissuade supporters of the cultural and democratic arguments from using the consensus view. Furthermore, the utilitarian argument can emphasize debate as a way to exemplify the rationality of science and NOS-style critical thinking, but as it has been used, it does not. However, the economic argument does not mention controversy in its focus on the findings of science for future scientists. Therefore, if educators and curriculum designers rely on the economic argument for motivating science education, then using the consensus view will be appealing because it ignores discourse over controversy in science and allows a focus on uncontroversial findings. So though the NOS can cover a wide range of ideological, procedural, epistemic, empirical and social features of science, in practice there is a tendency to use the consensus view (motivated by the economic argument) to select aspects of the NOS (such as the empirical findings of science) which limit discussion of controversial topics, like non-epistemic values, when teaching science.

In conclusion, the consensus view selects aspects of the NOS whose content is thought to be 'unequivocal' and 'uncontested' (Claxton, 1997). Though the cultural and democratic arguments for science might be willing to consider controversy in science, the utilitarian and economic arguments do not. As the economic argument is the most popular for teaching science (J. Osborne & Hennessy, 2003), and encourages a focus on the findings of the NOS, the consensus view helps select the least controversial findings, contributing to non-epistemic values getting left out of science education.

The Consensus View in Practice

The consensus view, supported by the economic argument, assumes that students need to know about the findings of the NOS that have agreement around them for science literacy. One example of how decontextualized empirical findings can get emphasized using the consensus view is in attempts to teach about climate change (S. Rosenberg et al., 2010).

It has been over a decade since 97% of climate scientists agreed that anthropogenic climate change is a real phenomenon (Oreskes, 2004). As a result, many teachers believe teaching about climate change is important (Fortner, 2001; Monroe, Oxarart & Plate, 2013). Scholars, as well as teachers, are attempting to develop tools to 'equip and empower' learners to deal with the environmental uncertainty of climate change (Bangay & Blum, 2010), though it still falls short of being a regular component of K-12 curriculums in many places (Sharma, 2012; Feierabend, Jokmin & Eilks, 2011), contributing to the struggle to increase science literacy (Lombardi & Sinatra, 2013). Because of the discrepancy between this scientific consensus and science literacy about climate change, how to teach it has become an increasingly important question, especially as the education sector appears to be an under-utilized resource to mitigate and adapt to climate change (A. Anderson, 2012; Mochizuki & Bryan, 2015).

Among the greatest barriers to teaching about climate change is the controversy surrounding the topic, much of which is value-laden (Jennings & Gaither, 2015; Leiserowitz, 2006; O'Connor, Bard & Fisher, 1999; Tschakert et al., 2017). This value-laden controversy has made many educators feel inadequate (Boon, 2010; Fortner, 2001) and generated a strong hesitation towards teaching it (Sullivan, Ledley, Lynds & Gold, 2014). To navigate around this controversy, those that do teach it have turned to the consensus view, whether intentionally or not. According to Sullivan et al., "The most commonly used strategy to address controversy and misinformation is to promote learning about the nature of science, evidence, and data." (Sullivan et al., 2014, pg. 550). However as I have explained, though teachers may turn to the NOS, since it is commonly the findings of the NOS that get conveyed (due to agreement around them), and these focus on 'evidence and data' anyway, students actually only end up learning the findings of science. In other words, even when climate change is taught, it still frequently leaves out how data is collected, by whom, and using which values. Plus, even students that have a chance to learn about climate change in a contextualized form (i.e. how it might affect local ecosystems (Dahlberg, 2001; Fortner, 2001)), they are still not taught a value-laden account of climate science (e.g. why certain thresholds of change are acceptable). Thus, because students only end up being taught the empirical findings of climate change (if the topic is covered at all), as opposed to a value-laden account of how this science is carried out and why it matters, information about climate change ends up being misrepresentative and less memorable compared to if it were explicit about values. As an alternative approach, some scholars have advocated for taking-up socially conscious education models that consider values in climate science.[21] I will present more on alternative value-conscious models of information transmission in the following chapter after reviewing some limitations of science communication since the value-conscious suggestions I provide can apply to either science education or communication.

In summary, the consensus view provides insufficient information about science to give students (and publics) a comprehensive understanding of science. This is because science educators continue to prioritize the empirical

[21] See Tuana's work on gender and climate change (2013), Bedford (2010) and Proctor's (2008) works on Agnotology, or Sadler's (2011) work on science addressing socio-scientific issues.

findings from the NOS around which there is agreement, as opposed to teaching controversial aspects of science such as how non-epistemic values are (and ought to be) used. For teaching about topics like climate change that are ripe with controversy, educators that use the consensus view often transmit exclusively the findings of science, however this leaves out relevant value-laden aspects. Thus, the consensus view decontextualizes science from society by being unable to discuss how controversy is relevant to science, contributing to the misrepresentation of science.

3.3 Science Communication

After leaving educational institutions like elementary and high school, students integrate into larger publics and because of the ongoing need for science literacy, rely on science communication. According to Massimiano Bucci (2008), science communication as we recognize it now has evolved over the last two centuries to match the perception of public interests and capabilities. For instance, in the eighteenth century, there were popular science books being written for specific segments of the public.[22] Then in the nineteenth century,

[22] A few noteworthy titles of the time include Algarotti's *Newtonianism for Ladies* (1737), in which he frames experimentation in a sensationalist fashion. The text is derived from a

daily press announcements, and public events such as World's Fairs (Kjrgaard, 2009) nurtured public curiosity about science. During this time, science was seen as directly accessible to publics on any intellectual level and it was believed that publics were more than capable of learning about science from scientists directly.[23] This continued with lectures by known scientists (such as Thomas Huxley, and Asa Gray (Weigold, 2001)) being routinely printed in the newspapers well into the late nineteenth and early twentieth century.

As a consequence of the institutionalization of research and increasing specialization of science (Schofer, 2003), it was believed that publics would struggle to keep up. And so, in the early to mid-twentieth century, the idea of science as something 'too complicated' for publics to understand became an established point-of-view (Bucchi, 2008).[24] At the same time that publics were seen as unable to comprehend science on their own, it was coupled with the idea that a conduit between publics and scientists was necessary. So,

Locke-inspired epistemology and would eventually go on to receive religious condemnation (Mazzotti, 2004). Also see de Lalande's 1817 *L'Astronomie des Dames*, written to introduce women to astronomy by highlighting the work of several female astronomers and denounce the impression that astronomy is primarily a male activity (Lalande, 1820).

[23]Such as Nikola Tesla at the 1893 World's fair showcasing his wireless lighting system (Bertuca, Hartman & Neumeister, 1996; Cheney, 2001)!

[24]Some authors, especially those less active in research, continued to write for lay publics because publishers valued their academic credentials which allowed the writing to be marketed as 'educational' (P. J. Bowler, 2006; Turney, 2008).

as opposed to scientists transmitting information to publics directly, it became the job of communication specialists (science journalists, popularizers, and exhibit designers) to translate raw science content into consumable information meant to grow public understanding of science (Burns, O'Connor & Stocklmayer, 2003). By training professionals for this role, it encouraged a distance between scientists and publics. The relationship between science and publics was afterwards seen as diffusionist or unidirectional (with information moving from scientists to publics) (Bucchi, 2008; Whyte & Crease, 2010).

3.3.1 Features of Science Communication

The broad diffusionist vision of science communication is a simplistic and idealized account claiming that scientific facts are transferred unidirectionally without significant modification from one context to another (Bucchi, 2008). Information is transferred via science communicators from scientists (as knowledge specialists) to publics (as non-specialists) (Bucchi, 2008). As science communicators are the ones transporting the information, scientists are able to self-proclaim themselves as removed from public communications (besides providing the content), but free to criticize the distortions and sensationalism that can sometimes come with communication.

Diffusionist (unidirectional) science communication is composed of four features (Bucchi, 2008): the knowledge being transferred, the channels of communication being used, the direction of information flow, and publics described as passive and ignorant.[25] Weigold (2001) also describes similar features of science communication, such as: the sources of science information (or news); appropriate media channels to communicate science; how the information is reported, edited and written; and the communication audience. The overlap between the categories is seen most clearly in terms of identifying the channels of communication and the recipients of communication. Bucchi (2008) and Weigold's (2001) lists differ in terms of how the information is presented and the direction of communication. Weigold's source of information is a potential component of Bucchi's knowledge transfer because it can include an account of where the knowledge originates. Similarly, the direction of communication (unidirectional under a diffusionist view: communicator to publics), is similar to Weigold's question of how the science is being reported (or transmitted). But, how the information is reported is integral in order to analyze models used

[25] Bucchi (2008) also notes 'communication as a broader process', but since this can be encompassed under the channels of communication and the direction of communication, I will describe the features of science communication in four parts.

in science communication. Thus, I will use a hybridized version of Bucchi and Weigold's components featuring: the knowledge being transferred (content), the direction of transmission (unidirectional - scientists to publics, or bidirectional - scientists to publics and vice versa), how the information is reported (value-free or value-conscious), and the perception of publics (active/passive) as my basis for discussing science communication going forward.

In more detail, the knowledge being transferred is the information about science being communicated. Under an uncompromising interpretation of diffusionist science communication, the information may not be malleable to different contexts (i.e. must emphasize the same aspects of the information in all transmissions). In contrast, a more flexible account of diffusionist science communication may instead focus on different features of science depending on audience. For example, communicators could focus on the economic consequences of climate change for audiences that consider fiscal concerns paramount, as opposed to emphasizing the implications to local ecosystems for those with environmental concerns. Note, in both instances there can be no direct manipulation to the information itself, but rather how that information is framed. The issue of re-framing will come up again as I consider how to adapt science communication to include a more contextualized account of science in Chapter 4.

The role of media is to act as a channel for transmitting information via print, television, installations etc. However, I will point out that this assumes that media entities have no other interest but to communicate information to publics. In reality, many popular media sources have their own value-laden incentives and priorities in terms of what they communicate and when. For example, conveying issues in a 'balanced manner' when both sides of the argument for anthropocentric climate change are not equal in terms of evidence, shows that certain media outlets might care more about the value of neutrality than weighing the quality of evidence (Boykoff & Boykoff, 2004). Therefore, when envisioning the ideal media format to transfer scientific information to publics, it is worth investigating the value-laden interests of the media to ensure science is being communicated appropriately.

In describing the transmission channels operating between media and publics, the relationship between these groups is directionally defined. The relationship can be unidirectional, as is the case when publics are perceived as ignorant of science, or bidirectional, as when they are able to contribute to science. In the case of unidirectional communication, note the overlap it has with the linear model of science policy. In the linear model, knowledge developed by scientists is eventually used for science applications and science policy; likewise a linear approach to science communication would similarly expect knowledge developed by scientists to be transmitted to publics (unidirectionally) only after the research is complete as opposed to throughout the process. In sum, communication models describe directionality differently and as a result, it is one of the most important ways of distinguishing among them.

In the change from publics being perceived as actively seeking scientific information in the eighteenth and nineteenth century to assuming them to be in need of pre-determined information throughout the twentieth (Bucchi, 2008), there is a corresponding difference in publics described as active learners, then as passive ones. In the active case, publics are keen for scientific knowledge and imagined to engage with science positively. But when described as passive, publics are assumed to be ignorant of science and generally uninterested by default. The perceptions of publics inevitably ends up being a substantial determinant of communication models. And so, provided that the defining features of science communication can be interpreted in various ways, different models of science communication have been developed in relation to these features.

3.3.2 The Deficit Model of Communication

Among the most popular, yet highly contested characteristics of diffusive science communication, are when publics are assumed to be passive participants (Trench, 2006). A classic example of this tendency is seen in the deficit model (Bucchi, 2008) – the default communication style in many sub-disciplines of science (Trench & Junker, 2001).[26] Under this view, publics are seen as 'deficient' in science knowledge (predominantly the findings of science) and scientists (as well as communicators) are considered 'sufficient' (Gross, 1994), allowing scientists and communicators to transmit science from a position of authority (Ahteensuu, 2012).

Similar to expectations outlined in rational choice theory,[27] the deficit

[26]The deficit model is also known as the knowledge deficit model (KDM). KDM suggests that scientists are more knowledgeable than publics about specific issues allowing scientists to better evaluate associated risks (Hansen, Holm, Frewer, Robinson & Sandøe, 2003; Kellstedt, Zahran & Vedlitz, 2008).

[27]According to Scott (2000, p. 127) Rational choice theory, pioneered by George Gomans (1961) using frameworks from exchange theory and behavioural psychology, is the idea that all action is fundamentally rational, based on the likely costs and benefits calculated by people before making a decision. Rational choice theory continues to be routinely criticized because human action involves both rational and non-rational components.

model assumes that publics operating with the same (or equivalent) information should reach the same conclusions (Arrow, 1982) whereas different information would lead to different preferences (Tversky & Kahneman, 1989). As a result, when lay people come to conclusions different than those of scientists, under the deficit model it is believed to be because publics do not know enough science. Thus, the solution to improving science literacy and reducing public skepticism under the deficit model is to simply transmit more information about science.

Though somewhat harsh in its characterization of publics as entirely deficient, there is evidence to suggest that the motivations for the deficit model are not completely unsupported. If the deficit model aims to increase science literacy and a favourable view of science, then deficit model supporters can point to the strong positive correlation between 'textbook' scientific knowledge and having a favourable attitude towards science (Sturgis & Allum, 2004). In other words, the deficit model's assumption that the more people know about science, the more they seem to appreciate it, is not entirely unreasonable. However, the model fails to recognize that publics' attitudes towards science also influence public understanding and trust in science (M. W. Bauer, 2008) which is a shortcoming. The shortcomings of the deficit model in accounting for publics' attitudes and values become readily apparent in practice and will be challenged with an approach to transferring information which is more charitable to publics in the next chapter.

The Deficit Model in Practice

Among the most popular examples of deficit model communication leading to public harm and reduced public trust in science is the 2001 outbreak of Foot-and-Mouth disease (FMD) in the UK. FMD is a highly contagious viral disease found in cloven-hooved animals that can cause death in these species. Believed to be introduced by waste meat products that were mixed into pig food (usually composed of scraps) in North East England, it quickly spread throughout the UK reaching its epidemic peak two months after the first case was confirmed. It was not until another 4-5 months later before the situation abated, and almost a full year after the first recorded case that the UK had disease-free status once more (Wright & Nerlich, 2006).

Based on the severity and scope of the outbreak, the government put into place several science communication initiatives in order to implement policy measures to control the disease (Wright & Nerlich, 2006). FMD policy closed the countryside to pedestrians, introduced animal movement licenses and resulted in the slaughtering of both infected and potentially uninfected animals on nearby farms – more than 6.5 million animals were killed in all (Haydon, Kao & Kitching, 2004).

To carry out the policy measures, the UK government used two different types of communications (Gregory, 2005): operational and public. Normally the two categories are not mutually exclusive since there can be information relevant to both groups. For instance, due to its usefulness to both parties, basic precautionary measures to limit the spread of the disease were explained in both operational and public communications (Gregory, 2005). However, what distinguishes these types of communication is whether publics are allowed to make epistemic contributions. Operational communication allows for transmitting information amongst select publics and institutional knowers (government officials, vets, and animal handlers). This makes the model bidirectional by allowing for communication between scientists and select publics. In contrast, the public communication model adopted more deficit model characteristics by being unidirectional (e.g. through use of a single point of contact – usually a member of the press or a local authority) and assuming publics (e.g. farmers) to be insufficiently knowledgeable about science (i.e. unrecognized knowers).

Further subdivisions of public communication separated those with a passive interest from those with an active interest – not uncommon in science communication (Grunig & Hunt, 1984). Those with a passive interest were imagined to be largely satisfied with the information provided via mass media. However, people with an active interest wanted more detailed information (typically those somehow affected by the news - i.e. animal welfare activists, and people with property in the infected regions). In response, the Ministry of Agriculture, Fisheries and Food or MAFF (now the Department of the Environment, Food and Rural Affairs), bought advertisements in general and trade specific media for passive and active publics respectively, as well as in print, local radio, and television, stressing the findings they had amassed so far (Gregory, 2005). In addition to the print, radio and television ads, there was also a helpline and web content made available. However, many individuals at the time had no internet, so word of mouth and the helpline became the only opportunities for true bidirectional communication (Gregory, 2005). Unfortunately, the helpline relied heavily on information from the website which was not regularly updated (Gregory, 2005).

These sources of information placed the MFAA in the position of 'knowers' and even in case of active public communications, information transmission was unidirectional. As opposed to those receiving operational communications and contributing to knowledge on the crisis, publics categorized as passive had neither government officials to talk to, nor the direct contact information of others affected by the crisis. This meant that the questions of publics living through the crisis could not be answered in realtime by the government or scientists, causing their experiences to feel unacknowledged (Wright & Nerlich, 2006).

In retrospect, scholars have argued that the crisis was not managed or communicated well (Gregory, 2005). This is due in part to the deficit model and how it was used for public communications. Here the deficit communication model failed because publics did not have ready access to the information they needed as well as insufficient means for voicing their concerns. Hence, alternative communication models could have been more effective at handling the crisis (Gregory, 2005; Ritchie, Dorrell, Miller & Miller, 2004). For example, the experiences of publics could have been harnessed (via discussion about how their stock could have been exposed to the disease and how they interacted with other animals) to better model and control the outbreak (Haydon et al., 2004). The presumed lack of knowledge of publics and disregard for their personal experience harmed the economy (Thompson et al., 2002), and society (Convery, Bailey, Mort & Baxter, 2005). Thus, the underestimation of publics in the FMD case reflects typical deficit model based science communication which reflects a decontextualizing description of science by separating publics from science.

3.4 Connecting the VFI, Science Education & Communication through Decontextualization

While it is true that great harm can come to individuals and communities if publics do not have ready access to reliable fact-focused information, alone it seems the findings of science are insufficient to rectify low levels of science literacy. After all, science is comprised of more than just its findings such as its methods and place in society, which is why being familiar with these other facets of science is important for having a comprehensive account of science. But, in neither the consensus view nor deficit model do publics get a contextualized account of science and as a result, these models have been ineffective at helping publics become better informed or able to retain information about science.

Unidirectional findings-focused models like the consensus view and deficit model have struggled to improve science literacy and as a result have been routinely criticized. However, science educators and communicators have yet to learn from their mistakes. With the consensus view, class time ends up focusing on the findings of science (Hodson & Wong, 2017), causing teaching to be misrepresentative and detrimental to its broader NOS-based science literacy goals. And, no sooner have deficit models of communication been shown to be ineffective at engaging publics, do they reappear (Wilsdon, Wynne & Stilgoe, 2005; Trench, 2006) - so why do we keep trying these approaches?

I suggest that it is because the VFI remains popular with scientists who remain the authority on information about science, so how they describe science (Bucchi, 2008) and envision publics (Simis, Madden, Cacciatore & Yeo, 2016) influences how science is portrayed in science education and science communication. Thus, if scientists adhere to the VFI and its decontextualizing viewpoint, then they are inclined to describe their work as free of non-epistemic values, influencing our arguments for science literacy and the models that we select to transmit information about science. This is not to say that the VFI necessarily precedes the consensus view and deficit model, but that all three mutually reinforce a decontextualized description of science. Hence, without addressing the decontextualization at the core of their collaborative misrepresentation of science, it will persist to the detriment of science literacy.

If, as I propose, decontextualization and the VFI have implications for how science is communicated, then this should come through in the features of information transmission models. To add to the literature and show that this is the case, I begin by elucidating how the consensus view and deficit model (as central to science education and science communication respectively) are readily combined. Then I more closely examine each one in terms of how they view values in science and how it aligns with the goals of the VFI. Finally, I review the historical milestones of the VFI, the consensus view and the deficit model to demonstrate that they go through periods of acclaim and doubt around the same time. By investigating the similarities between these transmission models and the VFI, I conclude that their decontextualizing features form a reinforcing conceptual link that is also evident chronologically, explaining why a decontextualized account of science remains popular.

3.4.1 The Consensus view and Deficit Model Combined

Whether it be scientists, educators or communicators, if one wants to present science as being value-free or decontextualized, then combining the consensus view for education with the deficit model for communication is a harmonious pairing. Areas where there are controversies (such as the role for non-epistemic values in science) are not taught under the consensus view. Plus, the denial of values as relevant to science can then be reinforced post-school by the deficit model which dismisses public attitudes towards science.

To better grasp how the partnership between these two transmission models manifests, consider how the alternate model presented for climate change and FMD can be applied: i.e, the deficit model as it pertains to climate change and the consensus view as it bears on FMD.[28] For the scientific consensus around

[28] Even though this analysis applies an education model to a communications project and a communication model to an education attempt, education in the classroom usually involves some form of communication (e.g. lecture) and communication models can include

climate change, educators and communicators assumed that information about the degree of consensus alone would be enough to convince publics (Van der Linden, Leiserowitz, Feinberg & Maibach, 2014). This inherently supposes that ignorant publics only need more information to adopt the opinion of the scientific community which is the basis of the deficit model (Moser & Dilling, 2011). So while science education focuses on consensus, it can also assume frameworks like the deficit model to minimize disagreement with consensus by neglecting the values of publics. Likewise, although the FMD crisis is typically described as an example of the deficit model in practice, where communicators neglected the attitudes of publics and their potential contributions as knowers (Haydon et al., 2004), it too has consensus view attributes. Most notably, scientists and government liaisons communicated primarily information about the findings that had consensus around them (Gregory, 2005). Focusing on the findings of the FMD crisis, such as the features of the disease and how to prevent the spread of it as opposed to communicating the social, economic and personal features of the crisis (Convery et al., 2005), represents a consensus view approach. Hence, because both the consensus view and deficit model

educational agendas, especially as both serve science literacy goals in the case.

presume non-epistemic values are undesirable for science, they partner well together in communication, especially if communicators aim to decontextualize science like with the VFI.

The Consensus View on Values in Science

As noted in section 3.2.3, the consensus view focuses on teaching NOS content around which there is agreement and prevents teaching about aspects of science that are controversial, even though disagreement is a regular part of science. When there was consensus around the VFI, it reflected that consensus. But, now that there is controversy, the consensus view is forced to shun this disagreement and hide non-epistemic values in science to avoid controversy while scientists still hold on to the ideal. As there is consensus about epistemic and non-epistemic values playing a role in the 'context of discovery' phase, theoretically values could be taught as part of the topic. However, the consensus view primarily communicates the findings of science found in the 'context of justification' (Hodson & Wong, 2017), which means that the discussion of epistemic and non-epistemic values in the 'context of discovery' phase are usually left out (Irzik & Nola, 2011).

Unlike the 'context of discovery' phase where there is consensus around epistemic and non-epistemic values playing a role in science, the findings in the 'context of justification' phase have unresolved disagreements in terms of what values to include. Recall from Chapter 2 that both supporters and VFI critics agree epistemic values should play a role here, but as we are unable to develop a discrete list of epistemic values (the descriptive challenge) nor distinguish them from non-epistemic values (the boundary challenge), there remains disagreement. This means that values in the 'context of justification' phase cannot be conveyed under the consensus view. Hence, values during either the 'context of discovery' phase (due to a focus on findings) or 'context of justification' phase (because of disagreements about the non-epistemic and epistemic values) are not transmitted under the consensus view.

By focusing on the findings of science, but ultimately not being able to discuss the values that are a part of these findings, it reinforces the idea that value-free science is attainable and desirable. This approach to transmitting value-free content in science education (but possibly science communication as well - see FMD example) is problematic for reasons similar to the major challenges to the VFI. First, failing to teach students about values in science relies on faulty background assumptions about what designates 'good' science (i.e. science that is value-free).[29] Second, it risks leaving students with the impression that the practice of science is homogenous across societies and all types of sciences (H. H. Bauer, 1994).[30] Third, the decision to teach consensus topics in itself is motivated by various social values, which is why to omit values from teaching about science could be considered hypocritical.

To show what the consensus view is leaving out, consider how the NOS is value-laden and the loss that comes with omitting these non-epistemic values in terms of the climate change consensus. First, from the perspective of content, the discussion surrounding which motivating values were used to reach this scientific consensus are missing when only the findings are transmitted. Without an explanation of how the consensus is achieved (based on the values that went into it) students and publics end up with only part of the story. Second, from the model's perspective, the consensus view would say that climate scientists agree that anthropogenic climate change is real even if only

[29]The same problem may even exist in selecting what it means to create 'good' science education.

[30]When discussing methods of science, it is usually only a singular scientific method that is described (Hodson, 1996). As there is no defining method that applies to all the sciences, this causes learners to have over-simplistic views of science overall (See Driver et al. (1996, p. 25) and Lederman (1986b))

97% are in favour. But what characteristic of the consensus view permits that 97% agreement is sufficient enough to warrant communication? The consensus view inevitably relies on value-laden thresholds of evidence to answer this question even though there is no room for these values to be conveyed. Hence, by omitting information about non-epistemic values, it allows the consensus view and VFI to work together (compatibly with the deficit model) to decontextualize science from society even though the view relies on non-epistemic values to determine what to communicate.

The Deficit Model on Values in Science

Under the deficit model as employed during the FMD crisis, there is little mention of values in science or the values of publics. For example, the decision to kill livestock to prevent the spread of the disease reflects a low-risk threshold for assessment made by scientists and decision-makers. Decision-makers decided that the risk of the contamination spreading was unacceptable due to the severity of the disease and the losses already sustained. However, the evaluative factors behind the justification to set this low-risk threshold was unknown to publics (Gregory, 2005). Not being able to question the processes and reasons for government decision-making created a disconnect between what publics were told about the issue and what they wanted to know. Additionally, publics' attitudes and evolving opinions of the government throughout the crisis influenced their interpretation of the situation. In particular, the inability for farmers to communicate their experience and the government's perceived lack of empathy for them denied the human and value-laden side of the crisis (Gregory, 2005), adding to publics' sense of resentment. The lack of consideration for publics in terms of communicating underlying value justifications led to their mistrust in science and government (Poortinga, Bickerstaff, Langford, Niewöhner & Pidgeon, 2004). In this instance, had the value judgements regarding how decisions to kill livestock been explained, and publics allowed to interact with government officials, publics' trust and understanding of science in society may have improved.

How the FMD crisis was handled is an example of the lack of consideration afforded to publics under the deficit model. The deficit model assumes that it is only publics' deficiency of scientific knowledge which can cause them to disagree with scientific consensuses (J. R. Durant, Evans & Thomas, 1989; J. D. Miller, 1983), when their value-laden impression of research can also influence their view of science. By supposing that a lack of knowledge is the only feature preventing publics from agreeing with scientists, the model discredits the attitudes and values of publics as legitimate reasons for being skeptical about science. Part of the reason the deficit model's characterization of citizens seems naïve is because it lumps all persons with an unfavourable view of science together as simply insufficiently science literate, despite instances where publics may have justifiable reason to be skeptical. In reality, publics tend to be specific about their skepticism based on norms related to their social situation.

As an example of justified public skepticism, take for instance the Flint water crisis that took place from April 2014 to December 2015.[31] Campbell (2016) details how the Flint city officials decided to switch the water supply source from Lake Huron to the Flint River. City officials decided not to treat the water coming from the Flint River with anti-corrosion chemicals that prevent lead particles and soluble lead from being released from the interior of water pipes (in noncompliance with the EPA's Lead and Copper Rule). This resulted in a marked increase in lead levels in children due to lead exposure

[31] The FMD crisis also offers an example how publics' skepticism towards scientists can fester (Poortinga et al., 2004); in this case, due to the insufficient publics communications around the FMD crisis (Gregory, 2005).

from the water coming into their homes. A study found that the number of children with elevated blood lead levels doubled and in the areas with the highest water lead levels and almost tripled compared to before the change of water source.[32] Beyond the blatant negligence shown by city officials, state scientists also exhibited a severe lack of judgement about the issue. Even as city staff began to question the lead levels, the Michigan Department of Environmental Quality (MDEQ) lied that the water was safe (Davis, Kolb, Reynolds, Rothstein & Sikkema, 2016). Due to the insidious deception by city officials and scientists who improperly and inaccurately described the situation (Davis et al., 2016), the attitudes of publics towards the science, scientists and the government remain skeptical (Kolowich, 2016) – and not just based on a lack of knowledge about science.[33]

Ultimately, the deficit model and the VFI fit well together because the VFI aims to omit non-epistemic values from the findings of science, and the

[32]Though lead poisoning can be acute, long-term problems such as behavioural disturbances and intellectual disabilities as well as physical issues like hypertension and kidney damage can present years after exposure (Campbell et al., 2016).

[33]As a result of this tragedy, several scientists have recommended that we reject a linear model approach to science based on a 'formulaic top-down funding paradigm' where scientists get funding to do research without concern for publics. Instead, they advocate for listening to publics to understand their problems and subsequently volunteer out their expertise (Edwards & Pruden, 2016). Approaches such as these are imagined to be the first steps to rebuilding public trust in science (Kolowich, 2016).

deficit model proposes a solution to public skepticism that denies the values of publics. By assuming that public skepticism about science is the result of insufficient information about science, the deficit model aims to correct public skepticism and turn it into public confidence by just transmitting more information. However, if science communicators admit that there is more to public skepticism about science than a lack of information (i.e. attitudes and values), then they would have to reconsider the content of science from scientists who also have attitudes and values that affect science. Hence, based on the type of information the deficit-model claims publics need (indiscriminately more of it), and because the model rarely discusses the value-laden features of information (see the case of FMD communication), the deficit model is amenable to the VFI, and compatible with popular science education models like the consensus view.

3.4.2 Timing of the VFI, Consensus view, and Deficit Model

In addition to the decontexualization I have argued to be stabilizing descriptions of science as value-free, I will also show that the VFI, consensus view (representative of science education) and deficit model (a standard approach to science communication) share a similar chronological trajectory. Their common timing in terms of development, popularity, criticism and re-emergence provide further evidence of their conceptual identity and supplemental proof of the decontextualization connecting them.

The VFI has a history going back hundreds of years (R. Proctor, 1991), but grows substantially in popularity after WWII, becoming recognizable in its current form during the cold war (Douglas, 2009). Throughout this time, scholars like Jeffery (1956) argue that establishing probability statements can make it possible to avoid needing value judgements to accept or reject scientific claims. In the same vein, Levi (1960) supports the value-neutrality thesis to discourage scientists from considering the societal implications of their work by having them rely only on epistemic values for justification. Shortly afterwards, criticisms of the VFI begin. In the late 1960s and 70s, Leach (1968) starts to critique value-neutrality, and Gaa (1977) tests the moral autonomy of science. Then in the 1980s, the main challenges to the VFI take form. Beginning with the descriptive challenge, based on problematic background assumptions, Fausto-Sterling (1985), Harding (1986; 1991), and Longino (1990) all mount attacks. This is followed by criticisms of unclear boundaries between epistemic and non-epistemic values in the 1990s by Rooney (1992) and Longino (1995). In the 2000s, advocacy for non-epistemic values playing a role in the 'context of justification' phase becomes fashionable based on initial arguments from Hempel (1965) and are taken-up by Douglas (2000), Brown (2013b), Elliott (2013; 2014) and Miller (2014) among others. Despite this, the VFI still maintains some support into the 2010s (see Betz (2013) and Hudson (2016)).

In comparison, for science education, the idea of developing science literacy is raised in the 1950s (DeHart Hurd, 1958) which leads to considering the NOS. According to Abd-El-Khalick (2014), several NOS assessment instruments to measure science literacy are developed between the early 1950s and 60s (see Wilson (1954) or Swan's (1966) methods that combine, "...cognitive, affective and attitudinal outcomes..." (Abd El Khalick, 2014, p. 622)). In the late 1960s, the NOS is further recognized as an important component of science literacy by Klopfer (1969), partially due to the research in the philosophy of science[34] and the psychology of learning going on at the time (Kimball,

[34] Abd-El-Khalick and Lederman (2000) argue that conceptions of NOS have also mirrored shifts in philosophy by dividing history into a pre and post-Kuhnian period. According to Abd-El-Khalick and Lederman, in the pre-Kuhnian period, philosophers developed a normative logical account (as opposed to a descriptive one), whereas the post-Kuhnian period focuses more on the sociology of scientific knowledge which is supposed to be reflected

1967). Abd-El-Khalick then describes a shift in the early 1970s within NOS assessment separating 'scientific attitudes' (like skepticism) and 'attitudes toward science' (or interest in science) from 'understanding of science' (Gardner (1975), MacKay and Whyte (1973)). With the separation of attitudes from understanding comes the need to decide what about the NOS to teach in the classroom. As a result, the consensus view in its present form begins to appear in the 1980s as a way to transmit information for the 'understanding of science' (Lederman, 1986b) while value-laden components of science (like attitude) get left behind. Criticisms of the consensus view quickly rise from scholars like Laudan (1986) who ask what elements exactly there are consensus around. But after the 1980s, there is a switch in learning goals from training future scientists to a broader 'science for all' approach (Duschl & Grandy, 2013), exemplifying a change in focus based on motivations for science education (i.e. further development of the economic argument). This causes Laudan's criticisms to spill into the 1990s (Abd-El-Khalick et al., 1998; Alters, 1997; McComas & Olson, 1998; McComas et al., 1998). Additional questions about why the view was adopted in the first place are raised (J. Osborne & Hennessy,

in how educators teach science (Abd-El-Khalick & Lederman, 2000).

2003), prompting the consensus view to be revised into the 2000s (Lederman, 2004; Lederman et al., 2002) in order to help it include 'authentic' cases of science in society by the 2010s (Allchin, 2011, 2012).

Though science communication has a history going back over two centuries (Bucchi, 2008), its present form corresponds with the development of science literacy. Science literacy becomes a formalized societal goal in the 1950s, concurrent with the space race.[35] Despite low levels of science literacy, roughly 90% of publics polled still believe that science is a positive contributor to societal progress, making life healthier and easier (Withey, 1959). Hence, transmitting more information about science becomes a priority. However, public attitudes are ignored and the focus on their knowledge of science is stressed instead. As part of this emphasis on knowledge, the deficit model is articulated most explicitly from the 1960s to the 1980s (Gross, 1994). The deficit model points to the need for communicating knowledge (Bodmer, 1987) and leads to publics being described as ignorant of basic scientific ideas (J. R. Durant et al., 1989; J. D. Miller, 1983). Afterwards, scholars shift their focus from

[35] Although it is now recognized as a myth that public science literacy peaks between the launch of Sputnik (1957) and the moon landing (1969) (Nisbet & Scheufele, 2009). For example, only 38% knew the moon was smaller than Earth (Michael, 1960), and only 10% of four-year college educated adults regularly reported paying attention to science news (Swinehart & McLeod, 1960).

public understanding of science to public attitudes from 1985 into the 1990s (M. W. Bauer, 2008). During the 1990s, substantial critiques of the deficit model begin to mount, showing the pitfalls of 'knowledge surveys'. This causes thoughts to turn towards promoting communications of 'knowledge-in-context' (Ziman, 1991) and how experts relate to publics (Wynne, 1993; Wynne & Irwin, 1996). Hence, almost until the end of the twentieth century, dominant models for communicating science are unidirectional (Stocklmayer, 2013, p.19). Yet, despite the attacks, during the 2000s the deficit model remains in use (Dickson, 2005; Sturgis & Allum, 2004) with new practitioners rallying to its fact-focused approach, especially for communicating controversial themes (Trench, 2006). Into the 2010s, the persistence of the model is linked to scientists that doubt the capabilities of publics and even the social sciences as a whole (Simis et al., 2016).

Overall, the timing of the rise and fall of the VFI, consensus view, and deficit model share several trends. Starting in the 1950s, because of growing scientific developments, the VFI appears promising a value-free vision for how scientists ought to perform research to protect science from bias. As a result of the socio-technological advancements being made, publics end up needing to know more science for personal and civic decision-making (not to mention to train more scientists for the future (J. Osborne & Hennessy, 2003)). Hence, science literacy becomes a new societal goal (J. R. Durant et al., 1989). Into the 1960s, we communicate science to adult publics assuming them to be ignorant (J. D. Miller, 1983; Moser & Dilling, 2011). At the same time, educators try and narrow their teaching down to the aspects of science thought to be essential, outlining the NOS (Irzik & Nola, 2011). Further refinement of the NOS to the parts that have agreement around them results in the consensus view forming which emphasizes the findings of science (Hodson & Wong, 2017). The focus on consensus comes under question by the 1980s (Laudan et al., 1986). Throughout the 1980s and 1990s, the VFI also falls under heavy attack as does the deficit model. This forces communicators to address the deficit model's description of publics by turning attention instead to the attitudes of publics in the late 1990s to 2000s (M. W. Bauer, 2008).[36] Meanwhile, the VFI also sees alternatives to the VFI become popular (Douglas, 2009, 2016; Elliott, 2013; Kourany, 2013; Steel & Whyte, 2012). Despite the deficit model's noted limitations, it remains a staple communication model (Simis et al., 2016) as

[36] For examples of these sorts of conceptual changes in science communication see the UK National Consensus Conference on Plant Biotechnology (Dixon, 2007) and the Biotechnology and Biological Sciences Research Council (BBSRC) (Trench, 2008).

well as the VFI (Betz, 2013), along with cyclic revisions of the NOS (and consensus view) into the 21st century (Lederman et al., 2002; Simis et al., 2016).

In summary, the VFI, consensus view, and deficit model have their origins rooted in the mid-twentieth century, they go through initial phases of popularity until around the 1980s when criticisms (some outlined decades earlier) are exposed, that mount into the 1990s as alternatives are suggested. However, we are never able to replace the originals even into the 2000s.[37] I propose that part of the reason for their continued usage is because scholars fail to attack the consensus view and deficit model's relationship to the VFI (and decontextualization more broadly), which determines the content of the communications, and in so doing, the transmission models themselves. Thus, together the VFI, the consensus view and deficit model reinforce the idea of science operating independently of society and provoke the need for more accurately representative

[37]Note the similarity here with regard to the linear model for science policy which is also highly decontextualizing. Godin (2006) traces the history of the linear model and breaks it down into three stages. From the start of the twentieth century to 1945, the terms 'basic' and 'applied' research are regularly used by natural scientists. Then, researchers from business schools add the final term (development/social benefit) to create the standard three-step model from 1934 to 1960. The last stage beginning in the 1950s, extends the model to publics due to economists. Criticisms regularly mount throughout the 1970s and 1980s (Kline, 1985; N. Rosenberg, 1976), though the linear model continues to retain support into the 2000s (Etzkowitz, 2006) and 2010s (Balconi et al., 2010).

descriptions of science which will be the focus of the next chapter.

3.5 Chapter Conclusion

Based on our growing technoscientific world (Briggle & Mitcham, 2009), developing science literacy becomes necessary for publics to thrive in their personal and civic lives according to the economic argument. As a result of this need for knowledge about science, science education decided to teach the NOS using the consensus view. The consensus view is the idea that we should only communicate science around which there is agreement from the scientific, philosophical, and social science communities. Since values in science are contested, values are not mentioned as part of the findings of the NOS under the consensus view, thus misrepresenting science.

Yet, science literacy is a lifelong process, and therefore must be supplemented. Hence, science communication helps publics continue to develop their knowledge of science. A popular framework with which to try and do this in is the deficit model. The deficit model of communication is the idea that publics lack knowledge about science and simply transmitting more scientific information to them will improve public understanding and opinion of science.

It positions scientists and communicators as 'knowers' and publics as insufficiently knowledgable, even though publics can possess relevant information or have good reason to be skeptical of science. As the deficit model ignores the attitudes and values of publics, it often fails to help generate public understanding and engagement with science.

Though both the consensus view and deficit models have been severely criticized, they remain in regular use. I have argued that this is because of the sustained appeal of the VFI, which encourages omitting values from science, and therefore selects for models of communication which are conceptually aligned. The congruity between the VFI, the consensus view and the deficit model is also seen in the trajectory of their development, major critiques, and continued popularity. Because the VFI encourages the use of misrepresentative and ineffective methods of communicating science based on decontextualization, I argue that this has negatively affected science literacy levels, providing yet another reason why the VFI should be rejected.

By revealing the conceptual and chronological harmony between the VFI, consensus view and deficit model, I have shown how the decontextualizing of science has influenced how science is transmitted to publics in terms of the models we use and the content we convey. Knowing this, we need alternative descriptions of science to more accurately communicate what science is and to make it more engaging. In other words, provided we are willing to grant that epistemic and non-epistemic values play a role in science, we need a way to describe values in science as well as information transmission models that can include values - a task I set out to resolve in the next chapter.

Chapter 4

Contextualizing Science through a Value-Conscious Approach

In Chapter 3, I showed how decontextualization serves as the central idea reinforcing the relationship between the VFI, science education (i.e. the consensus view), and science communication (i.e. the deficit model). Decontextualizing science hides debate in science (misrepresenting science), and removes science from the interests of publics (making it less memorable). It is not surprising then, that the goals of science education and science communication in terms of science literacy and public understanding of science have yet to be fully realized. In response to the need for more science literate publics, scholars have suggested that transmissions about science ought to contain an acknowledgement of values in science and reflect the interests of publics (Dietz, 2013). Hence, in this chapter I move to contextualize science by crafting a means to elucidate values in science and expand on current communication models so that they are better able to accommodate a value-conscious approach to science.

First, based on how the alternatives to the VFI proposed by Douglas, Elliott, Steel and Whyte, and Kourany can be used to describe values in science (presented in Chapter 2), I explore whether the consensus view and deficit model can account for the VFI alternatives – they cannot. Second, as the VFI alternatives in their original forms are incompatible, I re-combine them by highlighting key aspects for understanding values in science and call this the KAUVIS. Unlike their complete forms, the KAUVIS will show how they can work together to describe different features of values to provide publics a richer account of science. This adds to the literature by going beyond initial questions asked by the VFI alternatives regarding which values ought to go into science by instead proposing what publics need to know about values to engage with science. As with a complete account of the VFI alternatives, the consensus view and deficit model are unable to account for the KAUVIS. Third, in response to this need for new models for transmitting information about science, I consider contextualized norms for science communication. Though value-conscious models of science education are also required, the literature in science communication is already expressing the will to discuss values (e.g. see Wynne (2003b) and Dietz (2013)), but lacks the detail to do so. Thus, the KAUVIS will be shown to flesh out these details. This leads me to review the conceptual trajectory of contextualization as an ideal in science communication and the replacement models it generates. Under a contextualizing account of science, I review the Dialogue Model and Public Participation Model. I show how the Dialogue model is insufficiently engaging, and in an example related to sustainability, explain how Public Participation could be improved through use of the KAUVIS. Then, in knowing that epistemic and non-epistemic values play an important role in relation to inductive risk, I also consider a specialized version of the Public Participation model designed for communicating risk known as the Analytic-Deliberative Process (ADP). Similarly, I demonstrate that this model could also be expanded to include a more nuanced account of values using the KAUVIS for the benefit of publics. By assessing the ways with which these alternate models can adapt to a discussion of values, I show that they can be enhanced by the KAUVIS to offer a more detailed means of describing values in science. In so doing, the KAUVIS' outline for how to describe values can serve to combat decontextualization by more accurately and effectively communicating science.

4.1 The Consensus View, Deficit Model and VFI Alternatives

Knowing that science is inherently value-laden, we should expect our information transmission models to be able to incorporate discussions of values. However, the deficit model and the consensus view have been shown to misrepresent science as free of values. In this section, I will explain in detail why the consensus view and deficit model are also unable to accommodate the VFI alternatives, justifying a move away from these models.

In terms of the VFI alternatives, recall from Chapter 2 that Douglas imagines a value framework where epistemic values can appear in any role, but non-epistemic values are only allowed to be directly involved in the 'context of discovery' (Douglas, 2009, 2016). In contrast, Elliott (2011a, 2013) allows for non-epistemic values to play a direct role during the 'context of justification'. Provided this allowance, Elliott must find a way to verify that the non-epistemic values he allows to play a role adequately promote research goals. Steel and Whyte (2012) emphasize that scientists are not always honest with themselves, communicators, or publics about values in their work, so they advocate for transparency around values in order to protect publics from the potential negative consequences that can result from non-epistemic values being used. Lastly, Kourany's (2013) Socially Responsible Science (SRS) promotes understanding science as a social enterprise guided by ethical and epistemic standards in response to social inequality and injustice. In terms of values, SRS requires that neither ethical nor epistemic values take priority over the other and research only realized if it meets both criteria.

In the end, the consensus view and deficit model will be shown to be poor hosts for the VFI alternatives. The consensus view will be shown to have difficulty adapting to the VFI alternatives for two reasons. Besides the fact that the descriptive, boundary and normative challenges to the VFI already generate broad disagreement around values in science, I begin by explaining how the debate among VFI alternatives prevents values from being communicated as well. Second, the consensus view is additionally stunted by transmitting information mostly about the findings of science from the 'context of justification' whereas the VFI alternatives also discuss the 'context of discovery'. For the deficit model, not all the VFI alternatives outline how they envision publics to engage with science, permitting it by default to seem more amenable to communicating about values in science. However, the deficit model's description of publics as ignorant and not able to contribute to science define the model as unidirectional which will be shown to be debilitating as several of the VFI alternatives recognize the importance of publics to science and require bidirectional communication. Thus, as the consensus view and deficit model will be shown to be unable to adapt to the VFI alternatives, it gives reason to re-examine the pertinent points of the VFI alternatives and provides justification for exploring additional models.

4.1.1 The Consensus View and VFI Alternatives

The consensus view is limited in its ability to communicate values in science based on what part of the scientific process it focuses on and which values are prioritized. Ultimately this will prove problematic for adapting to the

VFI alternatives. First, recall that the consensus view focuses almost exclusively on transmitting information about the findings of science in the 'context of justification' (see section 3.2.3, specifically Osborne (2003) and Hodson (2017)). This causes the view to miss out on agreement that epistemic and non-epistemic values are an important part of the 'context of discovery' (see Churchman (1948), Rudner (1953), and Douglas (2009)). Then, because the consensus view only recognizes scientists/communicators as knowers (discounting publics' views on science through unidirectional communication), and much of science still subscribes to the VFI, epistemic values are prioritized. This occurs despite knowing from the descriptive, boundary, and normative challenges that utilizing a discreet set of epistemic values is seemingly impossible as well as undesirable. And, as if this were not enough to show how adverse the consensus view is to presenting values in science, the disagreements provided by these challenges may actually provide enough controversy to prevent the view from discussing values at all. However, since the objective of this section is to examine if the consensus view can adapt to the VFI alternatives, I will set these worries aside for the time being. Although, provided the consensus view's desire to avoid controversy, it will be shown to do a disservice to conveying the VFI alternatives anyway.

Douglas (2009, 2016) makes her boldest claim preventing non-epistemic values from playing a direct role during the 'context of justification' (see section 2.3.1). But, there is debate around this proposal – Elliott (2013) believes non-epistemic values should be able to play a direct role. And, since the consensus view avoids communicating disagreements amongst not only scientists, but historians and philosophers of science as well as STS scholars (see section 3.2.3), it is unable to convey Douglas' proposal due to controversy. Hence, in a best case scenario, when trying to accommodate the direct/indirect role distinction, the consensus view is limited to only discussing the roles for epistemic values in science which Douglas, Elliott and others agree on during the 'context of discovery'. But, whether or not there is agreement around epistemic values in these roles, because the character of Douglas' distinction is in how it emphasizes non-epistemic values playing an indirect role during the 'context of justification', and there is disagreement about this, the consensus view would have to leave out this crucial component of Douglas' formulation.

Elliott's (2013) focus on goals is limited to transmissions about those which have agreement around them under the consensus view (see section 2.3.2).

But, by attempting to incorporate Elliott's VFI alternative into the consensus view, it forces communicators to admit that it is scientists that have goals as opposed to 'science' itself. Admitting that the goals of science are really determined by scientists means conceding that values in science, as introduced by scientists through their goals, are a part of science and that diverse goals (and values) are possible. Since the goals (and values) of scientists do not always have consensus around them, and in fact complete agreement over research goals are rare (Langford, Hall, Josty, Matos & Jacobson, 2006), it hinders the consensus view's ability to talk about them. And so, if the goals (and values) of scientists are important to science, then they ought to be communicated, even (and maybe especially) if there are controversies around them - something the consensus view cannot do. Hence, Elliott's emphasis on goals to justify the values used in science are lost under the consensus view as it fails to be able to host discussions over goals with controversy, even as we recognize the need for such debates.

Steel and Whyte (2012) stress the need for transparency in science, especially around the values used by scientists (see section 2.3.3). This should include transparency about epistemic and non-epistemic values even though

Steel and Whyte agree with Douglas that non-epistemic values should not play a direct role in evaluating evidence. However, because there is controversy about whether epistemic or non-epistemic values ought to play a direct role in science, the details surrounding how they are used in science would be muffled under the consensus view. The forced omission of details around non-epistemic values, due to their controversy, contradicts Steel and Whyte's emphasis on transparency. Hence, the consensus view is unable to capture how epistemic and non-epistemic values are used in science, causing it to be unable to accommodate the Values-in-science standard.

Kourany's (2013) SRS is defined by a consideration of ethical and social values when doing research (see section 2.3.4). As SRS grants that publics are made up of diverse groups of stakeholders, their goals and values (which scientists are encouraged to consider) can produce varied suggestions for what research to invest in and how to carry it out. The diversity of publics and their values and interests can also lead to disagreement. Hence, the consensus view is unable to account for the heterogenous ethical and social values we would expect of diverse publics because it is only able to transmit information that has agreement around it.

In conclusion, the consensus view is unable to present values in science as described by the VFI alternatives except in circumstances where all the VFI alternatives concur (e.g. by focusing on the findings of science, that utilize epistemic values, during the 'context of justification'). Douglas' barring of non-epistemic values playing a direct role during the 'context of justification' cannot be communicated because it clashes directly with Elliott's position of allowing non-epistemic values to play a direct role. Plus, Steel and Whyte emphasize the importance of epistemic values taking priority in the evaluation of evidence which counters Elliott's position even as Kourany envisions both ethical and social values being considered. These internal debates around how to use non-epistemic values and their larger conflict with the VFI leads to more disagreement than the consensus view can bear. Thus, the consensus view is unable to accommodate the VFI alternatives and their descriptions about non-epistemic values in science, which are a crucial part of understanding and contextualizing science.

4.1.2 The Deficit Model and VFI Alternatives

The deficit model is lenient in terms of content, permitting communicators to transmit what they want to publics. But, it operates under the assumption that publics are ignorant about science. This model centres on communication being unidirectional, where information is transmitted from scientists and communicators as 'knowers' to publics that are assumed to be deficient (see section 3.3.2). Though shown to be blatantly false since publics can be useful contributors to science (Callon, 1999; Wynne, 1996), technically the deficit model can convey value-laden information about science. However, since the deficit model is defined by its view of publics, and several of the VFI alternatives mandate an active part for publics in science, the model ultimately fails. I begin by extending Douglas' role distinction to consider the values of publics, then point to the importance Elliott places on publics' reflections on research goals. Afterwards, I examine Steel and Whyte's emphasis on publics' response to the effects of science, and end with Kourany's stress on publics as diverse stakeholders to show that the deficit model is unable to adapt to the VFI alternatives.

Douglas' (2009, 2016) original proposal, forbidding non-epistemic values from playing a direct role during the evaluation of evidence, can be passed along by communicators under the deficit model since there is little restriction on content. However, besides describing values in science, I propose that Douglas' distinction can also help to develop a better understanding of publics' views of values related to science. By providing publics tools to describe how they would like values to interact with science, or help publics realize how they employ values directly or indirectly to evaluate science, the distinction can offer insight into how publics engage with science. This extends Douglas' model slightly, but not unreasonably since it is more than just scientists that use values to judge science (see Douglas (2017)). To explore this further (and match the intention of Douglas' alternative account), it could also be the case that communications work best when publics (like scientists) use only epistemic values directly to evaluate evidence, leaving social and ethical values to play an indirect role. Yet, as the deficit model writes off publics as nothing more than recipients of knowledge, there is no way to assess what role publics' epistemic and non-epistemic values should take on in their engagement with science. Hence, the deficit model may be missing a crucial part of the way publics interact with science, even though the model can transmit the roles for epistemic and non-epistemic values in science that Douglas wants.

The deficit model's lack of esteem for publics' attitudes towards science prevents it from engaging publics about their views on research goals, a problem for Elliott's (2013) Multiple Goals Criterion. Furthermore, the deficit model actually approaches a linear model style template in application by only informing publics about science after research is complete. In the linear model, publics are expected to utilize basic scientific research after the research process, meaning that they can have no direct impact on the research goals set out by scientists (see section 1.1). Considering publics after the research process limits public involvement in science the way Elliott intends. And because Elliott requires spaces like forums of deliberation for publics to express the values they desire, and the deficit model sees publics only as ignorant, the model is inadequate. Within a deliberative forum, publics are expected to discuss their opinions and values on the subject matter, even contributing some expertise of their own, but the sort of bidirectional communication this describes is not possible under the deficit model. Since the deficit model does not recognize the attitudes and potential epistemic contributions of publics, it is unlikely the model would see the need for publics to convene and discuss research goals at all. Therefore, the deficit model with its description of publics as passive, is unable to meet Elliott's active account of how to verify if research values and goals are appropriate.

For Steel and Whyte's (2012) Values-in-science standard to allow publics to reflect on the effects of science, scientists and publics need a bidirectional communication model that can facilitate transparency around science. This would enable scientists to transmit information about science, and publics to evaluate values as appropriate or not. However, the unidirectionality of the deficit model minimizes the role of the audience to only that of receivers of information, considering them to be incapable of relevant contributions to science – even in terms of being able to evaluate it. For instance, the deficit model could submit science to publics in a way such that values are transparent for Steel and Whyte, but because there are no built-in response channels, the model is unable to consider publics' responses to the effects of values in research (and whether they help or hinder the attainment of truth). Furthermore, in assuming publics to simply be ignorant about science under the deficit model, publics' interpretation of the effects of values could be easily discredited. Hence, due to the deficit model's view of publics as deficient of relevant contributions to knowledge (including being able to assess values), it prevents publics from being able to reflect on science, causing a key component of the Values-in-science standard to be lost. Therefore, without a minimum of bidirectional communication, the Values-in-science standard's reflection on the effects of science cannot be carried out.

The deficit model is even more unable to adapt to Kourany's SRS. Technically, while it is possible for communicators to convey epistemic and ethical values in science, the deficit model cannot appreciate the opinions of stakeholders protected by SRS. By overlooking the potential contributions of publics as exactly the diverse sorts of stakeholders that Kourany (2013) insists ought to help determine the ethical and epistemic standards that science should adhere to, the deficit model fails. In addition, the deficit model is bereft of bidirectional, but ideally multidirectional, communication channels to articulate and refine social values from diverse groups as outlined by SRS. Thus, Kourany's emphasis on society's ethical standards being given the same importance as science's epistemic standards could get lost under the deficit model. If either epistemic or ethical values cannot be communicated, it would risk one set of values taking priority over the other which goes against the point of Kourany's position. And so, the deficit model is unable to adapt to Kourany's value-rich alternative.

Overall, the deficit model struggles by being unidirectional and minimizing the importance of public engagement with science. This is mostly due to the model's skeptical opinion of publics' as simply deficient in information about science. Hence, although the deficit model can transmit value-laden information, it provides no means for publics to respond or contribute to science. After evaluating the likelihood of the deficit model being able to adapt to the VFI alternatives, it seems best able to adopt Douglas' direct/indirect role distinction as this alternative outlines the fewest requirements for structuring the relationship between publics and scientists. However, the model may miss the direct/indirect ways publics use values to evaluate science. Elliott, Steel and Whyte, as well as Kourany all outline explicit roles for publics in various capacities which makes the deficit model less amenable to them. Elliott, in his description of the Multiple Goals criterion, encourages scientists to consult with publics in order to evaluate which non-epistemic values ought to be used in science to determine if they are appropriate based on research goals.

Likewise, Steel and Whyte in their aim of protecting publics by preventing non-epistemic goals from taking priority over epistemic ones, expects scientists to be transparent about their research to allow for consultations about values which the deficit model cannot provide. Finally, Kourany outlines an even greater commitment to public participation in terms of the ethical and social aspects that go into research. But, this means that Elliott, Steel and Whyte, and Kourany all require active publics to engage with scientists which the deficit model cannot facilitate, ultimately preventing it from being a value-conscious model.

Conclusion

In assessing the ability of the consensus view and deficit models to adapt to the VFI alternatives, at least two trends become evident. First, the consensus view is impaired at communicating about values in the VFI alternatives because consensus around values appears too high a standard. Second, because the deficit model denies the importance of public attitudes towards science and public input in science, it struggles to attend to the publics-oriented details of the VFI alternatives. For Douglas' role distinction, the banishment of non-epistemic values from a direct role during the 'context of justification' phase is left out of the consensus view due to debate. However, I add that though the deficit model can convey information about the distinction, it would miss out on how publics envision values playing a direct/indirect role. Therefore, in recognizing that Douglas' distinction is a useful one, we should select models of communication that can harness the distinction. For Elliott's Multiple Goals criterion, perfect agreement is rare, and so the consensus view will struggle to convey goals without agreement around them. Plus, the deficit model's neglect of publics' attitudes makes it impossible for them to influence and evaluate science's goals. Thus, neither model is truly well-suited to Elliott's proposal. Steel and Whyte's Values-in-science standard requires a communication model that encourages transparency so that publics are able to respond to the effects of values in science. Though the consensus view can theoretically communicate the values of scientists to publics (if these values are transparent and agreed upon), neither model offers enough in the way of transmitting publics' responses to science. Lastly, Kourany's SRS poses serious problems for both the consensus view and deficit models primarily because of SRS' emphasis on bidirectional communication and the recognition of diverse publics (and values) as important contributors to responsible science. Hence, the unidirectionality of the consensus view and deficit model hinder the VFI alternatives' consideration of science as a socially embedded enterprise, and in so doing, perpetuates the decontextualization of science by obstructing descriptions of science that are value-laden and socially situated.

4.2 Introducing Key Aspects for Understanding Values in Science (KAUVIS)

It has been shown that popular models of science education (the consensus view) and science communication (the deficit model) cannot properly transmit information about values despite the fact that values play a crucial part in science. In this section, I will select **k**ey **a**spects for **u**nderstanding **v**alues **i**n **s**cience – which I will call the KAUVIS – that I believe best describe values in science from each of the VFI alternatives. As an advantage over their complete counterparts, the components of the VFI alternatives I select will be shown to be compatible with one another (but not with the consensus view and deficit model). And, unlike the complete VFI alternatives, the KAUVIS does not make claims about which values should do what in science, leaving it instead to scientists and publics to decide. The creation of the KAUVIS will lead to a review of communication models to see which can accommodate a value-conscious account of science, with the aim of cultivating a more accurate and engaging representation of science.

4.2.1 Components of the KAUVIS

As they are, the VFI alternatives are not readily compatible with one another. Douglas' sequestering of non-epistemic values to an indirect role during the justification phase is somewhat aligned with Steel and Whyte who forbid non-epistemic values from being favoured over epistemic ones in the evaluation of evidence. But, this is contrary to Elliott's allowance of non-epistemic values in a direct role or Kourany who advocates for epistemic and ethical (non-epistemic) concerns being given equal consideration. Yet, provided that each alternative offers a useful contribution to understanding how values can be recognized and incorporated into science, I add to the literature by identifying a means to describe values that unites features from them all. These elements are: the indirect or direct role that values can play; goal-setting as a way to determine appropriate values; and the types of values that can legitimately be taken into account in a particular scientific context; all of which, could not work without transparency on behalf of scientists and publics. My intention with the KAUVIS is that by providing a more value-conscious account of science by describing values in science, it can help scientists, communicators and publics make better personal and civic decisions using science to create a more truthful and engaging account of science.

First, Douglas' direct/indirect role distinction is helpful in that it draws attention to the fact that values (epistemic or otherwise) are not all used in the same way (see 2.3.1). For Douglas, this means that values are employed in different ways depending on the type of science, scientist and circumstance. The advantage of communicating about values in this way is that it allows scientists and publics to describe, as well as determine, in what capacity they want values to be involved. And although this risks utilizing non-epistemic values in a direct role against Douglas' wishes, at least if the roles of values are clearly elucidated, then they can be corrected if necessary. Thus, as a result of the direct and indirect ways values can engage science, society will be better armed to tackle the value-terrain with an understanding that values need not act uniformly.

By promoting Douglas' role distinction, scientists and publics will wonder how to determine if the role values should take on is appropriate. Leaning on Elliott, I think scientists and publics should align their views on values in relation to research goals to help them decide between direct and indirect roles for values. Recall that Elliott develops the Multiple Goal Criterion to decide whether values in their particular roles are appropriate and allows both epistemic and non-epistemic values to play a direct role (see section 2.3.2). However, I do not believe that we need to focus on Elliott and Douglas' central disagreement, about whether or not non-epistemic values should be used in a direct role to achieve these goals. After all, the KAUVIS is not intended to make claims about which values are appropriate, instead it is intended to provide a means to describe values for a richer account of science. Hence, using a goal-centred approach for science provides scientists and publics yet another tool for describing values in science in relation to the purpose of carrying out science, and in so doing contextualizes values in science in relation to research objectives.

But what sorts of values are worth communicating in terms of our goals?

Douglas, Elliott and even Steel and Whyte admit a place for both epistemic and non-epistemic values – though of course how they utilize them is different. And so, Kourany's proposal to weigh both ethical and epistemic values provides a viable option for how to evaluate values. In her emphasis on epistemic and ethical values being used in relation to social need, Kourany is committed to developing science to benefit society, part of which involves fairly distributing information about science.[1] Kourany writes, "... sound social values as well as sound epistemic values must control every aspect of the scientific research process, from the choice of research questions to the communication and application of results." (Kourany, 2013, p. 93) So here we see an attention to values as part of communications, even if just in selection of model. However, Kourany warns that scientists and publics must be wary that they do not take this allowance of both types of values to mean that just any values should be allowed. Kourany does not advocate for using all sorts of values – especially harmful ones that might reinforce social injustices (Kourany, 2010). By encouraging descriptions of epistemic and non-epistemic values, Douglas and Elliott's 'roles in relation to goals' can clarify discussions between scient-

[1]Stern and Fineberg (1996) are also keen on identifying fairness and competence as fundamental features of communicating science.

ists and publics about what sorts of values are involved in science and which ought to be.

Finally, Steel and Whyte offer an underlying component of transmitting information around values in science: transparency. Though their Values-in-science standard may rely too heavily on retroactively assessing whether or not certain values are truth promoting, the idea of transparency remains invaluable. The idea that scientists should be transparent about the values they are using is a powerful assertion underlying Kourany (2010), Douglas (2008), and Elliott's (2017) proposals. For Kourany, the inclusion of epistemic and ethical values forces scientists and publics to be forthcoming about their research goals and the values they intend to use to achieve them. For Douglas, without transparency, knowing which values have taken on a direct and indirect role becomes another retroactive guessing game. And for Elliott, to reflect on the goals of scientists, requires publics to be clear about the values underscoring these goals.[2] Hence, the transparency requirement presented by Steel and Whyte, though not the focus of their proposal, is a worthy contribution

[2] In greater detail, Elliott (2017, p. 10) outlines and defends his normative position on scientists legitimately incorporating values into science based on three requirements: that scientists are sufficiently transparent about how values are used; that their values adequately represent ethical principles and social priorities; and, that there be mechanisms through which these values can be readily scrutinized and managed.

to society's understanding of values in science because it allows for the roles, goals, and varied types of values in science to be conveyed.

By highlighting key aspects of the VFI alternatives, I propose that scientists and publics require a description of values to engage with science as opposed to what a decontextualized value-free account of science presents. Douglas' direct/indirect role distinction describes how values can be employed, Elliott's Multiple Goal criterion is meant to help orient values in terms of role, Kourany's requirement of both epistemic and ethical values ensures that one type of value does not dominate over the other and all three of these alternatives are helped by Steel and Whyte's emphasis on transparency. Though this might not be an exhaustive list of ways to describe values, the selection of these features from the alternatives are useful for reasons beyond description. First, the alternatives in their entirety have competing components, but selectively combined, they can offer complimentary ways for framing values in science. Second, taking elements from the alternatives makes no claim as to which alternative is best for science. Instead, it lets publics and scientists decide for themselves how and which values they think should be used – with epistemic and ethical (non-epistemic) values being used in tandem. Hence, my selection of VFI alternative components is designed as a way to frame how values work within science, and leaves the assessment of these values to society. Lastly, though the KAUVIS only uses parts of the alternatives, this does not mean that it is compatible with the deficit model or consensus view. Due to its explicit inclusion of values, which can generate disagreement, and its recognition of publics as a part of science, the KAUVIS cannot be accommodated by value-free decontextualizing models.

4.3 Contextualized Communication

The KAUVIS, a means to describe values in science to more accurately represent science as value-laden and contextualized, uses transparency to describe the role, goal, and types of values being used in science. By recognizing publics as stakeholders and contributors to science, the KAUVIS contrasts information transmission models that either assume that publics do not need to know about values (the consensus view) or underestimates their ability to understand and contribute to science because of their attitudes towards science (the deficit model).[3] As a result, the KAUVIS requires value-conscious contextualizing models of communication that are able to accommodate discussions of values in science. The "contextual approach" to public understanding of science sees new knowledge around science as a dialogue involving scientific facts and local knowledge with an understanding and interest in the problem to be solved (S. Miller, 2001). As further incentive, scholars know that contextualizing science can help to generate interest in science and aid with the retainment of information.[4] Hence, many have argued in favour of contextualizing science, even by developing a 'contextualized' model,[5] but not through an explicit description of values.

Building on arguments for contextualizing science broadly, next I will emphasize the possibility of contextualizing science with respect to values using the KAUVIS. But first, let us consider how general contextualization works in practice. As an example of how contextualized science can lead to more interest in science, consider how despite significant advancements in human

[3]This is not to say that epistemic contributions from publics are required in every instance, but the option should at least be a possibility.

[4]Information can be contextualized using values based on the priorities of the recipients (Fessenden-Raden, Fitchen & Heath, 1987), community sense-making (Passmore, Gouvea & Giere, 2014), or in class discussions for science education (Council et al., 2000, p. 83).

[5]See Ziman (1991) and more recently Gibbons (2000).

cloning as early as 1993, cloning did not become a readily discussed social issue in countries like Italy and others until the announcement of Dolly the sheep being born in 1996 (Neresini, 2000). The creation of Dolly, as a way to contextualize and communicate new information about genetics, lead to establishing a link in the minds of publics between the science of embryo development, in vitro fertilization, and abortion in relation to cloning. Scholars like Neresini (2000) have argued that the initial (research-based) stages of cloning were insufficient to garner public interest in this type of science until it could be visually linked to Dolly, and subsequently becoming contextualized in relation to familiar entities and anthropocentric values.

Note how the research in this example is only contextualized at the end of the experiment once Dolly is created and communicated about. Thus, this is also an example of how publics traditionally only engage with developments in science as the products of science become apparent. Such late stage engagement has traces of the linear model in it as we see scientists conducting research independent of publics who only decide on what to do with it afterwards, such as create The Universal Declaration on Bioethics and Human Rights adopted by the United Nations Educational, Scientific, and Cultural

Organization (UNESCO) in 2005 (Andorno, 2007; Greenlee, 2000).

Unlike with Dolly, we need not wait until research is complete to contextualize science. And as further motivation for describing values with the KAUVIS, scholars such as Brian Wynne, who recognize that the conventional boundary between facts and values is false (Wynne, 2003a, p. 3), also suggest contextualizing science in terms of values. He recognizes beliefs and values as the function of social relationships and not at all akin to the conventional approaches that see values as, "...coherent, self-sufficient, and discrete entities..." (Wynne, 2003b, p. 43). In response, he has advocated broadly for a contextualized ideal for communicating science by claiming that what is needed is better articulation of what science is in terms of three features, "...the formal contents of scientific knowledge; the methods and processes of science; and its forms of institutional embedding, patronage, organization, and control." (Wynne, 1992, p. 42) Here formal content is akin to the findings of science, methods are the methodological processes of science, and organization are the social features of science that reflect science's embedded position in society.

Re-describing the processes of science in a contextualized way can situate science in a value-conscious landscape which is why the KAUVIS appeals to contextualized communication. By examining Wynne's elements for contextualized communication in more detail for how the KAUVIS might be included, I will explain how there is room to better describe values in the three parts. For the formal contents of scientific knowledge, admitting that the findings of science come about via meeting thresholds of evidence means someone is required to set thresholds of evidence. Here whether non-epistemic values play a direct or indirect role is especially relevant. Secondly, during the methods and processes of science, publics may be curious about the goals motivating the methods selected, so they need a way to describe values to ask questions about these methods. Finally, the institutional environment that science finds itself in is ripe for an explicit discussion of values in terms of whether these institutions satisfy publics' social and ethical concerns[6] – if publics have a means to investigate them. Finally, none of these values could be known without transparency on behalf of scientists and publics. Thus, the KAUVIS can add refinement in terms of describing values in broad contextualization.

In sum, the three main aspects of science that should be contextualized according to Wynne (1992) are the findings, methods, and social structures of

[6] For instance, the relationships scientists have with their patrons and sponsors has been directly shown to influence the evaluation of findings (Als-Nielsen, Chen, Gluud & Kjaergard, 2003).

science. The KAUVIS can be used to contextualize these aspects by elucidating the values embedded in them. However, though contextualized communication broadly outlines how to describe information about science in relation to society, it does not describe how publics can critique and engage with science. In other words, contextualized communication places science in society without sketching how publics ought to engage with science. And, because the KAUVIS recognizes that publics may need to respond to scientists regarding the science they want and how science should be done, general contextualization is not enough to truly engage publics with science.

4.4 The Evolution of Contextualized Science Communication Models

As general contextualization offers no guide for how publics ought to engage science, and the KAUVIS is meant to facilitate publics' engagement with science via its description of values, additional communication models are needed. Because of the KAUVIS' framework for understanding values in terms of their role, goal, and epistemic or ethical nature (based on transparency) it connects publics to science and inevitably attracts bidirectional models of communication that allow publics to engage science.[7]

The models I will consider are ones known to be contextualizing and can adapt to value-conscious descriptions of science. This provides more detail than Wynne's broad account of contextualization, specifically in terms of being bidirectional. To determine which candidate models could work as replacements, I will briefly go over how trends in contextualized science communication have evolved in response to how they view publics. I review the Dialogue model, the Public Participation model and a refined version of the Public Participation model known as the Analytical Deliberative Process. I conclude that on normative and practical grounds that the Public Participation model and Analytic Deliberative Process are more charitable to the KAUVIS, even being enhanced by it, than the Dialogue model and broad contextualization.

To begin, consider Figure 4.1: Bauer's (2008) account of conceptual changes in science communication over time based on various challenges and how these issues have been addressed. Figure 4.1 is mapped out in terms of how knowledge of science is described during particular times (Period), how challenges

[7] Wynne and Irwin (2003a, p. 43) even believe that the reflexive capabilities of publics often go unacknowledged, providing further reason to examine additional models.

Different Paradigms, Problems and Solutions

Period	*Attribution diagnosis*	*Strategy research*
Science literacy	Public deficit knowledge	Measurement of literacy education
1960s–1980s		
Public understanding	Public deficit attitudes	Know × attitude
1985–1990s		Attitude change
		Education
		Public Relations
Science-in-Society	Trust deficit	Participation deliberation
1990s–present		
	Expert deficit	
	Notions of public	'Angels' mediators
	Crisis of confidence	Impact evaluation

Figure 4.1: A chronological description (Period) of different accounts of publics' engagement with science (Attribution diagnosis) and the research aimed at resolving these issues (Strategy research)(M. W. Bauer, 2008).

are conceptualized (Attribution diagnosis), and the research proposed to solve these problems (Strategy research). According to Bauer, initially when the term 'science literacy' was being used, publics were not believed to be very science literate due to a lack of knowledge about science (as opposed to lack of interest in science), hence 'Public deficit knowledge' was seen as the problem and routinely monitored using science literacy assessments. Note how during this period the responsibility to develop science literacy is on publics. But, as explained in sections 3.2.3 and 3.3.2, improving science literacy under this approach was relatively unsuccessful causing science literacy levels to remain low for students (OECD, 2016; Withey, 1959) and adults (J. D. Miller, 2012). By 1985, scholars moved away from thinking of publics as having a knowledge deficit to a negative attitude towards science which was prohibiting them from taking-up information effectively and agreeing with scientific consensuses. As a result, the framing of public knowledge about science changes to 'public understanding of science' focusing on 'Public deficit attitudes'.[8] Under both deficit accounts (knowledge or attitudes), the consensus view and deficit model are used unsuccessfully to try and improve public knowledge of science by either stressing the findings of science which have agreement around them, or transferring more information to publics unidirectionally.

Recognizing that science literacy had yet to improve and that publics could be useful contributors to science, from the 1990s onward a 'Science-in-Society' approach has been employed. This approach for communication focuses on trust in science, and scientists' understanding of publics' needs (Expert deficit, Notions of publics) with an evaluative impact component. Note the shift

[8]'Science literacy' and 'Public understanding of science' are designated as two separate time periods in Bauer's account of the evolution of communication. Yet throughout this work, I have used science literacy and public understanding of science together. I will continue to use the terms together because as science literacy is described by De Hurd (1958), Shen (1975), Shamos (1995) and Miller (1998), there is a strong element of understanding subsumed as part of science literacy and public understanding of science seems to still be an ideal worth striving for.

here by theorists moving the onus of science literacy from publics as the source of the problem (Public deficit knowledge) to science experts lacking enough information about the needs and interests of publics (Expert deficit, Notions of public and Crisis of confidence).[9] In admitting that the needs of publics and trust in science are important, the 'Science-in-Society' approach inherently lends itself better to a discussion of values in science because science is explicitly socially situated. Thus, 'Science-in-Society' is contextualized in a way that previous instantiations of science communication are not.

Drawing from the 'Science-in-Society' period, the remainder of this section will analyze two socially situated models of science communication, the Dialogue model and the Public Participation model. I will examine them with regard to their ability to adapt to the KAUVIS, and the KAUVIS' ability to enhance these models. In so doing, I show how these models are emblematic of this bidirectional generation of contextualized communication, and highlight how they might better account for values in science.

[9] This is markedly different than initial approaches to science as framed under the linear model where science research happens independent of publics. The idea of an expert deficit suggests that scientists must engage with publics' needs directly to ensure that publics are engaged in science as opposed to end-of-the-line recipients of science.

4.4.1 The Dialogue Model

By realizing that active publics were missing from broadly contextualized communication, the 'Science-in-Society' period saw the rise of the Dialogue model as a means to address this. The Dialogue model compared to the consensus view (which mostly transmits the findings of science with agreement around them), allows scientists and publics to discuss the methods of science, the findings of science and how values are used in either. The content of dialogue, "... in its pure form and its mass communication application could be either about concepts or about facts." (Van Der Sanden & Meijman, 2008, p. 92) This means that the model can transmit information about the methods or ideals of science as well as the findings of science. Furthermore, the Dialogue model is defined by bidirectional communication (Trench, 2008), meaning that information is transmitted back and forth, scientists to publics and from publics to scientists (compared to the deficit model and consensus view which only transmit information unidirectionally from scientists to publics). The Dialogue model introduces bidirectional communication by allowing publics to question science (Van Der Sanden & Meijman, 2008). However, because the dialogue model only permits publics to engage science by asking questions (as they are not recognized as legitimate contributors), it limits what is considered acceptable forms of engagement with science.[10]

According to Trench (2008), the Dialogue model has roots in constructivism and pragmatism. The model is 'constructivist' because it stresses that the understandings and experiences of publics are relevant to their learning. This implies that publics evaluate scientific material in the context of larger knowledge frameworks and construct attitudes towards science in relation to other knowledge. The model is also 'pragmatic' because it mandates that only scientists can be responsible for knowledge production, denying participation to lay publics based on a presumed lack of competence (Bucchi, 2008). This skepticism around publics results in a restriction on how publics are allowed to engage with science (i.e. by suggesting research questions, but not actually performing research). Hence, the dialogue and deficit models of communication both have an assumption about the capabilities of publics at their core.[11]

[10]Recall how with the deficit model, as used during the FMD crisis (see section 3.3.2), passive publics were only allowed to ask questions via the hotline. Hence, this instance of the deficit model also harnessed some aspects of the Dialogue model. But in general, publics were unable to speak with scientists directly and only active publics were allowed to contribute information to the knowledge forming around the event.

[11]Though the deficit and Dialogue models both make assumptions about the competences of publics, they frame science and evaluate effective communication differently. Using this

In terms of accounting for values in a broad sense, the Dialogue model can discuss values because it recognizes the social and inherently value-laden structures of science. In practice, this amounts to the Dialogue model giving publics the ability to agree with the content of science while questioning the social dimensions of science (e.g. the patronage that funds research). However, the Dialogue model lacks a fair view of the (value-laden) capabilities of publics. This spills into the model's decision to forbid direct epistemic contributions from publics by discouraging them from contributing their own expertise to science other than in the form of asking questions to scientists. This is not to say that in all cases all contributions must be deemed equally credible, but we should at least have bidirectional channels able to recognize the potential contributions of publics beyond just asking questions.[12] Therefore, by adopting the Dialogue model where the social features of science are communicated (including values during the 'context of discovery' and 'context of justification'

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opportunity to connect science communication to science education, the effectiveness of deficit communication is most often evaluated using quantitative evaluations (e.g. true or false, multiple choice question etc.), whereas contextualized (and dialogue) communication uses qualitative measures (e.g. long answer questions) (Sturgis & Allum, 2004). As qualitative measures can take more time to grade, and are trickier to judge, they are used much less frequently.

[12] In the case of the deficit model being used to handle communications for the FMD crisis, recall that it was theorized that the negative affects of the crisis might have been mitigated by engaging 'passive' publics' experiences using bidirectional communication (Haydon et al., 2004).

phases), communicators can begin to resolve the decontextualized portrait of science reinforced by the VFI but not fully correct it without considering publics (and their values) as contributors to science.

Though there are well-known examples of publics using the Dialogue model to eventually contribute to research,[13] consider the following case of the Dialogue model being used to communicate information about asthma. As outlined by Van der Sanden and Meijman (2008), dialogue between doctors and patients has the overall aim of building an effective doctor-patient relationship with the purpose of conveying pertinent information for treatment as needed. This means addressing the emotional aspects of the experience of having asthma, as well as the diagnostic elements. But, publics, patients, and doctors differ in their interest, emotional experience and knowledge of asthma. Under the Dialogue model, though the emotions of both parties may be recognized, it is often the case the experiences and knowledge of doctors are prioritized. In practice this means the emotions of the doctor, like having pleasant feelings when having effective treatments to offer, or the personal and professional reasons for suggesting one medication over another, are emphas-

[13]See Wynne's (1996) classic Cumbrian sheep-farmers post-Chernobyl disaster example.

ized. As a result, the experiences of publics and their knowledges or experiences can be overlooked (other than in retelling symptoms), including patient interpretations of the issue (especially in relation to other medical concerns).[14] Consequently, if publics are faced with information transmission styles like the Dialogue model, that facilitate patient compliance as opposed to contribution by restricting engagement, then there risks cultivating skepticism and issues of distrust on both sides. Doctors will be uncertain if patients are telling them the truth, and patients will hesitate to offer their own experiences if they think their contributions will be dismissed. Thus, the Dialogue model, though it creates space for publics to ask about science, lacks a mechanism for publics to contribute to science which can hinder the patient-doctor, or public-scientist, relationship.[15]

[14]To complicate matters, not all voices in a dialogue resonate with the same force. It is well known that cultural orientations can play a role in assertiveness and communication apprehension during medical interviews (Beisecker, 1990; Kim et al., 2000). Unfortunately, there have been studies showing that even required courses in medical school on the social and cultural issues in medicine had little to no difference in clinical rotations (Beagan, 2003). This means that certain publics may struggle to communicate their medical concerns or question the diagnostic process even under the Dialogue model where they are able to ask questions.

[15]For further reason to consider the Dialogue model as a more engaging model of communication than the deficit model, consider Goldenberg's (2016) examination of publics' resistance to the scientific consensus around vaccine safety. Public skepticism around vaccination was initially believed to result from publics' misunderstanding and ignorance of science. But, Goldenberg argues that it is publics' lack of trust in scientific experts and institutions, not science itself, that has led to publics' to resist calls to vaccinate. As a solution, Goldenberg advocates to switching from unidirectional communication models (like

The Dialogue model is tested by the KAUVIS to incorporate a highly detailed description of values. Taking the asthma example of the Dialogue model once more, it will be shown to only be able to account for some aspects of my value-conscious approach. Using the KAUVIS, doctors and patients would have to be transparent, meaning they must be honest about values in order to have meaningful dialogues about science. Even though the Dialogue model may welcome transparency (e.g. when publics recount symptoms or doctors evaluate the situation), since it only allows patients to ask questions, publics may struggle to communicate their interests (e.g. in relation to other value-laden medical concerns). However, to at least facilitate clarity even in these restrained discussions, scientists and publics can use the KAUVIS' direct/indirect role distinction to help elucidate which epistemic and ethical values are desirable and in what role (e.g. the value of comfort taking a direct role). Then to assess whether values in their role are appropriate, a goal-oriented approach can be used to focus dialogue (e.g. on comfortable treatment options). Hence, with an objective clearly stated, publics are at least able to question scientists about values in relation to specific goals. However, without

the deficit model) to dialogical ones. This is meant to allow for constructive and conciliatory discourse, compared to a combative framing of the issue as intelligent/informed science versus an ignorant society (Goldenberg, 2016).

publics being given contributive recognition, publics' opinions on research goals and values may be minimized in favour of those of scientists (e.g. pleasant feelings of the doctor). Realistically, meeting the social and ethical needs of publics may go beyond allowing publics to ask questions, causing the KAUVIS to suffer due to the limited role for publics afforded by the Dialogue model.

In summary, the Dialogue model presents science and a social structure to embed it in with a semi-bidirectional communicative component. This model relies on dialogue as a means for interaction between scientists and publics, but dialoguing about science has limits. Publics can ask questions about science, but are not recognized as potential epistemic contributors to science. As a result, the KAUVIS can only be utilized in limited ways because the roles of values, goals of research, and social considerations presented are mostly limited to those of scientists. So, if we want publics to have the option for epistemic input into science, simply allowing publics to question science may not be enough for their contributions (and values) to be taken up into science. Hence, though the Dialogue model creates bidirectional communication channels, it limits what information is recognized and as a result, lets the potential epistemic contributions (and values) of publics languish.

4.4.2 The Public Participation Model

Whereas the Dialogue model only allows publics to ask questions about the scientific process, the Public Participation model, in addition to allowing for questions, permits publics to set the aims and agendas for research (Trench, 2008). By setting research agendas, publics get to use their values and knowledge to decide on research topics as opposed to just commenting on science. Hence, the Public Participation model is bidirectional and recognizes multiple ways for publics to engage with science. This more active role for publics encourages further engagement with science and contextualizes science in society with respect to public interests.[16] Lastly, the Public Participation model does not limit what type of science content it can transmit. So unlike the consensus view that is blocked from communicating about controversy, the Public Participation model can transmit information about debated content, including values, which I will show to be enhanced by the detail of the KAUVIS.

Public Participation is imagined to have three main goals: to improve the quality of decisions, to enhance the legitimacy of decision-making, and to

[16] Recall that scholars have found that contextualizing science can help to generate interest in science and help make science memorable (Fessenden-Raden et al., 1987; Passmore et al., 2014; Council et al., 2000).

improve capacity for future decision-making for scientists, publics and policy-makers (Carpini, Cook & Jacobs, 2004). Part of the rationale for these goals is that it may help to decrease conflict and raise acceptance and trust in government decisions when scientific research is used (National Research Council, 1996, p. 119). But, as opposed to building trust with publics, scientists often view communication objectives as designed to support only educating publics (unidirectional communication) and defending science from misinformation (Dudo & Besley, 2016). In response to this, the Public Participation model moves away from scientists' views by facilitating publics' engagement with science throughout its processes and letting publics set the aims and agendas for research; encouraging participation when deciding on appropriate thresholds of evidence; and when determining how scientific knowledge should be applied (either as products or through policy recommendations). The model does this through citizen juries (Joss & Brownlea, 1999),[17] deliberative technology assessments (Hörning, 1999), and science shops (Wachelder, 2003) among other

[17] Citizen juries, usually chosen to represent a much larger population, are brought together to discuss proposals and options (M. Leach, Scoones & Wynne, 2005, p. 250). Citizen juries are different from citizen science projects whereby publics volunteer to collect and processes data as part of the scientific inquiry process (Silvertown, 2009). Citizen science is particularly popular in ecology and environmental sciences (Cooper, Dickinson, Phillips & Bonney, 2007; Dickinson, Zuckerberg & Bonter, 2010), but is steadily expanding to other avenues like museums (Sforzi et al., 2018) thanks in part to an increase in the use of online databases (Bonney et al., 2014).

options. Hence, the Public Participation model offers opportunities for publics to engage science throughout its different phases, and as a result, aids in facilitating discussions of values through engagement with science.

In practice, Public Participation utilizes a conversational style of communication, a sense of 'self-learning', and elements of 'relativism' (Trench, 2008). In terms of conversational styles, like the Dialogue model, the Public Participation model relies on dialogue and deliberation as opposed to discussion or debate. This is because discussion and debate can sometimes be seen as a battle of ideas back and forth which can be discouraging for participants (Bohm, 2013, p. 7). Dialogue, on the other hand, is simply an exchange of information where it is not about winning or convincing others (Van Der Sanden & Meijman, 2008). Additionally, the Public Participation model frames the purpose of these conversations by focusing on 'self-learning' for both scientists and publics. This 'self-learning' component lowers scientists from their position as absolute knowers and requires them to listen to the experience and knowledges of publics – a substantial departure from the Dialogue model that exalts scientists as exclusive knowledge producers. In terms of relativism, the Public Participation model recognizes situation specific frameworks for understanding and contextualizing scientific knowledge. In other words, different publics may interpret science differently, making meaning of information in ways relevant to them, even if that entails assigning no importance to the science at all. Ultimately, the Public Participation model allows scientists and publics to 'self-learn' leading to them shape issues, set agendas, and negotiate meanings.[18]

Take for example, Public Participation used for sustainability indicator selection in Vancouver, Canada as outlined by Meg Holden (2011). Conducted by the Regional Vancouver Urban Observatory (RVu) and a local university, the aim of the initiative was to generate sustainability indicators for policy and to guide governance (Holden, 2011). Sustainability indicators are, "...sets of strategic measures used by planners, policy analysts, the private sector and community groups to assess progress or performance toward aspects of sustainability that have been determined to be important." (Maclaren, 1996) However, as publics can lack expertise, the link between selecting 'good'

[18]One of the outcomes of this more immersive role for publics, is an openness to including knowledges from domains external to science. If we agree with the work of Longino (1990), Harding (1991), Solomon (2001), Intemann (2009), and Fehr (2011), then there is a benefit to public participation from external domains based on the potential of epistemic diversity. Hence, integrating public participation into science should be done carefully and intentionally so as not to bias certain publics (or seem ad hoc) but with the clear goal of creating a more informative version of science.

sustainability indicators and public participation has been doubted (Holden, 2011). This often results in two types of recommendations being offered, a set of expert-based sustainability indicators and a set of citizen-based indicators. But, Public Participation has increasingly been used to mitigate the difference between these two sets of indicators because of its ability for scientists and publics to connect and 'self-learn'. Furthermore, since Public Participation is able to take into account the views of stakeholders, information is better contextualized, increasing the likelihood publics and scientists will take up and utilize the results. This is a desirable outcome, because in the end, publics (and the environment) are the intended beneficiaries of the process (Holden, 2011; S. Bell & Morse, 2001).

According to Holden (2011), to develop the sustainability indicators in this case, approximately 150 participants from diverse backgrounds throughout the Vancouver region were separated into eight groups, each covering a sustainability topic (e.g. food systems). After the initiation event, the groups (guided by a neutral facilitator) met regularly over a period of six months to dialogue about the issue where they developed research agendas and suggested plans for implementation (informative materials were sent out in advance). During the reunions, participants were encouraged to engage the idea of sustainability from both personal and broad perspectives to collectively identify sustainability indicators (e.g. land use) and desirable action items (e.g. sustainable mobility, fair-trade industrial zones). The process concluded with a public event discussing plans for implementation.[19]

In terms of values, Holden (2011) found that there was a trade-off between the core values of participants and generating sustainability indicators for governance. That means that the connection between publics' values and decision-making could be improved. I argue that the KAUVIS can address improving communicative rationality by helping publics describe how values can and should relate to sustainability indicators and decisions about governance (e.g. by articulating that the value of fairness be employed directly in the assessment of land use). For example, Holden notes that the participants worked backwards from what they had collectively identified as desirable action items to sustainability indicators (Holden, 2011, p. 321). A detailed description of

[19]Inviting diverse participants to an initiation event, sending out informative materials, separating publics into groups with a facilitator, then asking them to engage the issue from personal and broad perspectives to generate action items which are later presented to the public at a closing event is known as the study-circle method (Leighninger & McCoy, 1998) - a means for carrying out public engagement with a basis going back centuries (Bjerkaker, 2006).

motivating values (e.g. fair-trade in a direct role) for action items or goals (e.g. sustainable food systems) would undoubtedly have been helpful in translating these values to their indicators (e.g. land use), providing clearer justification for governance decisions. Thus, while in the end public participation was seen as beneficial by allowing publics to determine sustainability indicators, the full power of the method was arguably not harnessed because it did not describe the value-laden relationship between these aspects of sustainability. Thus, to minimize the trade-off between core values and governance, the KAUVIS could have been helpful in elucidating how values relate to sustainability indicators, and in turn, connect to governance.

In summary, the Public Participation model provides scientists and publics with a dynamic way to interact with each other regarding different parts of science to increase public interest, engagement and understanding of science within society. Since leaving public engagement till the end of the scientific process (e.g. application and policy writing stages) has been revealed to be problematic under the linear model (section 1.1) and broad contextualization (section 4.3), the Public Participation model instead gets publics engaged from the beginning by deciding on aspects of science like sustainability indicators which guide research and governance. Furthermore, the Public Participation model can be expanded through use of the KAUVIS as a way to deepen conversations about values. Thus, Public Participation has great potential to produce value-conscious communication.

4.4.3 The Analytic Deliberative Process

Though the Public Participation model can appear to engage publics readily, it is not without flaws. For instance, communication errors can occur either in terms of failing to convey pertinent information or by conveying pertinent information ineffectively. In terms of conveying pertinent content ineffectively, stakeholders can still be disappointed even if information is value-laden and derived from deliberation. This regularly happens when communicating about risk. To address the special care risk communications must take to be effective, I point to the KAUVIS to clarify the influence of values on risk. By using the KAUVIS to extend a popular model for risk communication known as the Analytic Deliberative Process, I will show how expanding our descriptions of values as they relate to risk affects how science is contextualized and in turn, understood.

Risk is, "...a situation or event where something of human value (including humans themselves) is at stake and where the outcome is uncertain" (Aven & Renn, 2009, p. 1). As a result, risk can be broken down into two-dimensions: uncertainty and consequence. Risk analysis is the systematic use of information (e.g. historical data, theoretical analysis, informed opinions and stakeholder concerns) to identify the causes and consequences of risk (Aven, 2012). Risk analysis is also envisioned to be value-free so as not to let politics and other social biases interfere. However, we cannot avoid subjective elements in the analysis of risk (Aven, 2012). In other words, by knowing that science is preformed with values, risk analysis conceived as value-free is misleading.[20] Hence, risk analysis hides values used in conceptualizing the consequences of science, even though science itself is value-laden and experts will inevitably use values in their analyses.

Based on the 'value-free' possibilities developed by risk analysis, risk assessment is the evaluation of the potential harm that can result from the possibilities imagined in risk analysis.[21] As the standards used to determine harm

[20]Even though risk analysis has a relationship to the VFI, it is different from inductive risk. Recall from the normative challenge to the VFI, that 'inductive risk' will always be a part of science (see section 2.2.3). When scientists decide whether their evidence supports or rejects a hypothesis, they always risk making a false positive or false negative claim.

[21]Slovic et al. (2004) describe analytic and experimental systems of risk assessment.

are value-laden, they inevitably prevent risk assessment from being value-free. The results from risk assessments are amassed to make risk characterizations (a summary/translation of information for use by decision-makers (National Research Council, 1996, pg. 1)) and help publics manage their risk-taking (Fowle & Dearfield, 2000). Thus risk characterizations can be used for,

> ...informing regulatory decisions on approving drugs, chemicals, and vaccines; setting chemical exposure standards; setting priorities for public expenditures on risk reduction; informing populations at risk from hazardous substances, infectious disease, or their own behaviour; and informing legislative debates. (National Research Council, 1996, pg. xii)

However, risk characterizations typically fail to meet publics' expectations because of ongoing inadequacies in risk assessment and risk analysis (along with the degree of uncertainty that comes with risk in general (Dietz, 2013)). One way to try and minimize disappointment is to correct for traditional value-free risk analyses with a value-conscious approach to risk communication. By incorporating transparent discourse about the values used to set thresholds for risk assessment, publics can consider whether they find the reasons for these thresholds acceptable and state their own value-based concerns.

The analytic system relies on algorithms and normative rules whereas the experimental (or emotive) system uses intuition and emotion.

To try and meet publics' expectations and effectively convey the limitations of risk characterization, special communication models like the Analytical-Deliberative Process (ADP) have developed. The goal of the ADP is to harness public engagement with science by appreciating public attitudes towards risk. This is seen as a means to minimize disappointing stakeholders (Burgess et al., 2007; National Research Council, 1996). As a specialized version of the Public Participation model, the ADP contextualizes communication around risk by engaging directly with publics to investigate thresholds of acceptable risk. The ADP is a way to organize public participation discourse to formulate problems, guide analysis for understanding, assign meaning to analytic findings and recognize the uncertainty present in science (National Research Council, 1996).

The analytic component of the ADP is based on, "...ways of building understanding by systematically applying specific theories and methods that have been developed within communities of expertise" (National Research Council, 1996, pg. 97), which are meant to represent how research and theory coalesce to make knowledge. The deliberative component is a recount of how, "...people confer, ponder, exchange views, consider evidence, reflect on matters of mutual interest, negotiate and attempt to persuade each other" in an, "...iterative process that moves towards closure" (National Research Council, 1996, pg. 73). In other words, how publics exchange views about science in an attempt to reach consensus about what to do (though consensus or closure might not always possible).

In conceptual detail, the ADP as described by Stern and Fineberg (1996), is greatly influenced by Webler's reading of Habermas' 'pragmatic model' of communication (Webler, 1995; Webler, Rakel, Renn & Johnson, 1995). Here Habermas argues for a critical interrelationship between science and politics as opposed to a decisive separation between the two domains (Habermas, 1963; Peters, 2008). The ADP adopts much the same view by socially situating science. Stern and Fineberg (1996) also outline normative and descriptive principles for ADP. From a normative perspective, fairness for publics – which can include public officials, natural scientists and social scientists along with stakeholders and the broader public – means that they should all have ready access to information as well as research.[22] This includes the ability to shape

[22] One obstacle to overcome for ready access to information is the paywall system for published research. Whether legal like Wikipedia (Teplitskiy, Lu & Duede, 2017) or illegal like Sci Hub (Bohannon, 2016), options have arisen to address publics' thirst for information, though talks of more stable solutions are ongoing (see discussions in the United Kingdom (Hawkes, 2012) and United States (Van Noorden, 2013)).

research questions along with the chance to determine thresholds for acceptable results. From a discursive standard of competence, public capacity to actually undertake these participatory roles in assessment is also taken into consideration (Burgess et al., 2007). All of this, "...to provide a sound way of incorporating our best understanding about uncertain facts and diverse values into public decision making..." (Dietz, 2013, pg. 14083) with the goal of cultivating more engaged publics.

According to the National Academy of the Sciences (1996), the relationship between publics and scientists (cultivated through use of the ADP) can be judged to be successful based on 5 criteria. The first is 'getting the science right' which means that depending on the decision that must be made, or the impact the results may have, the science performed ought to provide sufficient evidence for decision-making while being conscious of the inductive risk involved in assessing this evidence. Sufficiency standards should be developed by scientists in consultations with publics where explicit risk considerations are detailed. In practice, these standards influence what analytical methods are used, measurement scales, the databases utilized, the plausibility of assumptions, the degree of uncertainty involved, and the limitations of our hypotheses (National Research Council, 1996).[23] The second ADP criteria is that we get 'the right science'. This means that the science being explored should address the concerns of publics, especially in terms of risks related to health, economic stability, ecological well-being and social values (National Research Council, 1996). Without engaging publics, understanding their needs results in a 'guessing-game' and can undermine their autonomy, hindering them in gaining knowledge. Third is the goal of getting the right sort of participation at the right time. Options include public forums, round tables, lab visits, outreach activities and public polls. Ensuring the right sort of participation allows us to be certain all parties' legitimate concerns are responded to - and those that cannot be accommodated to are explained as to why not. While the previous point refers to participation style, the fourth point demands that scientists and publics feel satisfied with their participation through adequate representation - meaning that participants see that their ideas have been accounted for in how scientific risk is categorized and understood. This means that scientists must be explicit in terms of how they

[23] In situations where risk assessments predict little harm, presumably a high threshold for risk could be set. But what is perhaps most important here, is that other communication models are unable to even account for the value-based discussion that would need to happen between scientists and stakeholders around thresholds of acceptable risk.

go about research, come to conclusions based on their findings and offer justification for their recommendations. Finally, ADP calls for communicators to develop accurate, balanced and informative syntheses of science. In terms of risk, this means characterizing the present state of knowledge without over or underselling it, explaining uncertainty, expressing disagreement, and summarizing this mixture of analytic and deliberative techniques (National Research Council, 1996). These five features of ADP make it contextualized and bidirectional by being sure that scientific analysis informs (and is informed) by public participation about scientific issues in a way that encourages deliberation as a means for engagement with science.

To further detail the potential of ADP, I point out what appears to be missing from present descriptions: how values can come into play. This oversight comes despite Burgess et al. (2007) explaining that the ADP was instigated by, "...the failure of technical-expert and bureaucratic-rationalist modes of option appraisal to engage effectively with the knowledge, values and interests of stakeholders and wider society." (p. 300) So allow me to be more forthcoming on the model's behalf. As explained in Chapter 2, values unavoidably play a role during the 'context of discovery' and 'context of justification' phases of science, especially when it comes to evaluating risk. Hence, the analytic process developed by, "...systematically applying specific theories and methods that have been developed within communities of expertise..."(National Research Council, 1996, pg. 97) is value-laden. But, what differentiates the ADP from other models, is that by welcoming publics to come together to reflect and exchange views on risk, it necessitates that communication be explicit about values in science because determining acceptable thresholds of risk cannot be discussed without values.

To show how values underpin the framing of the ADP, take Karjalainen et al.'s (2013) recommendation of using analytical-deliberative techniques for ecosystem service evaluations targeting at risk populations. As a consequence of not considering the trade-offs between relevant values and high-impact categories, traditional ecosystem service evaluations can miss the concerns of publics and certain stakeholders (Coleby et al., 2012). In response, there has been a move towards more holistic evaluations of ecosystem services (Chan, Satterfield & Goldstein, 2012) and analytic-deliberative techniques to create a more holistic account of the issues.

In an environmental impact assessment of options for regulated rivers in Finland, organizers used value-conscious multi-criteria decision analyses[24] based on analytical-deliberative techniques from the ADP to: (1) frame at-risk activities (like salmon catching) in a more understandable way for stakeholders; and (2) to take into account ecosystem processes and supporting services more carefully (Karjalainen et al., 2013). I argue that these two concerns are explicitly value-conscious as; first, prioritizing publics' 'understanding' requires some degree of consideration for the perceptions of publics (affected by values) which can influence uptake of information; and second, because ecosystem processes (or intermediate services) underpin final ecosystem services, that not only include provisioning and cultural services but, "...fish, wild species diversity and environmental setting, [that] directly contribute to goods or benefits, such as food harvest, recreation and tourism, that are valued by people." (Karjalainen et al., 2013, p. 56) Hence, values are the undercurrent of the motivations and actions of these analytical-deliberative techniques.

Karjalainen et al. (2013) conclude that in contrast with an ecosystem service approach alone, which was found to prioritize direct concerns (e.g.

[24]Multi-criteria decision analysis (MCDA) comes out of value-focused literature concerned with traditional planning and assessment processes moving too quickly to the evaluation of options while overlooking publics' concerns (Keeney, 1996). This concern has led scholars to advocate instead for prioritizing values when developing options (Keeney, 1996, p. 95).

the worth of the catch), a more value-focused approach was better able to help elucidate the importance of indirect concerns (e.g. societal functioning benefits) and allow for a bottom-up forming of value-categories with regard to publics' viewpoints (Karjalainen et al., 2013). So provided that a value-focused approach is the more promising option for communicating risk and considering view points of publics, let me show how the KAUVIS can further the description of values utilized. First, the ADP's value-conscious approach recognizes the indirect non-epistemic values of publics – like the KAUVIS. The role values take-on can be further described in relation to research goals in order to contextualize and orient value-selection. For example, a value (e.g. pro-environmental exploitation) can affect the social-ethical goals (e.g. attending to marginalized communities) by impacting socio-cultural development depending on the role values take on. Plus, epistemic and ethical values are both being used in the evaluation of ecosystem processes for supporting services (measured empirically) and holistic evaluations. Lastly, for this discourse to be fruitful, scientists and publics must be transparent about the values they are using to ensure the communication is effective. Hence, the KAUVIS formally frames descriptions of values as they relate to risk and can help structure discourse when communicating about risk.

However, I must warn that by being forthcoming about values, the ADP risks fostering disagreement about which values ought to be prioritized in relation to risk. Although, since there is already disagreement about how to assess and communicate risk and what to value, at least by describing the values we use to assess science and risk, we can have a clearer picture of the landscape of our dissent as a step towards resolution.[25] Hence, the KAUVIS can be a beneficial addition to the ADP by helping to describe the ways values interact with science to facilitate that both scientists and publics understand risk in relation to values.

In summary, to 'get the right science', the ADP recognizes the interests of publics as they relate to risk but with the framing of the KAUVIS, can describe epistemic and ethical values in terms of roles and goals. Goal-setting can then allow scientists and publics to make sure they 'get the science right' by offering

[25]For an example of disagreements related to values and communication, recall the 6.3 magnitude earthquake in 2009 that surprised citizens in L'Aquila, Italy resulting in over three hundred deaths and thousands injured (Yeo, 2014). The incident gave rise to legal action against scientists who, just days before, participated in an official meeting to assess risks in view of recent seismic activity – involuntary manslaughter convictions in 2012 were later successfully appealed. The case became a source of controversy related to anti-science discourse; a potential failure of science communication; the roles of government and scientists; and the conflation of science and politics (Yeo, 2014). All of these subjects are value-rich (e.g. as related to human welfare).

a guideline for what values are appropriate in specific roles (direct/indirect). Once again, this does not mean that goals will never be in conflict or that using the KAUVIS guarantees that the right goals (or values) are used, but at least by elucidating our values as opposed to obscuring their relationships, we have a chance to resolve disagreements that may occur. Therefore, the ADP and its focus on risk can provide a framework for discussing values in science that can benefit from the details provided by the KAUVIS.

4.5 Chapter Conclusion

In conclusion, the consensus view and deficit model have been shown to be unable to adapt to the VFI alternatives of Douglas, Elliott, Steel and Whyte, and Kourany. This adds to the inadequacy of these information transmission models but now in terms of describing values in science. From the VFI alternatives, I selected **k**ey **a**spects for **u**nderstanding **v**alues **i**n **s**cience, calling them the KAUVIS. The KAUVIS is composed of Douglas' direct/indirect role distinction (without the restriction on non-epistemic values), Elliott's notion of goal-setting, Steel and Whyte's emphasis on transparency, and Kourany's reflection on the epistemic and ethical values of society. These components were selected because they offer scientists and publics the tools they need to describe values in science, while allowing them to make their own conclusions about which values are desirable in science. In order to accommodate the KAUVIS and move away from decontextualizing communication models, contextualized information transmission models were reviewed in response to this focus on values. I considered the Dialogue model and Public Participation model as value-conscious information transmission models, but knowing that values are especially relevant in relation to risk, the Analytic Deliberative Process (ADP) was also examined. The Dialogue model mandates bidirectional communication between publics and scientists but only by permitting publics to ask questions and forbidding their contributions to science. By allowing publics to ask questions, yet preventing them from contributing to scientific knowledge (or assess values in science), the Dialogue model misses out on publics as knowers. To recognize the potential epistemic abilities of publics, the Public Participation model permits publics' input on science agendas and assigning meaning to research. The KAUVIS can further engagement here by elucidating the influence of values in and towards science. But, the Public Participation model can struggle to communicate complex topics such as risk.

As a type of Public Participation model, the ADP invites publics to learn about and reflect on appropriate thresholds for risk, a particularly value-rich topic. Once again, by expanding the ADP to explicitly describe values using the KAUVIS, I have shown how a more holistic account of risk can be developed. Hence, with the KAUVIS I have selected both what stakeholders need to know about values (role, goal, and social reflection), and a way to express them (transparently), that work best with contextualized communication models that are bidirectional and value-conscious. Since value-conscious models of communication and the KAUVIS rely on contextualization, in the next chapter I conclude by contextualizing the KAUVIS itself in democracy.

Chapter 5

Implications for the KAUVIS in Democracy

Throughout this work, I have emphasized how publics can arrive at a more accurate understanding of science if it is described as value-laden and contextualized. In light of this, I developed the KAUVIS (see section 4.2) – a means to describe key aspects for understanding values in science based on a direct/indirect role distinction for values, framed by research goals, that expect ethical and epistemic values to both be accounted for, and requires transparency. Using the KAUVIS to describe values in science serves to contextualize science, making it more memorable, relatable and better representative of science than presenting science as value-free. Looking to the KAUVIS to describe how values are integrated into science has led us to the Public Participation model of science communication (and the ADP as an especially value-conscious option). Within value-conscious models like these, the KAUVIS can enrich communications about science by providing scientists, communicators and publics a framework with which to describe values in science. But, even these value-conscious models operate within larger value-laden frameworks like institutions, societies, and political systems.

In this final chapter, I contextualize the KAUVIS itself in democracy and show how this connects to decision-making in society. First, I explore how 'good' decision-making can come about with the KAUVIS, which as outlined by Dietz (2013), is construed as well-informed decision-making. I argue that part of being well-informed involves having an appreciation of values in science which the KAUVIS can help to establish. Starting with Dietz makes sense given the purpose of the KAUVIS is to describe values in science for communication, and Dietz explicitly calls attention to the need for values in transmissions about science. But, so as not to suggest that simply describing values in science is the only proposed solution to being well-informed, I also examine Drummond and Fischhoff's (2015) scientific reasoning skills and

Scientific Reasoning Scale. Their approach relies on transmitting information about the processes of science which is itself a departure from communicating the findings of science under models like the consensus view (see section 3.2.3). Like with Dietz, I will show that Drummond and Fischhoff's proposal requires publics to have an appreciation of values in science. Hence, I will show that the KAUVIS can further develop the scientific reasoning skills and benefit the Scientific Reasoning Scale. The inclusion of the KAUVIS expands on what it means to be well-informed by transforming scientific reasoning skills from a teaching of methods to an understanding of scientists' motivations.

Afterwards, in recognizing that not all decision-making environments are the same, I explain how the KAUVIS can be integrated into direct, representative, and deliberative democracies to help publics engage with science in their civic lives. Lastly, to reflect on what (if anything) is lost by adopting a value-conscious approach to science, I investigate what this means for scientific knowledge as a basis for discourse. I broach this area of future research by reviewing two examples of what publics are traditionally expected to know to engage with science: Du Bois' motivations for minimizing values in scientific knowledge, and Rawls' common understandings or 'laws of human psychology' behind the 'veil of ignorance'. In response to Du Bois who aims to foster trust in science, I suggest his proposal generates a tension in terms of how diverse (value-rich) publics are intended to engage with science that has been misrepresented as value-free. Then for Rawls, who requires publics to use information for moral decision-making, I challenge whether it is possible to act morally without being aware of the values embedded in the basis of knowledge. Hence, in either case a framework for describing values can help these proposals elucidate values. However, I acknowledge that further research is needed here as elucidating values in science can lead to varied starting points for discussions about science - though at least with the KAUVIS we can be aware of how values might be contributing to this disagreement. I conclude by recapping how I came to develop the KAUVIS in response to the decontextualization inherent in the VFI, science education and science communication, with hopes that going forward, science is presented more value-consciously.

5.1 Good Decision-Making

The decision-making capabilities of publics are an integral part of a well functioning democracy. However, there are different accounts of what it means to make a ‘good’ decision, and what information is required to do so. Thomas Dietz (2013) proposes that to make a good decision, publics must be well-informed. As values are an integral part of science, knowing about values in science is required for being well-informed. Hence, Dietz (2013) argues that values in science should be a part of communications about science. Although, Dietz does not elaborate on how to describe values which is why the KAUVIS can help. Other scholars like Drummond and Fischhoff (2015) focus less on the traditional information found in transmissions about science and instead argue for communicating the methods of science as more useful for publics to engage with science. But, here I will once again show that what is needed is a means to describe values in science which the KAUVIS can elucidate. In both cases, the KAUVIS will be shown to help deliver the objectives of the authors in ways that can strengthen publics’ understanding of science and the potential for engagement with science.

5.1.1 Dietz’s Good Decision-Making

Collective decisions are aggregated individual decisions, thus by supporting individual ‘good’ decision-making, we can encourage collective ‘good’ decision-making.[1] According to Dietz (2013), 'good' decision-making (using science) relies on being well-informed. For a decision to be well-informed, the decision must be factually competent, value-competent and adaptive to change (Dietz, 2013). Factual competence depends on how accurately our understanding of science describes phenomena. To be value-competent means considering how values relate to the interpretation science. Lastly, adaptiveness is how flexible or open to change decision-making is based on available information and relevant values. Hence, in this section I review these three elements of being well-informed to show how adding an understanding of values using the KAUVIS can better inform publics for good decision-making. The description of values provided by the KAUVIS, I will afterwards show to aid decision-making in democracies.

As it stands, science is the most reliable means for knowing about the world. Therefore, science's predictions contribute heavily to knowledge by allowing publics to imagine what might happen if one decision is made over

[1]Scholars can also describe the relationship between individual and collective decision-making more elaborately. Longino (1990, p. 79) for instance, challenges whether collective decisions are more than aggregated individual decisions because they can rise out of discourse (also see Longino (2008, p. 242)). But, whether a simple aggregate or complex/emergent account of decision-making is used, what matters for this discussion is what publics need to know about values and this applies to either arrangement.

another. The predictions of publics depend upon their knowledge of how the world works, and this understanding of the world forms the basis for publics being factually competent (Dietz, 2013). Dietz argues that when we attempt to make well-informed decisions, we should consider our factual competence in conjunction with our values. For example, factual competence depends on information that has met certain thresholds. If research does not meet certain thresholds, we should not assume it to be reliable and therefore less important to our understanding of the world. Scientists use values to determine thresholds for acceptable evidence and how much evidence is required. In which case, the KAUVIS can facilitate describing values that contribute to thresholds of evidence by describing the roles values take on, how they relate to research goals, and if these values are both epistemically and ethically sound with regard to social interests. Thus, we can improve publics' factual competence by providing a richer value-laden account of science based on the KAUVIS.

Dietz's second requirement for good decision-making is value-competence. Value-competence is based on the epistemic and non-epistemic values used by publics and of all the elements of well-informed decision-making, being value-competent has the most evident connection to the KAUVIS. The values of publics influence their interpretation of science, including values in science. The least that can be done to promote value-competence is to provide publics with an explicit account of values in science so their interpretation of science relies on a more accurate account of science. Without being explicit about values in science, and ignoring how this can influence publics' interpretation and acceptance of certain scientific findings (e.g. theories of gravity) and not others (e.g. anthropocentric climate change), we will continue to struggle to comprehend publics' understanding of science. Hence, the KAUVIS can help ensure that when publics use their values to engage with science, they at least have a value-conscious account of science to rely on.

To understand the relationship between values and decision-making Dietz writes, "Science can help us achieve value competence by informing us about what values people bring to a decision and how the decision process itself facilitates or impedes cooperation or conflict." (Dietz, 2013, p.14082). Even though Dietz recognizes that values are a well-developed and researched concept in the social sciences, he maintains that science is capable of uncovering the values publics hold if they continue to benefit from adaptive social learning. For

Dietz, social learning is our ability to learn from direct experience, observation and engagement in conversation, which he emphasizes science studies best (Dietz, 2013, p.14081). However, I challenge whether science in its current decontextualized form is really able to help us achieve value competence and embrace social learning if science is encouraged to deny non-epistemic values under the VFI (throughout the context of justification).

To remind us of just how relevant values are to public understanding and uptake of science in terms of value-competence, take Corner et al.'s (2014) review of the literature around values and climate change. Publics that distrust the scientific consensus about anthropocentric climate change tend to do so because they prioritize 'self-enhancement' values like power and ambition, over 'self-transcendent' values such as loyalty and altruism. Self-transcendent values generally tend to lead to publics being more likely to believe the scientific consensus (Whitmarsh, 2011), report concern about climate change risks (Demski, Poortinga & Pidgeon, 2014; Poortinga, Spence, Whitmarsh, Capstick & Pidgeon, 2011), and support policy changes to mitigate climate change (Dietz, Dan & Shwom, 2007). Knowing that publics can have these attitudes towards science, communicators using the KAUVIS can stress the role and goals of values in science based on the interests of publics.[2] This is not the same as manipulating publics with information, but rather shifting the thematic focus of the information to align with either self-enhancing or self-transcending values to improve publics' uptake of science. In practice, this might mean stressing the long-term economic gains of switching to green energies instead of assuming publics are motivated by environmental concerns alone (Kahan, Jenkins-Smith & Braman, 2011). But scientists and science communicators in their traditional value-free approach might struggle to recognize values like altruism or ambition as relevant which appear crucial to 'informing us about what values people bring to a decision'. Hence, with value-competence as an element of good decision-making, we need frameworks like the KAUVIS to describe values in science and explore how they relate to decision-making.

Dietz's third and final aspect of being well-informed is an appreciation that information is adaptive or open to change. If new data is found to be in conflict with our pre-existing theories, and proves to be a genuine case of a phenomena that cannot be accounted for, then science is able to alter its hypotheses to

[2]This is similar to the push to change transmissions about vaccines from a public deficit assumption to a dialogue-based communication model centred around constructive discourse (see section 4.4.1).

better represent the world (Dietz, 2013). Likewise, for publics to be adaptive, their knowledge of science must too be revisable. According to Dietz, science can play a role in monitoring how information changes by helping us, "...assess uncertainty about facts and values, properly take account of uncertainty in weighing alternatives, and monitor change over time." (Dietz, 2013, p. 14082) However, to assess uncertainty we need a means to describe the values that go into determining what amount of uncertainty is acceptable, which science under the VFI is unlikely to provide. The KAUVIS, on the other hand, can help illustrate the values scientists and publics use to navigate uncertainty in order to create a more adaptive account of science.[3]

In summary, if the aim of transmitting information is to facilitate good decision-making, then we need well-informed publics. Well-informed publics are in a better position to engage in personal and civic decision-making. According to Dietz (2013), well-informed publics utilize science that is factually competent, value competent, and understand that scientific information is adaptive. Factually competent information must be determined using thresholds of evidence, which incorporate values that the KAUVIS can help disclose.

[3]The KAUVIS can be even more effective here when coupled with a bidirectional communication model like the public participation model (or ADP), because these models are amenable to accounting for how values evolve over time (National Research Council, 1996).

Value-competence is based on the values used by publics to evaluate science which science under the VFI cannot account for but that the KAUVIS can help to describe. Finally, as science is adaptive, being well-informed requires publics to appreciate how science can change, which the KAUVIS can help to do by describing the values we use to navigate uncertainty. Thus, by recognizing that all three of these features of good decision-making are effectively value-laden, the KAUVIS can compliment Dietz's account of being well-informed by giving publics and scientists the language to describe values in science for a more comprehensive account of science.

5.1.2 Drummond and Fischhoff's Scientific Reasoning Skills

Besides Dietz defining good decision-making as being well-informed enough to make choices that are fact/value competent and adaptable to change, there are those who believe that good decision-making using science comes from understanding important concepts and methods in science. One such account is Drummond and Fischhoff's (2015) scientific reasoning skills to help publics grasp and interpret scientific explanations. Drawing on the philosophy and methodology of science to inform their normative analysis, the authors assemble scientific reasoning terms based on a survey of concepts in methods textbooks that present these terms as a guide for doing quality research.[4] The terms/methods selected are: blind/double-blind controls, causality, confounding variables, construct validity, control groups, ecological validity, history, maturation, random assignment to condition, reliability and response bias. The authors believe that scientific reasoning skills can help clarify whether people who reject the scientific consensus are actually able to assess the quality of the evidence, or whether publics' interpretations of such evidence is problematically biased – preventing them from using good science appropriately.

Consider the following scientific reasoning skills which are often used together in research: random assignment to condition, confounding variables, control groups and double-blind testing. Random assignment to condition is when researchers assign subjects to different experimental test groups based on chance (one of which being the control group). The control group is made up of

[4]Drummond and Fischhoff (2015) source the Cochrane Group (endorsed by the Agency for Healthcare Research and Quality) (Barkhordarian et al., 2013) and the Numeral Unit Spread Assessment Pedigree criteria for evaluating the strength of sciences (Funtowicz & Ravetz, 1990; Fischhoff & Davis, 2014).

participants that do not undergo test conditions to compare the test group(s) to. The purpose of the random assignment is to make sure that subjects have an equal chance of being in the group(s) (Jüni, Altman & Egger, 2001), and to equally distribute possible confounding variables. Confounding variables are aspects of an experiment that may inadvertently affect the experiment. Such methods are commonly used in drug trials where participants are randomly assigned to groups and given either placebo treatments or the actual test drug. Citizens that understand random assignment, confounding variables, and control groups are thus more likely to comprehend medicinal trials that use them, which can be helpful when faced with the decision of participating in such trials, or deciding to use products tested with these methods.

A closer look at the scientific reasoning skills reveals that many of them have been developed to minimize bias in science. For example, random assignment to condition relies on chance to reduce the risk that researchers sort participants into group(s) based on biases. Furthermore, values can contribute to bias (Wilholt, 2009), but not all values lead to biases, so knowing which values are at play is important. Techniques such as blinding can minimize bias, but these techniques do not necessarily 'fix' science and make it bias-free, nor do such techniques address values underlying bias. Values generate biases and as such, are worth communicating to ensure that publics understand the motivations behind methodology. Thus, by stressing methods that attempt to decrease bias in science, there is a hidden account of values that form part of the scientific reasoning skills which ought to be described.

To clarify, this is not to say that Drummond and Fischhoff have selected the wrong skills, or that they are lacking others, but my criticism is that an account of values should be included no matter which skills they select. To show how a description of values could enhance the scientific reasoning skills, take a group of industry scientists in a herbicide safety experiment. Imagine the scientists select problematic experimental and control groups (e.g. by using species known to be unreceptive to components of the herbicide) – that risks skewing research results. In this case, publics might know what test and control groups are, but without considering the potential motivating interests/values of scientists in selecting species for the control group (e.g. to make the herbicide seem harmless in certain species), they may not question the methodology of the experiment. However, publics who use the KAUVIS in conjunction with scientific reasoning skills to explore the goals of the scientists are advantaged by understanding how values can motivate science. Thus, publics need an understanding of values in science to truly appreciate the scientific reasoning skills which the KAUVIS can help to establish.

In addition to proposing the scientific reasoning skills, Drummond and Fischhoff (2015) also develop the Scientific Reasoning Scale. The authors craft the Scientific Reasoning Scale based on literature from the philosophy of science, public understanding of science, and psychology research to measure publics' scientific reasoning skills (Drummond & Fischhoff, 2015). First, the scale uses the philosophy of science to select what skills are required to evaluate science. Second, the public understanding of science literature leads to several useful skills assessed by science literacy testing. Third, cognitive developmental psychology aids by discerning how publics learn to 'think like scientists' (Drummond & Fischhoff, 2015). In sum, by requiring participants to apply their reasoning skills (determined using the philosophy of science) to analyze evidence (as with cognitive developmental research) which is then evaluated through the use of surveys (found in the public understanding of science), the authors aim to assess convergent, divergent and predictive validity in terms of education, numeracy, cognitive reflection ability, and openmindedness (Drummond & Fischhoff, 2015).

Perhaps most promising about the Scientific Reasoning Scale, is that it appears better able to predict agreement with scientific consensuses than other widely used measures of science literacy (Drummond & Fischhoff, 2015). However, Drummond and Fischhoff note that 'belief bias' – or the degree to which participants offered arguments for their positions – remains troublesome to assess because sources of disbelief may be unrelated to scientific reasoning abilities (Drummond & Fischhoff, 2015; Fiske & Dupree, 2014).

One possible response to 'belief bias' might be to use the KAUVIS to compliment the scale by uncovering how perceived values latent in science can influence scientific reasoning abilities. For example, by giving researchers and publics the conceptual language of the KAUVIS to elucidate values in science, questions can be added to the survey to prompt considerations of self-transcendence (altruism) or self-enhancement (personal power) in order to uncover how personal values and belief bias relate to values in science. In so doing, the Scientific Reasoning Scale with the addition of the KAUVIS, can offer a more comprehensive understanding of why dis/agreement with scientific consensuses occurs, specifically as it relates to values.

In summary, alternative ways of promoting well-informed decision-making through learning scientific reasoning skills relies on values in science. Though scientific reasoning skills promote an understanding of several techniques used to minimize bias in science, these biases stem in part from values in science. Therefore, a tool like the KAUVIS can compliment the scientific reasoning skills by describing how values in science relate to biases in science. Knowing how values can become embedded in the methods of science, generates a fuller view of science. This richer account of science can then be utilized for well-informed decision-making, and in instances where publics disagree with scientific consensus, the KAUVIS can be coupled with the Scientific Reasoning Scale to help decipher why.

5.2 The KAUVIS in Democracy

To cultivate good decision-making in democracies that use science, Dietz considers what publics need to be well-informed whereas Drummond and Fischhoff offer the scientific reasoning skills as what publics require. Yet, there appears to be a paradox with regard to democracy in that those who do not have democracy, want it, but those that have democracy, seem disillusioned with it

(Giddens, 1999). In support of this, others have found that publics in western pillars of democracy have grown increasingly skeptical of politicians, government institutions and the fairness of the democratic process (see Bohman (2000, p. 175) and Gershtenson and Plane (2015)). Furthermore, according to Durant (1999), a similar analogy can be drawn to science. Those that do not have much scientific development are desperate for more, and those that have it in abundance, are becoming increasingly skeptical. Part of the reason for the skepticism around science is believed to be because publics want more from scientists and political institutions, such as a better understanding of scientists' motivations, actions and justifications (J. Durant, 1999).

As a result of this skepticism (and an increase in overall education levels), publics are becoming more interested in science, causing them to search out more information and become more politically active (Dalton, 2015). Publics can take part in political decisions by being politically active (via voting and public polls), but the fear remains that if publics lack reliable information, besides facilitating misinformed 'bad' decision-making, unreliable information can also breed alienation and extremism (J. D. Miller, 1998) which can have serious negative effects on democracy (Aly, Taylor & Karnovsky, 2014; Vermeulen, 2014).

This section contextualizes the KAUVIS in terms of how it can enhance direct, representative and deliberative democracies. Direct democracy is when publics vote on policy decisions themselves, representative democracy relies on spokespeople who vote on behalf of publics, and deliberative democracy utilizes open discussions for decision-making. Through comparison of how the KAUVIS can be integrated into these democratic forms, deliberative democracy will be shown to be the most fertile terrain for discourse around values for well-informed decision-making.

5.2.1 Direct Democracy

Direct democracy is a broad term covering various political processes allowing publics to vote directly on issues, as opposed to voting candidates into office to act on their behalf (representative democracy). The most popular version of direct democracy uses ballot measures or propositions, where publics vote yes or no on issues such as physician-assisted suicide, medical marijuana, abortion, and tax cuts (Matsusaka, 2005). Final approval can be determined by a majority vote of the electorate, a supermajority vote (e.g. a two-thirds vote), or a majority with quorum. Once approved, decisions can be amended using a referendum/vote or through subsequent alterations by elected representatives.

Given its ability to allow publics to directly impact policy decisions, and perhaps abate some of the skepticism around democracy, the use of direct democracy is growing worldwide (Altman, 2017). Within the last several decades, the proportion of Americans that either live in a state or a city where the tools of direct democracy are available has risen to 70% (Matsusaka, 2004).[5] Furthermore, Switzerland, Italy, Liechtenstein and San Marino similarly show very high levels of direct democratic activity (Altman, 2017). In Latin America, Uruguay is a notable standout, along with Ecuador, and Venezuela further south. In Eastern Europe and Central Asia, Azerbaijan and Belarus also show high levels of direct democratic engagement. And further East, Taiwan has used direct democracy referendums for years (e.g. the 'Peace Referendum' with China) (Hwang, 2005; Matsusaka, 2005).[6]

Part of what allows publics to channel their broad skepticism around democracy to engage in it directly are improvements to communication technology

[5]The first state to adopt using direct democracy for certain issues was South Dakota in 1898. Since World War II, about one state per decade has decided to adopt direct democracy, and no state has done away with using it (Matsusaka, 2005).

[6]In contrast, Germany used to have an open environment for direct democracy which it no longer does after the fall of the third reich (Altman, 2017).

(Morris, 2001). The internet has given unprecedented access to information and a heightened desire to participate in policy decisions (Matsusaka, 2005). However, there is the concern that publics may not have the attention span necessary to decide on complex policy matters, and as a result, could be manipulated into passing harmful laws (Matsusaka, 2005).

On how values in decision-making get taken-up in direct democracies, Bowler writes, " ...choices often appear consistent with the interests and values of the voters, and they reflect a responsiveness to the available information sources." (S. Bowler & Donovan, 1998, p. 1) This means the choices publics make are usually done with the information they have access to and in reflection of their values and interests. As such, we ought to make sure publics have reliable value-conscious information in order to ensure that they have a realistic account of science, and one that is of interest to them. Knowing that contextualized information is more readily retained (Fessenden-Raden et al., 1987; Council et al., 2000; Passmore et al., 2014), and that publics will reflect on their own values in relation to science, I propose that the KAUVIS can be useful in direct democracies to help capture the interest of publics and provide them with a more accurate account of science to be well-informed for direct participation in democracy. For example, publics should be able to describe which values (e.g. empathy, dignity) they want to prioritize when voting on if doctor-assisted suicide should be legalized which the KAUVIS can be used to outline. Hence, the added structure the KAUVIS can help clarify content in decision-making in direct democracies where publics rely primarily on their own understanding.

5.2.2 Representative Democracy

The relationship between representation and democratization is a marriage of convenience intended to improve the effectiveness and legitimacy of government (Alonso, Keane & Merkel, 2011). Representative democracy is an indirect form of democracy where representatives hold the voting power of publics. To prevent publics from being ruled arbitrarily, the size of publics serve as a source of power that manifests in the form of representatives chosen to act on their behalf (Sager & Bühlmann, 2009). Lastly, representatives are accountable to publics through periodic elections (Maravall & Sánchez-Cuenca, 2008, p. i), providing more pragmatic justification for representation overall (Alonso et al., 2011).

In more detail, Goodin (2008, p. 194) writes that there are four stages of representative democracy. First, members of a single party plan their program. Second, debates are held where representatives from all parties publicly present their programs in relation to other positions. Third, an election campaign occurs where candidates compete for office based on the policy positions of their parties. Lastly, election party leaders negotiate policy based on the number of elected representatives per party. But provided these stages, it is hard to know how and where science should be involved - in party programs? Policy negotiations? Everywhere, or only selectively? According to Brown (2009, p. 235), the challenge of locating science in representative democracy comes from the diversity of publics that require representation. I will show that when considering the diversity of publics, like with direct democracy, we must be aware that publics will go into decision-making using the information they have at their immediate disposal and reflect on decisions in relation to their interests. This means that the diverse values of publics will inevitably play a part in representative democracy, providing a need to describe values in science which the KAUVIS will be shown to provide.

Liberal Democracy

Representing diverse publics is a focal point of liberal democracy,[7] a form of representative democracy (though it can sometimes use direct democracy tools (Lupia & Matsusaka, 2004)). Based on the pursuit of, "...material prosperity, maintenance of civil peace, respect for liberty, and the just distribution of wealth and privilege..." (Callan, 1997, p. 1), liberal democracy fragments traditionally associated publics by grouping them into additional categories (e.g. based on socio-economic status). It also assumes knowledge of science and technology to partially define publics' diversity, recognizing them as relevant factors for decision-making (M. B. Brown, 2009). As a result of this fragmentation, calls for the democratization of science are often aimed at increasing the quantity of (diverse) public engagement with science, as opposed to addressing criticisms over the quality of engagement, of which values in science fall under. This generates an oversight with respect to the type of information provided to publics, easily allowing information to continue to be misrepresented as value-free.

[7] Though I will not engage with the many forms of liberal democracy any deeper here, among the most popular models are the majority system (where the preference with the most support is adopted as the common preference) and the pluralist system (where amount of participant influence is proportional to interest in the decision) (D. Miller, 1992).

Current liberal theories as they relate to science draw heavily on John Dewey's (1946) important work highlighting the bidirectional relationships between individualism and liberal, realist, and elitist theories of representative government. Brown (2009) summaries Dewey by outlining two major features of liberal theories of representation. First, there is the assumption that individuals have the required capacity to engage intelligently in politics. Second, it is assumed that frequent elections, general suffrage and majority rule suffice to ensure that elected officials act responsibly. These requirements feed into liberal democracy's notion of rights to political participation, freedom of expression, religion, and equality before the courts (Callan, 1997).

To show how values can come into play in representative democracies like liberal democracy, consider the formation of a legislative assembly. One way a legislative assembly can represent popular preference is in terms of values. Representatives can exercise value-judgements based on their own views (as publics selected them for their judgement); follow public opinion polls on values; or act in line with party values. Hence, if politicians are going to represent the values of publics and act with respect to publics' values, politicians ought to be able to articulate which values they prioritize and in what capacity.

Furthermore, the institution of elected representatives is believed to symbolize the will of the people and act as a safeguard against corruption. For this to occur, publics must vocalize how they want values to be used, and politicians must reveal how they use values in decision-making. For example, if a politician is known to regularly support legislation that benefits plastics manufacturers because this politician values short-term economic growth over long-term environmental concerns, they should say as much. If the values of politicians (like short-term economic gain) align with those of publics, publics can continue to support their representatives. But to remove unwanted values, publics can also vote for a change once the politician is up for re-election (or perhaps even sooner in extenuating circumstances).

In line with the assumption that publics must be able to engage intelligently with politics, Callan (1997) explains that liberal democracy requires a special type of education in order for it to be successful - I simply add that part of this education should include an appreciation for values in science instead of an abstraction from them. The KAUVIS has been designed to describe values in science in order to help publics and politicians recognize values in science when using it for decision-making. Plus, in the same way that contextualizing information makes it more readily retainable (Passmore et al., 2014; Council et al., 2000; Fessenden-Raden et al., 1987), having a description of how values are integrated into science-informed policy-making may provide publics greater motivation to participate in democracy and be well-informed while doing so. Thus, with the KAUVIS providing a way to describe values in science, publics have a richer means to articulate the sort of science they want their representatives to seek out.

Overall, representative democracy is intended to account for the preferences (and values) of publics through elected representatives. As a consequence, we need a manner to describe values in science for publics to articulate the sort of science they want, and for assembly members to justify decision-making that relies on science. This is why it is important to have frameworks like the KAUVIS to elucidate values in science and ensure that desirable values get taken-up in decision-making, or else risk not truly accounting for the desires of publics representative democracy is designed to depict.

5.2.3 Deliberative Democracy

As an alternative to aggregating individual preferences, a common agreement among preferences can be searched out via deliberation. Deliberation is powerful because it can help individuals acquire new information, order preferences, and allows for reflexivity (response and adaptation) (Benhabib, 1998; Einsiedel, 2008). Deliberative democracy begins with the assumption that political desires will conflict so it is up to institutions to resolve this and find agreeable solutions based on epistemic and ethical concerns with respect to political expertise (D. Miller, 1992). These deliberative discussions are intended to be purposefully open and un-coerced (D. Miller, 1992), but demand that publics have reasons for the claims they support. For example, a simple 'Group X should get financial support' sans further explanation will not suffice (especially if the person arguing for it is a member of that group). Hence, deliberative democracy stresses the need for justified reasoning.

Tacit in the justified reasoning component of deliberative democracy is the expectation that publics will be willing to modify their initial positions after taking into account the viewpoints of others. How quickly publics are convinced depends in part on the strength of reasons given by others, rhetorical persuasiveness, how deliberations are structured, prior values, and other conditional probabilities in a Bayesian sense (Goodin, 2008).[8] Miller describes this expectation of publics as,

> "...I am committing myself to a general principle, which by implication applies to any other similarly placed group. Thus I am forced to take a wider view, and either defend the claim I am making when applied not only to my group but to groups B, C and D, which are like A in the relevant respects, or else to back down and moderate the claim to something I am prepared to accept in these other cases too..." (D. Miller, 1992, pg. 55)

This means that publics who accept or reject claims for themselves must be willing to do the same for others. Perhaps, this is a hyper-idealized account of rationality and openness (Dietz, Fitzgerald & Shwom, 2005; Millar, 1996), but by the end of the deliberation, publics are expected to decide on the policy that best meets the claims advanced or the most fair compromise that is still beneficial (D. Miller, 1992). Thus compared to liberal democracy, deliberative democracy is more concerned with generating conversations and allowing people to be swayed by rational arguments for the sake of overall fairness than aggregating preferences.

[8] This is reminiscent of the adaptability described by Dietz (2013) for being well-informed.

Publics acting in a deliberative democracy ideally come prepared to engage with science and each other. However, given generally low levels of science literacy, concern over public understanding of science, and the chance of a lack of interest, publics may have difficulty articulating their concerns in decision-making. For example, when deciding on policy, publics may struggle to justify why animal testing is permissible in some instances and not others, especially as it is a heavily value-laden issue (Lund, Lassen & Sandøe, 2012; Saucier & Cain, 2006). Lupia (1994) notes that in cases like these, the positions of publics' can end up determined by cognitive shortcuts, such as adopting the decisions of others with similar attitudes and values. Though it is not necessarily a negative thing to utilize shortcuts, if the shortcuts publics take involve misinformation (of the sort that has been traditionally communicated under the guise of decontextualization), then publics risk being misguided. Hence, if publics end up relying on alternate means to come to a decision, we should at least provide them tools to describe the values in science they intend their shortcuts to ultimately reflect.

In sum, deliberative democracy is unique in that it brings publics together under the possibility of compromise based on justified reasoning. Hence an important part of deliberative democracy is being able to articulate one's reasoning, requiring the ability to describe values. Realistically, even if publics do not actively deliberate, and take shortcuts by deferring to others, they still need a means to recognize and describe values in science to best select whose views to defer to. Thus, in either case, publics need to be able to describe values in science to effectively deliberate and make decisions (even of deferral) about science, providing further reason for the KAUVIS.

Comparing and Concluding on Democracy

Now that I have reviewed the defining characteristics of direct, representative and deliberative democracies, it is worth comparing the potential contributions of the KAUVIS to each. In a direct democracy, publics are able to vote on policy issues, meaning that they rely heavily on their own understanding of science. Appreciating the role of values in science, as part of understanding science, is important to making informed decisions and so, the KAUVIS can help with crafting these descriptions. In representative democracies publics use their voting power to elect officials to make decisions on their behalf. Knowing about values in science here in great detail might not be as important as being able to articulate which values publics want representatives to prioritize when using science for decision-making, so the KAUVIS can be used here as well. Lastly, in deliberative democracy where publics come together to find mutually agreeable solutions, publics are required to vocalize the justification for their choices which also likely involves values. By forcing publics and decision-makers to provide justification for their decisions, the KAUVIS can help search out value-conscious solutions for cooperative compromise. Thus, publics ought to be able to describe values in science whether for their own understanding or for expressing the sort of science they want politicians to use for decision-making which the KAUVIS can enhance.

5.3 Values in Science for Public Debate

My goal for developing the KAUVIS was to lay out a means for scientists, communicators, politicians and publics to describe values for a richer account of science. By emphasizing descriptions of values through the KAUVIS, I have destabilized the tradition of using 'value-free' scientific knowledge - or knowledge thought to be good regardless of values - as a starting point for public discussions about science. Under my account of value-conscious science, values in science are taken as an integral and contextualizing feature of scientific knowledge. As such, when engaging with science for personal or civic reasons, an appreciation of values is required. However, in knowing that values in science might influence publics' uptake of science, it is worth asking, "what, if anything, is lost by expanding our account of scientific knowledge to include values?"

The many possible implications for altering the role for scientific knowledge by contextualizing it with values extends beyond the scope of this work, but to outline where to begin, I examine Du Bois' suggestion of starting with the VFI for scientific knowledge and Rawls' idea of agreed upon facts for moral reasoning. I will review how in each case, accepting that values are present in science (as a basis for information) generates a more realistic account of scientific knowledge, thereby providing reason to use tools like the KAUVIS to describe values. I conclude with hopes that the future of science can become a value-conscious one, wherein the values of publics and scientists guide science in service of discovery and society.

5.3.1 Du Bois' scientific knowledge

In Chapter 2, I covered literature on the VFI, including its major challenges and alternatives. Yet, there is one particularly well-motivated argument that I intentionally left out: Du Bois' support of the VFI. Du Bois' view is grounded in using a 'value-free' basis of scientific knowledge to foster public trust in science and ensure that those in decision-making positions are well-informed (Du Bois, 1898). In line with the VFI, Du Bois argues that scientific knowledge should be free of non-epistemic values in two ways - one justificatory and the other normative-psychological.

The justificatory argument is that scientists should be discouraged from taking into account non-epistemic values when determining what can be justifiably asserted from research for fear that non-epistemic values may skew the interpretation of evidence for policy-making (Bright, 2018).[9] But, as biases can still creep into research that uses epistemic values (the descriptive challenge), a concise list of epistemic/non-epistemic values cannot be item-

[9] Douglas' role for values grows from the same concern as Du Bois. However, the authors differ in that Douglas (2009, 2016) believes that scientists should state their interpretations of evidence and are qualified to make value-judgements (on the basis of their own expertise regarding the consequences of error), whereas Du Bois does not think scientists should be responsible for interpreting evidence.

ized (the boundary challenge), and in some instances we might want to use non-epistemic values (the normative challenge) - the justificatory point fails.

The normative-psychological argument suggests that when scientists engage in their work, they should only be motivated by a sense of curiosity and a desire to seek the truth (Bright, 2018). Without a pure desire to seek the truth, Du Bois worries scientists risk losing public trust in science (Bright, 2018). Ulterior goals such as social reform, according to Du Bois, would hinder scientific research and potentially even progress on issues trying to be reformed (Du Bois, 1898). However, in knowing from challenges to the VFI that there are inevitably non-epistemic values in science (some desirably so), it seems self-defeating not to include a truthful value-laden account of science when trying to foster public trust in science.

Compared to other VFI supporters (such as Jeffrey (1956) and Levi (1960)), Du Bois' account is special by inviting diverse publics to evaluate evidence. On this, Bright writes that Du Bois' defence of democracy is epistemically based, relying on the premise that decisions made through consultation with varied knowers will lead to better decisions than those which consult fewer people with less expertise (Bright, 2018). As such, Du Bois' VFI is socially situated (by emphasizing the need for diverse publics to evaluate science) without being value-conscious (by presenting science as 'value-free'). This mix of admitting and denying values produces a tension in terms of how Du Bois imagines publics to trust in science that has been misrepresented to them.

In further detail, the VFI account of science advanced by Du Bois intends that when publics go to make decisions using science, they start with value-free information. However, by urging diverse publics to engage with science, publics will inevitably come to science with varied understandings of values in science, including values towards science. This means that even if science were value-free, publics certainly are not. And, in knowing that publics' attitudes towards science influence agreement with scientific consensuses (Sturgis & Allum, 2004), presenting value-free scientific knowledge as a starting point is not only misrepresentative, but unhelpful to understanding how values in science impact publics' (value-laden) engagement with science. Of course by admitting that values play a crucial part in science, it leaves science open to criticism by publics who might disagree with values used in science (Evans & Durant, 1995; Kolstø, 2001), or with the values of other citizens (Kahan & Braman, 2006), but at least by acknowledging the presence of these values, we can attempt to navigate them.

Because of the importance of the VFI in Du Bois' approach, simply applying the KAUVIS here will not work. To clarify, the KAUVIS can be used to increase transparency in science by describing values in terms of the roles and goals they take on. The KAUVIS also recognizes the merit in considering social values through ethical and epistemic considerations as a relevant part of doing science. But this goes against Du Bois' idea of producing research independent of social agendas, even if Du Bois considers socially situated contributions from publics (Du Bois, 1898). Furthermore, scientists who interpret evidence and report it with the inclusion of values (even non-epistemic ones) may actually promote the truth more effectively than 'value-free' truth-seekers by nurturing public trust in science through being transparent about science (Bright, 2018). Therefore, Du Bois (like other VFI advocates) appears mistaken in trying to remove values from science because it is not necessarily values that publics do not trust, but perhaps undisclosed values that appear to be the problem.[10]

In conclusion, to ensure that policy-makers and publics have the best in-

[10] See footnote in section 4.4.1 on Goldenberg's work regarding publics' skepticism towards vaccination based on distrust of scientific experts and institutions but not necessarily science itself.

formation available for decision-making, Du Bois develops justificatory and normative points in support of the VFI. While on the surface Du Bois' position in support of the VFI may seem familiar, his reason for maintaining the ideal – to improve democracy – is connected to an appreciation for diverse publics that differentiates him from other VFI supporters. However, this creates tension by expecting value-laden publics to interact with 'value-free' science, even though publics' attitudes towards science are known to influence acceptance of science. Thus, Du Bois' 'value-free' scientific knowledge betrays its goal of promoting public trust in science by expecting value-laden publics to engage with science that has been misrepresented.

5.3.2 Rawls' scientific knowledge

For Rawls, consensus is comprised of individuals deciding for themselves. He writes, "...all are to decide, everyone taking counsel with himself, and with reasonableness, comity, and good fortune, it often works out well enough." (Rawls, 1971, p. 341). Rawls also believes publics need some appreciation of scientific knowledge (or common understandings as part of human psychology (Rawls, 1971, p.119)) behind the 'veil of ignorance' for an underlying principle of justice. The veil of ignorance is a thought experiment arguing that if someone did not know what their position in life were to be, they would be inclined to rely on moral considerations as opposed to self/class interests in decision-making. In some cases, moral considerations and the anticipation of their potential implications, requires an understanding of science. Of interest to us is the scientific knowledge publics need to form a basis for moral decision-making, and if values matter here.

Rawls describes the sort of value-free scientific knowledge publics should use behind the veil of ignorance with respect to liberty of conscious.[11] He explains that the expectation is that publics will use evidence and socially acceptable reasoning in their decision-making. In other words, decision-making, "...must be supported by ordinary observation and modes of thought (including the methods of rational scientific inquiry where these are not controversial) which are generally recognized as correct." (Rawls, 1971, p.187) But note the stress on uncontroversial science (similar to with the consensus view, see section 3.2.3), which must exclude at least some discussions of values (non-epistemic in particular). Hence, the type of science Rawls' appears to advocate

[11] Liberty of conscious falls under Rawls' idea of social justice and comprises of, "...the way in which the major social institutions distribute fundamental rights and duties and determine the division of advantages from social cooperation." (Rawls, 1971, p.6)

for using as a basis remains the traditional ‘value-free’ kind.

However, in knowing that morality has a direct connection to values in terms of how we view ourselves (Gunia, Wang, Huang, Wang & Murnighan, 2012; O‘Fallon & Butterfield, 2005; Krebs, Denton & Wark, 1997), basic scientific knowledge should include an account of values (including non-epistemic values) to connect science to publics’ morality. If values in science are hidden, publics are unable to fully use science for moral reasoning. For example, take the morally problematic research produced by the immensely value-laden human ‘physiology experiments’ conducted under the Nazi regime (Bogod, 2004; Seidelman, 1989), or the Tuskegee Syphilis study in the United States (S. B. Thomas & Quinn, 1991; Freimuth et al., 2001). In both cases, the value-provenance of this research is relevant to determining how information produced in these instances should be used (if at all). Therefore, values in research should be disclosed, especially if this information is intended to be part of our basis of understanding, because the quality of information can impact how publics interpret information and affect moral decision-making.

Including values in the common understandings behind the veil of ignorance does risk that from the outset, publics will disagree with science based on their values. However, there is already disagreement for many polarizing issues (e.g. climate change (Kahan et al., 2012), vaccinations (Goldenberg, 2016) and stem cell research (Allum et al., 2017)). Yet, at least with the KAUVIS, how values in science relate to moral decision-making can be discussed. Thus, further research is needed to investigate the relationship between using value-conscious information and moral decision-making. But, by realizing the importance of values through tools like the KAUVIS, we might be able to begin the inquiry into moral decision-making by providing a way to present values in science more transparently.

Conclusion

Overall, both Du Bois and Rawls' conceptions of the basic scientific knowledge (or common understandings) needed to engage with science raises the question of what about values in science publics need for decision-making using science. Du Bois in support of the VFI, creates tension by not acknowledging non-epistemic values in science, even though he recognizes the advantage of diverse publics evaluating science to facilitate publics' trust in science. Rawls, in his take on how publics act behind the veil of ignorance, assumes that publics will act morally, but to do so they require a familiarity with the values used to generate these common understandings. Hence, in both cases, publics are better equipped to make well-informed decisions if they know about how values permeate science, because values are an inescapable feature of science. This opens up the question of which values exactly publics need to be aware of and what, if anything, is lost by expanding our account of scientific knowledge to include values. Giving tools to scientists and publics to outline values in science risks additional controversy and disagreement erupting over science, but disagreement over values in science is already a part of science. Hence, the least we can do is be aware of the values contributing to it.

5.4 Chapter Conclusion

Within this chapter, I explored what it means to utilize a value-conscious approach to transmitting information about science within larger value-laden societies and political systems. First, I considered what it is for publics to make good decisions, which according to Dietz (2013) requires publics to be well-informed, and for Drummond and Fischhoff (2015), have an understanding of the methods of science. In either case, a description of values, provided by the KAUVIS, is needed to be fact/value competent or to understand the motivations behind science's methods (as linked to bias). Second, I reflected on how a value-conscious account of science might work in various types of democracies, finding a need for a description of values in direct, representative and deliberative democracies. Lastly, I imagined what implications there might be in dissolving the value-free basis of information for publics acting in democracies. While further research is needed here, I still found that even arguments for a value-free basis were at odds with a value-laden descriptions of publics (Du Bois, 1898) and the goal of moral reasoning (Rawls, 1971). Thus, there is a need to elucidate values in science and include these values in information transmitted to publics to foster a more accurate and engaging account of science.

5.5 From the Linear Model to Value-Conscious Democracies

Let us now return to the initial question, "How should we communicate values in science?" In Chapter 1, I began by describing the linear model for science policy as an introduction to the idea of decontextualization. Decontextualization is the separation of science from its social setting, and though this can be investigated in different ways, I focused on how undisclosed values in science remove science from society. I used criticisms of the linear model (misrepresentation and lack of public engagement) to outline the sort of decontextualization I later show to connect the value-free ideal (VFI), science education and science communication, causing them to remain in use despite well-established criticisms.

The VFI, or the idea that non-epistemic values should not play a role in the evaluation of evidence, was the focus of Chapter 2. I presented a summary of major criticisms to the ideal; namely the descriptive, boundary and normative challenges along with alternatives to the VFI. The alternatives are: (1) Douglas' direct/indirect role distinction for values which argues that non-epistemic values should not play a direct role in the evaluation of evidence; (2) Elliott's Multiple Goals Criterion that encourages publics to evaluate the goals of research in order to determine the most appropriate values to use, including the possibility that non-epistemic values play a direct role in the evaluation of evidence; (3) Steel and Whyte's values-in-science standard suggesting that non-epistemic values should be forbidden from taking priority over epistemic values in the evaluation of evidence - requiring scientists to be transparent; and (4) Kourany's emphasis on social needs preventing epistemic values from taking priority over ethical (non-epistemic) values and vice versa. All four alternatives to the VFI better represent science by recognizing the non-epistemic values involved but recommend different configurations for how these values ought to be accounted for.

In Chapter 3, I added to the literature by showing the VFI (motivated by decontextualization) has spread to extensions of science like science education and science communication. As science literacy is the goal of science education and communication, I began by reviewing definitions of science literacy that outlined it as the ability to critically engage with information about science based on an understanding of science. Public understanding of science is often described as knowledge of the nature of science (NOS). The NOS is comprised of the methods, findings and institutions which science is developed in. In science education, the focus of the NOS ends up being on the findings of science because of the degree of agreement around them. This narrowing of the NOS to science's findings is known as the consensus view. Since there remains debate about values in science (e.g. challenges to the VFI), information around values are not conveyed under the consensus view. In a similar value-obscuring fashion, the deficit model of science communication deems the values of publics not relevant to how they take-up information. The separation of science from society's values misrepresents science and deters science from truly captivating publics. Lastly, the VFI, consensus view and deficit model share a chronological trajectory resulting in popularity bursts and weakening criticisms occurring around similar times. Their common denial of values and chronological alignment have led me to conclude that the VFI, consensus view and deficit model are mutually reinforcing which has prevented individual criticisms of them from being successful at changing their popularity or the narrative of decontextualization.

In Chapter 4, I corrected the decontextualization reinforced by the VFI, science education, and science communication, by returning to descriptions of science that include values. From the four alternatives to the VFI, I curated key aspects for understanding values in science (the KAUVIS). The KAUVIS comprises of Douglas' role distinction; Elliott's focus on research goals; Steel and Whyte's need for transparency; and Kourany's view of science meeting epistemic and ethical standards. The purpose of the KAUVIS is to give publics and scientists tools to better understand and articulate how values can be involved in science – without dictating which values are the correct ones. The consensus view and deficit model were also shown to be unable to accommodate the KAUVIS, which forced me to look to new information transmission models that could accommodate values in science and engage publics. Beginning with discussions on contextualizing information in general, I considered two popular models: the Dialogue model and the Public Participation model (plus the particularly value-conscious Analytical Deliberative Process (ADP)). The KAUVIS works well with the Public Participation model and ADP because these models leave room to discuss values in science, where transparent conversations can be guided by research goals, the roles values take on, and what ethical and epistemic standards should be used.

As values in science form a part of decision-making, I ended my investigation of values in transmissions about science with implications for using the KAUVIS in democracies. Beginning with requirements for 'good' decision-making, I reviewed Dietz's account of being well-informed where publics should be fact/value competent and adaptable. To have these competencies, a means to describe values – like the KAUVIS – is required. Alternative accounts of being well-informed, such as Drummond and Fischhoff's scientific reasoning skills, focus on communicating the methods of science. However, for the motivations of these methods to be appreciated, a way to describe values in science is once again needed. I then reviewed direct, representative, and deliberative democracies to see how the KAUVIS might be applied in different democratic contexts. As these forms of democracy require personal reflection and social interaction, having a means to elucidate values becomes invaluable for understanding science and each another. The KAUVIS is thus able to describe values in science to help stakeholders understand values as they vote on issues directly, evaluate the science used by representatives in policy-making, default to someone else's opinion, and negotiate with others. However, explicitly incorporating a description of values into science opens up new questions such as, what (if anything) is lost by incorporating values into basic scientific knowledge? I initiate this investigation by laying out the limitations of a value-free basis of scientific knowledge, but found it to ultimately be misleading and maladapted for decision-making. Even though a value-conscious description of science risks publics' disagreements about values impacting how they engage science, a transparent account of this relationship is more helpful than the opacity at present. Thus, further implications of adopting the KAUVIS are worth investigating because by defining how values interact with science, we can enrich how we represent science for the publics science is intended to serve.

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