Uncertainty and Epistemic Cultures in the Endocrine Disruptor Expert Deliberation

by

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Abstract

As with other complex areas of scientific research, the risk assessment of endocrine-disruptors (EDs) involves significant uncertainty. An added complication is preliminary research suggests there are different 'Epistemic Cultures' present in the field – groups of scientists that, due to differing experimentation practices, framings, reasoning, and values, have divergent understandings of the problems at hand, and relatedly, different understandings of the uncertainty the field faces. This study aims to (1) take a first step towards 'mapping' the different understandings of uncertainty in the field and (2) evaluate if these differences provide further support for the proposed existence of different epistemic cultures in the ED scientific landscape. To do this, a methodology inspired by Parsons and Lavery's 'Brokered Dialogue' is employed, involving conducting uncertainty focused interviews with two scientists understood as being members of different epistemic cultures, and then showing the footage of each interview to the other scientist for response, before repeating the process for a third and final round of comments. The data is then analysed thematically, dialogically and narratively. This research technique reveals a number of interesting similarities and differences between the two participant scientists' understandings, most notably, a core narrative divergence in what part of the broader system they understand the uncertainty issues as stemming from. By this core divergence, it's concluded the results broadly support the existence of different epistemic cultures in the ED scientific landscape.

Lay Summary

Chemicals and substances that adversely interfere with people and animals hormonal systems, called Endocrine Disruptors (EDs), are increasingly present in the natural and human-made environments, they have also been linked to a number of significant human and natural health issues. However, in many instances, the science is far from settled and uncertainty is rife. Through developing a dialogue between experts, this study investigates how different expert groups understand the uncertainty present in their field. The findings support earlier studies that indicate different groups of scientists in the field have different understandings of the situation, particularly in terms of how they understand the significant uncertainty present in the field. This divergence complicates the question of where we should focus our resources in improving ED science, it also brings into view the importance of hearing different perspectives when getting to grips with an uncertainty-fraught scientific discussion.

Preface

This dissertation is original work by the author, Jack Durant. The focus and philosophy of this research was heavily informed by the work of Bronwyn McIlroy-Young. Aside from this, Dr. Gunilla Öberg, Dr. Daniel Steel and Dr. Annegaaike Leopold provided direction and feedback throughout the research process.

The interviews this study is based around were carried out with ethics approval from the Behavioural Research Ethics Board. The UBC BREB Certificate Number is H20-02473.

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A final thank you to the two study participants who gave vast amounts of their time and attention to the project with little to gain. Their insight and open-mindedness was vital for the study's functioning and is hugely appreciated.

Chapter 1 - Introduction

The myriad environmental challenges we presently face have put new pressures on policy-relevant science[1]. In tandem with the continually expanding research on environmental issues, an emerging realisation of the complexity involved in these challenges has ensured the central importance of understanding scientific uncertainty and what to do in the face of it[2]. One pressing environmental problem area that involves immense uncertainty is the scientific assessment of the potential harms of endocrine-disruptors (EDs)[3].

'EDs' refers to substances or chemicals that interfere with and adversely affects hormonal systems in animals and humans. EDs are everywhere. The exact figure is unknown, but most estimates put their numbers at around 800[4]. They are found in plastic bottles, toys, beauty products, food and tap water, to name but a few. Living a modern life untouched by them is an impossibility. Their ubiquity alone demands attention, but this is compounded by a number of complicating features of the EDs themselves. These include the potential for latency from exposure (i.e. harms manifesting significantly after the exposure event), additive or synergistic harms (i.e. ED exposure in the environment is rarely a single chemical, and combinations may have unforeseen and more pronounced effects), non-monotonic dose-response dynamics (i.e. more exposure doesn't necessarily equate to more harm, this makes responses harder to predict and opens the possibility of harmful effects at low exposure levels – N.B. this is a controversial idea, some experts pressure the significance of this phenomenon as a generator of adverse outcomes[5]), epigenetic harms (i.e. subsequent generations can be adversely affected after exposure) and lastly life-cycle dependent effects (i.e. organisms at certain stages

[1] Turnhout et al., 'New Roles of Science in Society'.
[2] Reckhow, 'Importance of Scientific Uncertainty in Decision Making'.
[3] Roig et al., 'Endocrine Disrupting Chemicals and Human Health Risk Assessment'.
[4] World Health Organization et al., 'State of the Science of Endocrine Disrupting Chemicals 2012'.
[5] Hill, Myers, and Vandenberg, 'Nonmonotonic Dose–Response Curves Occur in Dose Ranges That Are Relevant to Regulatory Decision-Making'.

of their life may be more or less vulnerable, e.g. developing fetus might be more vulnerable than adults)[6].

These complicating factors to the chemicals and their effects ensure uncertainty and ambiguity are rife. When combined with an array of knotted social, economic and cultural factors[7], we find an ideal environment for divergent and sometimes conflicting scientific communities to develop. Several insightful investigations, conducted by those in my lab and others, suggest that different scientists in the field demonstrate different values, framings and ways of knowing[8][9][10]. This work indicates that Knorr Cetina's 'Epistemic Cultures'[11] concept could be applicable in the ED deliberation context; and that these different cultures may exhibit fundamental differences in how they understand the state of ED science. A fortiori, this in turn suggest that we have reason to believe that the immense uncertainty in the field is also understood differently by these different cultures. Investigating these uncertainty understandings and their potential divergences forms the central task of this study. It's understood that if the understandings of uncertainty in the field that are sufficiently divergent, it will provide evidence of differing underlying epistemic mechanisms and so the presence of different epistemic cultures. How I'm employing the Epistemic Cultures concept in this paper will be unpacked further in '1.2 – Epistemic Cultures'.

Though this research is not explicitly designed to inform policy, the policy significance of mapping these understandings forms a straightforward case. Developing a complete picture of the expert understanding of uncertainty in the field should, in theory, allow for a full picture of the total sum of expertise on the matter and so facilitate optimally informed decision making under

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[6] Diamanti-Kandarakis et al., 'Endocrine-Disrupting Chemicals'.
[7] Vandenberg et al., 'Bisphenol-A and the Great Divide'.
[8] Vazquez et al., 'Exploring Scientists' Values by Analyzing How They Frame Nature and Uncertainty'.
[9] McIlroy-Young, Leopold, and Öberg, 'SCIENCE, CONSENSUS, AND ENDOCRINE-DISRUPTING CHEMICALS'.
[10] Clahsen et al., 'Understanding Conflicting Views of Endocrine Disruptor Experts'.
[11] 'Epistemic Cultures — Karin Knorr Cetina'.

conditions of uncertainty. This study, though primarily exploratory, can be seen as a small step in this direction.

In the chapter that follows, I will first attempt to illustrate the anthropological lens I will be taking throughout this research, arguing for its usefulness and contextualising it in the development of anthropology of science within STS. Next I will discuss the core notion of 'Epistemic Cultures' and it's relevancy to my research. The following section will involve turning my attention to scientific uncertainty, touching on recent developments in the literature and presenting how I will be framing uncertainty in this study corresponding to them. To conclude the chapter, I will present some guiding research questions and study aims, before a final section aimed at reflection and providing some study context through a brief description of the epistemic culture I'm working within.

Moving to chapter 2, I will here cover my research methodology. I will explain the 'brokered dialogue' approach, why I have slightly altered it, and why the approach is well placed to provide insight in the ED uncertainty context. From there, I move to the final chapter, where I will present and discuss the research results, before reflecting on the study as a whole.

1.1 - Anthropology of Science

The 20th century saw a growing understanding that science is inescapably intertwined with social structures and phenomena[12][13]. An important step in this process can be found in Kuhn's *Structure of Scientific Revolutions*[14]*.* His proposal that science develops in a non-linear pattern of established 'normal' science, followed by a period of crisis and a resultant 'paradigm shift' to a new 'normal', presented science as a somewhat clumsy, crisis-prone and changeable phenomenon replete with its own observable quirks and irregular patterns. A key idea advanced

[12] Longino, 'The Social Dimensions of Scientific Knowledge'.
[13] Daston, 'Science Studies and the History of Science'; Fleck, *Genesis and Development of a Scientific Fact*.
[14] Kuhn, *The Structure of Scientific Revolutions*.

in Kuhn's theorising is incommensurability. Each paradigm shift in the history of sciences involves a fundamental change in the standards by which 'good' science is judged. This shift is understood as so fundamental that comparisons between different scientific paradigms are impossible as there is no neutral standard by which both can be judged. The superseding paradigm isn't necessarily 'better', as better implies comparability, but is instead just different. This marked a stark contrast to the notion of science as a cumulative process that, despite occasional blips, consistently builds on itself moving towards truth. It also served to present science as a phenomenon particular to place and time, an idea that, as I will cover, forms an important motivating premise of anthropology of science.

Kuhn's work contributed to a groundswell of science studies activity in the late 20th century. The work of Collins[15], Shapin[16] and Bloor[17], amongst others, would see the development first of a sociology of science. In what has been called the 'second wave' of science studies[18], this period saw a flurry of science study's work that moved on from attempting to describe the scientific process with scientific ideas and terms, and instead attempted to characterise and explain science with 'extra-scientific factors'. This involved understanding science as a social phenomenon like any other - one beholden to its own customs, traditions, hierarchies and tribalism.

From this context, a further sub-discipline of science studies emerged which largely avoided addressing the deeper epistemological and explanatory questions directly, and instead pursued a deflationary, practice-focused approach based on real-world observation and description - an anthropology of science. Sociology of science sought to explain the functions of science through scientific analysis of the social interactions and structures that make it up. On the other hand,

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15 Collins, 'The Sociology of Scientific Knowledge'.
16 Shapin, 'History of Science and Its Sociological Reconstructions'.
17 Bloor, 'II.2 The Strengths of the Strong Programme'.
18 Collins and Evans, 'The Third Wave of Science Studies'.

anthropology of science understood science as a cultural phenomenon made up of constituent, often disparate sub-cultures, and suggested that we can gain significant insight on scientific processes without understanding any complex social patterns or wrestling in abstraction with philosophical implications, but instead through pursuing ethnographic fieldwork committed to immersion and real-time monitoring of scientists' day-to-day functioning.

Drawing from a reflection of Emily Martin, often considered a founder of the discipline[19], anthropology of science concerned itself with three primary questions: (1) 'In what ways do non-scientists and scientists interact?', (2) 'In what ways can science be understood as a culture' and relatedly, (3) 'In what ways are there cultures within science?'[20]. Stemming from questions 2 and 3, the aforementioned ethnographic work entirely focused on scientists began to develop. Starting in 1979 with Latour and Woolgar's revolutionary 'Laboratory Life'[21], the 80s saw several influential ethnographic explorations of a host of different scientific communities[22]. All utilising the same attention to detail, critical distance and championing of the qualitative that characterises anthropology elsewhere.

A point to be clear about here is that I take it as consistent to appreciate science's[23] epistemic rigour and the indispensable role it plays in modern life, whilst still maintaining that we stand to gain a lot in understanding its intricacies if we study it anthropologically. By this I mean approaching a given scientific endeavour without prejudice, observing the processes that make it up and listening to the thoughts and feelings of those involved. Regardless of science's epistemic status, whether a portal to absolute truth, modern mythologising or anything in-between, it remains an activity done by people, based on reasoning done by people, emerging

[19] 'An Anthropologist Investigates How We Think About How We Think | The New Yorker'.
[20] Martin, 'Anthropology and the Cultural Study of Science'.
[21] Latour and Woolgar, *Laboratory Life*.
[22] Stephens and Lewis, 'Doing Laboratory Ethnography'.
[23] Science here understood broadly as a systematic approach to studying the world using empirical data gathering and testable explanations

through an interaction of people and people-made things, and finally understood by people. It stands to reason that by studying it at the everyday people level, some of its inner workings may come into clearer view. This thought informs the investigative philosophy of this research.

1.2 - Epistemic Cultures

A major contributor to the flurry of ethnographic work mentioned in the previous section was Knorr Cetina. Drawing from her field studies, Knorr Cetina proposed the concept of ‘Epistemic Cultures’ as a framework for understanding the production of scientific knowledge[24]. In contrast to the idea of a unitary approach to science, Knorr Cetina suggested that different groups of scientists develop and work within different sets of processes she dubs an ‘epistemic culture’. These different cultures involve divergent social organisation, patterns of reasoning, approach to experimentation, modes of classification, weighing of evidence etc., with these processes forming the ‘underlying mechanisms’ behind the generation of knowledge in a given culture. Each groups’ underlying mechanisms develop and evolve spontaneously from the groups’ functioning. This idea marks a divergence from Kuhnian paradigms by pressuring the existence of a unitary ‘normal’ phase and advancing the idea that incommensurable epistemic cultures can exist and thrive side-by-side, rather than just superseding one another across time.

For the purposes of this research, an essential aspect of epistemic cultures is that different cultures in a given discussion can have what seem to be conflicting understandings and yet both advance important, well-supported ideas that are in keeping with sound reason and tried and tested experimentation practices. The key thought here is that neither is more right or wrong; both provide insight and both mark part of the picture. The ancient Indian parable of the blind people and the elephant provides a memorable way of conceptualising this. Each person feels a different part of the elephant and describes what they feel. One person feels a trunk and

[24] ‘Epistemic Cultures — Karin Knorr Cetina’.

concludes they're feeling a snake-like creature, another the elephant's torso and concludes the animal is built like a wall, and so on. Though they are making appropriate claims within their remit, neither has the total picture and so their conflicting accounts don't mark one's truth over another, but just the best conclusion they can reach given the circumstances of their respective analyses. Taking this analogy seriously, we see that getting a fuller picture of the science involves getting to grips with multiple expert groups' perspectives. And further, we see the importance of inter-group communication, where a diversity of viewpoints might help researchers question their assumptions and encourage novel and synergistic thinking.

In suggesting that the ED science can be understood as the sum of a number of epistemic communities and their interactions, the usefulness of employing the brokered dialogue methodology comes into focus. I will go into detail on the specifics of the methodology in chapter 2, but for now we can note that the inter-cultural dialogue it involves facilitates communication between members of presumably different cultures so providing the analyser with an indicator of the dynamics across these different groups – this is crucial as these dynamics themselves ought to be vital constituent parts of the emergent ED scientific landscape.

A helpful ontological tool for conceptualising the make-up of epistemic cultures and the ED scientific field as a whole can be found in Latour's Actor Network Theory (ANT)[25]. Understanding each epistemic culture as an assemblage, we can describe a network where a huge variety of human and non-human actants interact to produce the emergent culture. An actant is understood very broadly as a source of action, the concept is divorced from intentionality, consciousness and animateness. Human actants are most obviously scientists, but also other involved persons like lab technicians, funders etc. Non-human actants are things

[25] Latour, 'On Actor-Network Theory'.

like equipment, animal test subjects, laboratories, and more abstract things like a lab's collective values. These produce the assemblage of an epistemic culture which is itself an actant in the broader ED scientific system. This is a useful explanatory framing because it highlights the importance of the non-human material and abstract components of the epistemic cultures (the relevance of which will become clearer when exploring the diverse types of uncertainties present in this discussion). It also highlights the importance of understanding these cultures' interactions for comprehending the field as a whole, as it is precisely from their interactions that the broader assemblage of ED science emerges. As aforementioned, understanding this interactivity as a core productive process highlights the usefulness of inter-cultural dialogue-based analysis which I will be employing in this study.

With the core concept of epistemic cultures delineated and contextualised, the section that follows concerns itself with the remaining key concept in this study: *uncertainty*.

1.3 - Uncertainty

Several compelling general technical definitions exist in the literature but the working definition of uncertainty I will be drawing from comes from Walker et al.[26]:

Uncertainty is any deviation from the unachievable ideal of completely deterministic knowledge [CDK] of the relevant system

The degree of generality involved in this definition is a first thing to note here. Any deviation from CDK in a particular scientific context is understood as uncertainty. This involves a number of seemingly different phenomena. Ambiguity, vagueness, unreliability and unpredictability are all phenomena whose presence in a given context would contribute to a deviation from CDK and so uncertainty. Further, a vast array of different phenomena can contribute to a deviation from CDK. Anything from an imprecise microscope to racism in the workplace – as long as it is

[26] Walker et al., 'Defining Uncertainty'.

a phenomenon that moves the science in a given context further from CDK, then it is a constituent part of the total uncertainty in that context.

A further consideration here is that uncertainty understood in this way is inherent to empirical research. Empirical research uses inductive reasoning which involves a leap from incomplete data about the world to totalising conclusions about the world, this inherently involves the introduction of uncertainty and a deviation from the ideal of deterministic knowledge. In knowledge contexts where this uncertainty isn't introduced, then the knowledge at hand stems from a priori reasoning, like logic and maths. This inherent uncertainty in empirical study is not the focus of this research – instead I focus on the *understood* deviation from the *understood* ideal of completely deterministic knowledge. Put simply, I'm focusing on the scientific uncertainty as perceived by the participant scientists.

My use of uncertainty will be fleshed out considerably more throughout this chapter, but the key takeaway here is this base notion that uncertainty is ultimately any shift away from any perfectly predictive understanding of a system.

1.3.1 - Developments in Uncertainty Understanding

Scientific uncertainty has sometimes been understood as something that must be avoided or overcome for scientific success[27]. On this understanding, it's a term that marks incomplete information, representing the limits of knowledge and the direction of future study, instead of being a feature worthy of consideration in itself, or a feature of the system that we can happily ignore.

[27] Booker and Ross, 'An Evolution of Uncertainty Assessment and Quantification'.

This mindset has gradually receded and recent decades have seen an influx of work focusing on uncertainty and attempting to characterise the uncertainty in complex systems in more nuanced ways[28]. Within this movement, I take there to be three primary developments:

1. Uncertainty as referring to several discernable epistemic phenomena

A lot of uncertainty literature has been focused on getting as precise as possible on the different phenomena the term and related concepts denote. Ignorance (specified and unspecified, open and closed, reducible and irreducible), non-knowledge, liminal knowledge, negative knowledge, nescience, known unknowns, risk, unknown unknowns and unawareness are all concepts emerging out of the drawn and redrawn anatomies and taxonomies associated with uncertainty[29][30][31].

The one concrete pattern in this tangled web of shuffling definitions is the notion of uncertainty encompassing fundamentally different phenomena and that getting clear on these ideas is vital in better understanding the state of the science in a given context.

2. Uncertainty as multi-dimensional

Following reflections from Walker et al and others, another development in understanding uncertainty has been recognising its multi-dimensional nature[32][33]. How the dimensions are characterised varies somewhat, but broadly they involve a locus (a particular part of a system where the uncertainty is stemming from), a degree (uncertainties being more or less severe) and a 'nature' (uncertainties existing in ontologically diverse ways). From this we can observe

[28] Gross, 'The Unknown in Process'.
[29] Rocha Souza et al., 'Towards A Taxonomy of Uncertainties'.
[30] Regan, Colyvan, and Burgman, 'A Taxonomy and Treatment of Uncertainty for Ecology and Conservation Biology'.
[31] Tannert, Elvers, and Jandrig, 'The Ethics of Uncertainty. In the Light of Possible Dangers, Research Becomes a Moral Duty'.
[32] Han, Klein, and Arora, 'Varieties of Uncertainty in Health Care'.
[33] Walker et al., 'Defining Uncertainty'.

that a given uncertainty has certain set features, and these features are related but distinct and so warrant different analyses and presentation.

3. Uncertainty as varied in form

Another development concerns the form that a given uncertainty takes. As just touched on in the dimensions of uncertainty, there are different kinds of uncertainty that have different fundamental make-up. This has been divided up in different ways across the literature, but a consistent thread amongst the different typologies is immense variation[34]. Things like linguistic vagueness, tool imprecision and social-structure influence are all very different in form, but all can result in a deviation from the unachievable ideal of completely deterministic knowledge and so mark uncertainties. How I prefer to distinguish the different types of uncertainty will be explored in the following section.

With these significant developments delineated, I will present my own understanding of uncertainty as it corresponds to these three major developments, explaining and defending the different choices I've made at each stage.

1.3.2 - My Understanding of Uncertainty

My understanding of uncertainty as it corresponds to these developments is visualised in figure 1 below. The relevant concepts in each development are highlighted in grey with their nested interrelation represented by the brace lines in-between. Due to this interrelation, and following from convention in taxonomic work elsewhere[35], I will use the shorthand 'ranks' to refer to these three uncertainty developments from now.

[34] Rocha Souza et al., 'Towards A Taxonomy of Uncertainties'.
[35] 'Taxonomy - Ranks | Britannica'.

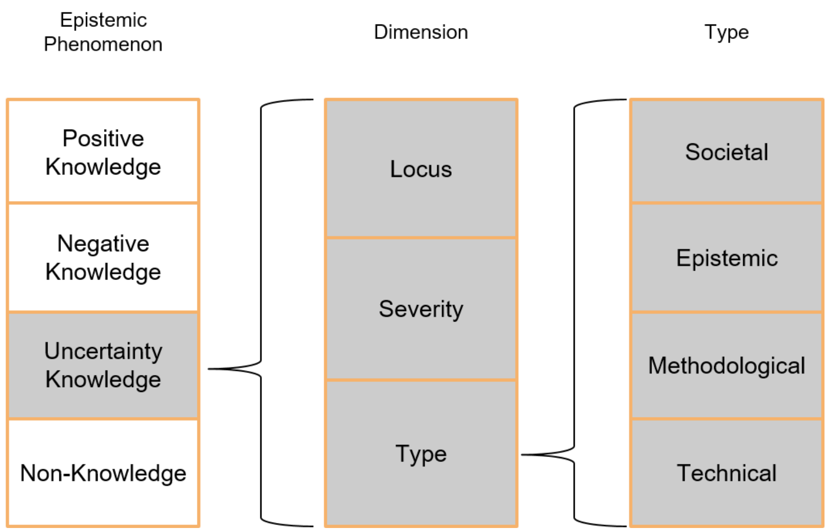

Figure 1 – *Taxonomy of the three ranks of uncertainty as judged from recent developments in the uncertainty literature*

This section concerns itself with explaining the taxonomic choices at each of these three ranks.

Firstly, epistemic phenomena. I have settled on a simple four part breakdown which I delineate in the table below:

Epistemic phenomena	Description	ED Example
Positive Knowledge	Claims about what we know without an explicit probability qualification	"BPA has been linked to developmental issues in babies"
Negative Knowledge	Claims about what we don't/can't know without an explicit probability qualification	"We don't know if non-monotonic dose-response dynamics are present in Atrazine exposure cases"
Uncertainty Knowledge	Claims (either positive or negative) that have an explicit probability qualification. They illustrate the understood distance from the unachievable ideal of completely deterministic knowledge	"We are *fairly confident* DDT affects the strength of egg shells in exposed bird populations"
Non-knowledge	Non-knowledge refers to areas of total ignorance. Unknown unknowns, the prerequisite for surprise in scientific investigations	n/a

Table 1 – Core Epistemic Phenomena Typology

This ranks' typology is very straightforward compared to others in the literature. Though each category may contain intuitive and compelling routes for further breakdown, its simplicity, the fundamental differences between these ideas and how they bring the unique properties of uncertainty knowledge into clearer focus makes this typology a strong fit for my research purposes.

Positive knowledge is what one might pre-theoretically equate with 'knowledge'. It refers to an appropriately justified true belief that asserts something about the way the world is.

'Negative knowledge' is an epistemic phenomenon term I am drawing from the work of Knorr Cetina. She describes it as knowledge about the limits of knowing gained from the disturbances, distortions, errors and uncertainties of research[36]. Where positive knowledge marks 'known knowns', negative knowledge marks 'known unknowns'. These concepts function similarly in epistemic terms, as though their focus is different (one on what falls within the boundaries of our knowledge and one on what doesn't), they both involve an explicit or implicit expression of certainty.

Uncertainty knowledge involves an expression of uncertainty through a claim combined with an explicit probability qualification. Explicit probability qualification is understood very broadly as any component of a knowledge statement that intentionally communicates a state of being unsure - this would include statistics (e.g. 30% chance this is true), direct verbal referral (e.g. "we're only partly sure this is true") and messier phenomena like implication through tone and body language (e.g. hesitant tone in voice, retiring or uncomfortable body language).

A further helpful way to illustrate the difference between negative knowledge and uncertainty knowledge comes in degree. Uncertainty knowledge has the dimension of degree, whereas negative knowledge doesn't. Returning to the Walker et al. definition, uncertainty knowledge

[36] 'Epistemic Cultures — Karin Knorr Cetina'.

attempts to describe the distance from the unachievable ideal of completely deterministic knowledge, whereas negative knowledge describes the things that are judged to be far enough away from the ideal so as not be considered knowledge at all.

Most typologies in the literature leave room for things like 'meta ignorance'[37] 'unknown unknowns'[38] or 'nescience'[39]. These concepts, though framed differently[40], all make some reference to the hypothesised dark spot in and around a given knowledge base. We don't know what things in this area are like, we don't know what they're not like, we can't make any claims about certainty with regards to them because we can't make any claims about them at all. In my typology I use the term 'non-knowledge' to refer to this phenomenon.

Despite the differences in these phenomena, an essential running thread to note between them is that they are all produced in a given epistemic culture through that culture's underlying epistemic mechanisms. What is considered positive knowledge, negative knowledge, uncertainty knowledge, and what doesn't fit into any of these categories (i.e. non-knowledge) is all dictated by the processes that underpin the functioning of a given epistemic culture so can differ from culture to culture.

Moving onto the next rank, we find aforementioned three dimensions of uncertainty knowledge I will be drawing from:

Locus: Where in the system the uncertainty is being generated

Degree: The severity of the uncertainty

Type: The kind of uncertainty we're dealing with

[37] Smithson, *Ignorance and Uncertainty*.
[38] 'None Too Solid: Medical Ignorance - Ann Kerwin, 1993'.
[39] Calabrò, 'Georg Simmel (1989), Sociologia, Milano'.
[40] Gross, 'The Unknown in Process'.

This dimensions breakdown is largely taken from Walker et al.[41] but with one significant difference relating to the understanding of type. Where Walker et al. understand type in broad terms as aleatory (uncertainty inherent in the system) and epistemic (uncertainty in our knowledge of the system), I've chosen to ignore aleatory uncertainty and use a typology inspired by Van Der Sluijs et al.[42] that sees epistemic uncertainty divided into four subcategories. The choice not to include aleatory uncertainty is based in the goals of this study - I'm not aiming to shed light on the actual functioning of EDs and their interactions with humans and animals; I'm once-removed from this process and am instead studying the knowledge of the scientists who conduct this work. Thus epistemic uncertainty is the focus, and I need a typology that breaks this down into intuitive categories for coding, analysis and comparison.

Understanding uncertainty again as 'any deviation from the unachievable ideal of completely deterministic knowledge of a given system', the four-part typology is presented and preliminarily described below:

(1) **Technical Uncertainty**: Deviations resulting from inappropriate technical choices, mistakes, equipment error or imprecisions

(2) **Methodological Uncertainty:** Deviations resulting from inappropriate methodological choices or mistakes

(3) **Epistemic Uncertainty**: Deviations resulting from inappropriate or insufficient knowledge contexts (N.B. this is a much more specific definition than Walker et al.)

(4) **Societal Uncertainty**: Deviations resulting from the interactions of people, groups, social structures and institutions

With this typological diversity, we can again note the conceptual usefulness of drawing from ANT. More specifically drawing from ANTs framing of systems as being made of a vast array of

[41] Walker et al., 'Defining Uncertainty'.
[42] Sluijs, 'The NUSAP Approach to Uncertainty Appraisal and Communication'.

different actants, both human and non-human[43]. Each uncertainty type could therefore be understood as emerging from a part of the broader system where actants of that uncertainty type are functioning. For example, the uncertainty that results from microscope imprecision (i.e. a technical actant) is a technical uncertainty. However there remains an important disanalogy here between how I'm understanding these uncertainty types and ANT which I will address later in this section.

Something to cover at this stage, for the sake of transparency and conceptual context, is how I understand each of these types of uncertainty as relating to one another. I am not making any claims about the objective nature of these systems' interrelations, only clarifying how I will understand them. I conceptualise their relation as 'nested' - the below figure provides a visualisation of this dynamic:

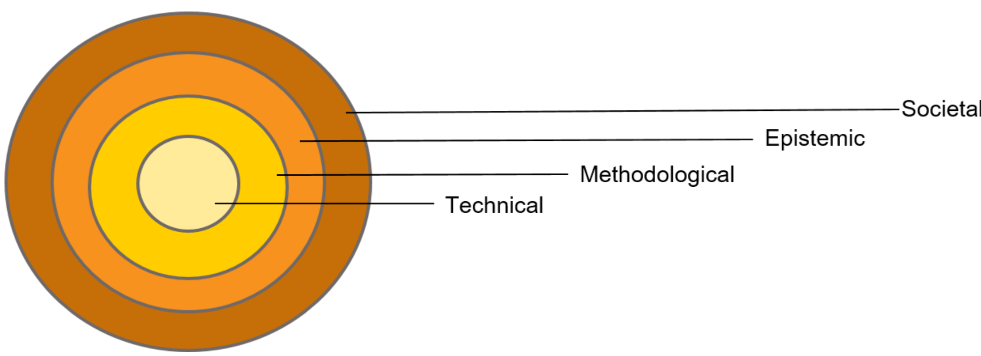

Figure 2 - *Visualisation of the 'nested' relation of the four systems that correspond to the four types of uncertainty*

Here each layer represents a system, with each system corresponding to the type of uncertainty that emerges from it. The societal system forms the outer-layer within which all the other systems are contained. Then epistemic, which is contained with societal and itself contains the

[43] Latour, 'On Actor-Network Theory'.

methodological and technical systems and so on. What the containment order means in practice is that an ED uncertainty statement can be explained as a part of its corresponding system (e.g. an epistemic uncertainty can be explained as emergent from the epistemic system), and the systems that contain it (in the epistemic case, it can be explained in terms of the societal system, but not methodological or technical).

To illustrate this further, an example of this nested dynamic in action might be a deviation from the unachievable ideal of completely deterministic knowledge that has resulted from relying too heavily on models where more testing out in the field might be more appropriate for given scientific investigation i.e. a methodological uncertainty. This is determined by societal processes because, say, the reason why the given scientists are leaning too heavily on models in the first place is based on a scientific mindset they've inherited from their professors or epistemic culture which emphasises the importance of models and abstraction over real-time real-world monitoring. Importantly, this methodological uncertainty can't be explained in terms of technical systems, so the explanatory order of the systems comes into clearer view.

I take this hierarchical framing to be useful in the ED expert deliberation context because there is strong evidence that societal and epistemic systems are shaping much of the controversy[44][45][46]. Aspects of the debate that hinge on technical and methodological uncertainties seem to be influenced by upstream societal processes. Aligning with this assessment brings into a sharper focus why I understand studying the outer-systems to be so important in the ED case.

Another thought to address in providing typological context is a key disanalogy between the notion of a nested hierarchy of systems and ANT. In ANT, there is no system hierarchy, all

[44] Vazquez et al., 'Exploring Scientists' Values by Analyzing How They Frame Nature and Uncertainty'
[45] Clahsen et al., 'Understanding Conflicting Views of Endocrine Disruptor Experts'.
[46] McIlroy-Young, Leopold, and Öberg, 'SCIENCE, CONSENSUS, AND ENDOCRINE-DISRUPTING CHEMICALS'.

actants are understood as playing an equal and indispensable role in the emergence of a given assemblage. In the case of the systems at hand, if we applied an ANT understanding, we could understand each uncertainty as emerging out of a complex interaction of actants from any of the four categories of system, with no actant-type bring more explanatorily useful than another – a 'flat ontology'[47]. Though I think this is an interesting conceptualisation, it is unhelpful in my study context for two reasons: (1) it makes distinguishing between types of uncertainty difficult as a mess of generative actants with equal contribution to a given uncertainty provides little indication of where said uncertainty should be categorised, (2) it doesn't capture the aforementioned influence societal processes seem to have in the ED scientific landscape.

1.4 - Research Aims

Drawing from the recent work of those in my lab and elsewhere[48][49][50], there is reason to suspect that there are different epistemic cultures present in the ED scientific landscape. Further contributing to work here, this research can be understood as an attempt to 'map' these cultures by investigating and describing the different understandings associated with them. Due to the immense epistemic and policy importance of uncertainty in studying complex systems, and its contemporary significance in the ED expert deliberation, specifically deciphering how the cultures under focus grasp the uncertainty in the broader ED scientific landscape forms the particular mapping project I pursue in this research.

A last thing to mention before getting into specific research questions is that, for reasons I will cover in the 'Scientist selection' section, I selected two participants (1) who we have reason to believe are members of different epistemic cultures, and (2) are broadly representative of their respective cultures.

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[47] Bryant, 'The Democracy of Objects'.
[48] Vazquez et al., 'Exploring Scientists' Values by Analyzing How They Frame Nature and Uncertainty'.
[49] McIlroy-Young, Leopold, and Öberg, 'SCIENCE, CONSENSUS, AND ENDOCRINE-DISRUPTING CHEMICALS'.
[50] Clahsen et al., 'Understanding Conflicting Views of Endocrine Disruptor Experts'.

With these two core research goals presented, below are some of the study's guiding research questions:

1. How do the two expert participants understand the uncertainty in their field along the lines of uncertainty degree, uncertainty type and uncertainty location?
2. Are there differences between their respective understandings of the uncertainty in the ED scientific landscape? If so, what are they?
3. How and to what degree do the participants, agree/disagree with one another?
4. Are there uncertainties in the field that are held to be more important than others? If so, what are they? Are they different to the uncertainties presented as most important by the other participant?
5. Do findings support the notion that the two interviewees belong to different epistemic cultures?

Aside from these lines of investigation, there are a number of extra opportunities this research provides:

- An opportunity to get a sense of the efficacy of ethnographic research in the context of the ED expert deliberation
- An opportunity to develop the brokered dialogue research body further
- An opportunity to encourage productive dialogue between different epistemic cultures in the field

Aside from these aims and opportunities, throughout this research I will endeavour to keep in mind that this is an under-examined area in policy-relevant environmental science and there may be a number of unforeseen insights emerging from the investigation. Adjusting to this exploratory research context will entail a consistent attempt to maintain an open mind and process all components of the eventual data produced, including things that fall outside the focus of the core research questions.

1.5 - Reflection

As famously advanced by Bloor in his strong program of sociology of science, any social studies of science should involve reflexivity and an understanding that all claims made about the social epistemic workings of science can and likely will apply to the STS scholar and their methods and epistemology too[51]. With this in mind, briefly reflecting on my own epistemic culture may provide useful context for the reader.

The epistemic culture I work within is the Egesta Lab at the Institute of Resources, Environment and Sustainability (IRES) at the University of British Columbia. Our work varies significantly in methodology and focus, but it broadly operates within policy-relevant environmental science with a particular focus on chemicals management.

My supervisors and the other students in our lab have diverse views on what science is and how we should best understand it. Those of us working within the ED field also have different views on the nature of the threat they pose. One common thread between the lab members is a willingness to approach science as a human process like any other, and a belief that science and scientists need to do more work to reflect on and communicate thoughts and theories about science's nature and place in society. However, perhaps given our close work with scientists and the fact of many of our backgrounds being explicitly scientific, scientific methodology is understood as having rightful special epistemic and societal status. The ultimate vision is to provide additional insight on policy-relevant scientific endeavors in fields that are characterised by large uncertainties and where policy relies heavily on science advice.

[51] Bloor, 'The Strengths of the Strong Programme'.

With core concepts, historical context, broad research approach, typologies and some of my generative epistemic culture presented, I will spend the following chapter delineating my methodology.

Chapter 2 - Methods

2.1 - Brokered Dialogue

The methodology employed in my research is based on 'Brokered Dialogue', a research methodology developed in 2012 by Parsons and Lavery to shed light on and promote productive discussion in debates surrounding controversial health and social issues[52]. The methodology sees a researcher conduct a filmed interview with an expert or experts on a given side of a selected controversy, and then, drawing from interviewee input, the researcher edits the resultant video into concise clips covering the main points made during the interview. The interviewee is given final say on the clips and so can remove certain points from the final cut without a need for explanation. The post-edit footage is then shown to another expert on a different side of the discussion for comment. These comments are, as in the first round, co-operatively edited with the interviewee to produce a short video of key points. This second video can then be shown to the original expert, or to another expert from a different side of the discussion. This process is then repeated as much as time, resources and research aims prescribe. See figure 3 below for a visualisation of the process.

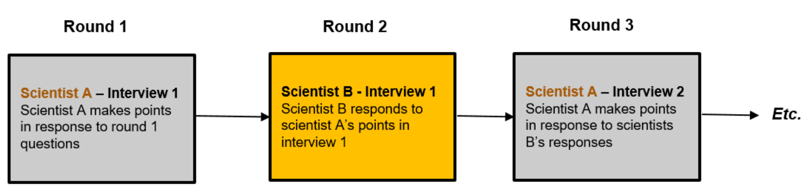


Figure 3 - *Visualisation of brokered dialogue research*

[52] Parsons and Lavery, 'Brokered Dialogue'.

The methodology draws from visual anthropology and counts the richness of the audio-visual data set as one of its core strengths. This richness allows for additional analysis avenues over and above just transcribing (e.g. body language, facial expressions) and for more engaging prompts for the participants as they watch the other participant's replies. The use of film also allows for the end-product of a video showing the full conversation, which forms a helpful and accessible resource for any expert or layman wanting to get to grips with the controversy under study.

The brokered component of the methodology provides several additional methodological advantages. Firstly, it permits some organisational benefits through avoiding the need to get everyone in the same room at the same time. Secondly, it helps discussions remain civil and considered through removing opportunities for interjection and interruption, this civility advantage is further bolstered by aforementioned opportunity the participants have to filter any potentially inflammatory comments during the post-interview editing process. Lastly, the one-on-one interview format it involves allows for potentially less-guarded responses and so can provide insight that might be smothered in a more directly confrontational group set-up.

Though all these components to the methodology are hugely beneficial to my research ends, the dialogic component is perhaps the most advantageous for my purposes. This is because, as previously mentioned, I am aiming not just to shed light on the thoughts and understandings of the interviewed experts, but, on the way these experts, and by way of representation, these cultures, interact with one another.

To further increase the utility of Brokered Dialogue for my research purposes, I made some slight modifications to the methodology which I will present and support in the next section.

2.2 - 'Promptive' Brokered Dialogue

My research evolved into what I have dubbed 'promptive brokered dialogue'. This is brokered dialogue as detailed above, with some slight but notable modifications. Visualised in figure 4 below, the key changes are: (1) running two conversations in parallel, rather than a single conversation stream (the two streams represented by the orange and the grey) and (2) use of prompts and questions in each of the three rounds, rather than allowing for a more organic conversation dynamic (represented by the prompts sign attached to each interview box).

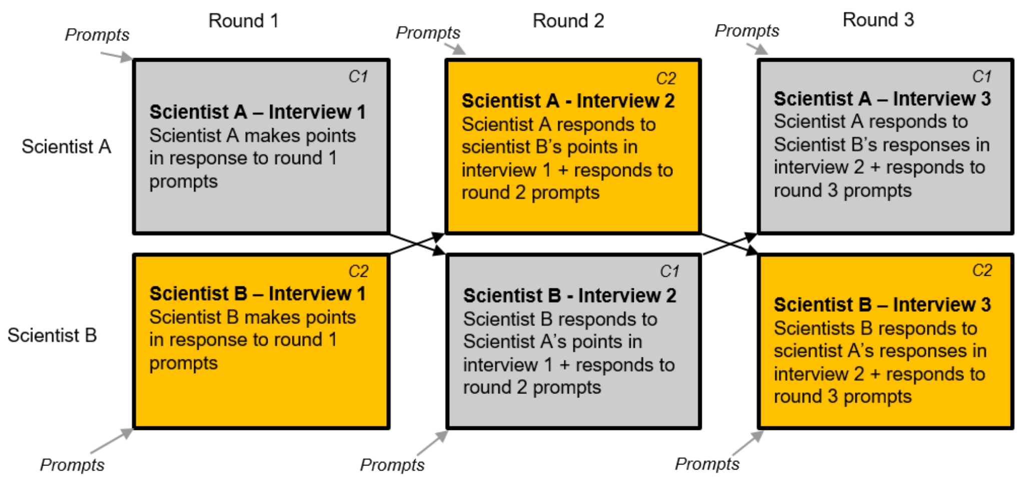


Figure 4 – V*isualisation of a 'promptive' brokered dialogue methodology with two conversation streams running in parallel across 3 rounds of interviews*

In conventional brokered dialogue, as mentioned in the previous section and visualised in figure 3, the methodology hinges on a single conversation stream, where one participant talks, another responds, and the original (or a new participant in multi-participant conversations) responds to the response and so on. Running two conversations in parallel rather than a single conversation stream was chosen to ensure both participants got a chance to set the terms of a conversation by airing their thoughts at the outset. This was to avoid one participant having an outsized influence on the discussion topics and direction.

A disadvantage of the parallel conversation stream approach is that the requirement of responding to two different conversations streams entailed some areas of discussion were covered twice. Though covering the same topics twice limited the total number of possible topics covered through taking up more interview time and not covering new ground, as well as risking the frustration of the participants, in practice, it caused relatively limited disruption and led to some interesting additional insights on certain topics that weren't fully explored first time around.

The use of questions and prompts, though not strictly prohibited by the original design of brokered dialogue, might be seen as running against the organic, conversational dynamics that the original methodology was designed to encourage. I judged this more semi-structured interview format to be worth introducing despite the potential compromise in conversation dynamics primarily because it served to keep the conversation on topic and within the research aims, this was especially important as the lines of questioning were sometimes novel to the interviewee and so judged to be less likely to come up organically. Round 1 consisted solely of prompts and responses, much like a conventional interview. Round 2 consisted of responding to the points of the other participant made in their first round, then answering a new set of prompts. And Round 3 involved responding to the points made by the other participant in Round 2, followed by a final set of prompts.

The 'prompts', understood in line with Jiminez et al.[53] as a more open-ended, less prescriptive mode of questioning, were, when possible, favoured over 'questions', understood as more tied to protocol and involving a restricted scope of possible answers. I will delve into the specifics of the prompt design in section 2.2.2, but for now, it's worth highlighting that using prompts over

[53] Jiménez and Orozco, 'Prompts, Not Questions'.

questions was understood as the better option for promoting the receptive and open-minded investigative dynamics that the exploratory nature of this research required.

A final difference between promptive brokered dialogue and conventional brokered dialogue is the omission of a final video product. This was largely unintentional but marks a significant divergence from the original brokered dialogue conception. We had originally planned to produce an audio-visual product in line with the suggestions from Parsons and Lavery, but the unfortunate timing of the research window falling at the height of the Covid-19 pandemic ensured the end audio-visual product would be a Zoom edit and so would be vulnerable to connection disruption, poor audio and resolution, and generally being visually less attractive. The overall poor quality of the potential end-product significantly disincentivised pursuing this approach, as did the thought that not releasing the footage would allow for the participants to remain anonymous, so leading to a less intimidating process and a less guarded data set. A final consideration to mention is that the research was primarily exploratory and focused on understanding the participants' views, rather than any attempt to actively contribute to developing a consensus in the broader real-world discussion, which is a central goal of the original method. This meant the audio-visual end-product was not as essential to the core goals of the research as it might be in conventional brokered dialogue.

2.2.1 - Scientist Selection

In selecting the experts for interview, five inclusion criteria were developed in dialogue with my committee. Participants had to meet all five before a decision was made to reach out. The components are listed and briefly explained below:

1. **Participants are judged to be from different epistemic cultures**

This criterion requires (1) that there is good reason to believe they are conducting science within a particular epistemic culture and (2) that the two epistemic cultures are different from one another.

Working these out was not straightforward first and foremost because we do not know for certain that different epistemic cultures exist in the ED landscape and, if they do, epistemic cultures, by their organic and sometimes overlapping nature, are hard to clearly distinguish[54]. Our mode of negotiating this was through leaning on the expertise and field knowledge of a member of my committee, who made some recommendations for participants that they judged likely to be part of different epistemic cultures. Examples of the types of consideration my committee member drew from in the judgement come in the experts working in different research environments (one for a governmental agency, one for a university, also in different countries) and the types of scientific discussions they have been involved in and the statements made in these discussion. Also, we selected to lean on a controversial topic: their views on the possibility of low-dose effects from ED exposure (we understood one considered it a threat, and the other thought there was insufficient evidence for it to be considered as such).

Despite these considerations, this selection process clearly was not an exact science. Thankfully, despite some initial reservations, it seemed that our original judgement was somewhat vindicated by the study results.

2. **15+ years of experience in ED research**

There were two reasons why a high level of experience was key to a participant's suitability. Firstly, and most importantly, the nature of the prompts and the topics under discussion meant a significant degree of day-to-day experience in the field would be hugely beneficial in providing considered responses. For example, providing informed answers about patterns in the daily

[54] Cetina, 'Culture in Global Knowledge Societies'.

minutiae of technical research, or responding to prompts about the best areas to focus on in the broader system for effective change would be challenging if someone did not have significant experience in the field.

A further more speculative reason for the experience requirement was based on the assumption that scientists who had spent a significant amount of time working in the field might be more embedded in and thus more representative of the epistemic culture we hypothesised they belonged to than a scientist in the same culture who has just started their career. The reasoning being their long-term immersion in that working environment might result in them embodying the views and attitudes of the epistemic culture they have spent their working life in, whereas a scientist who was just entering the culture might be less likely to have views affected by the particular understandings of that culture, and so their views might be less likely to be representative of their epistemic culture.

Building on this idea further, earlier focus group work by those in my lab[55] suggests that scientists understood to be in the same epistemic culture can align themselves with a narrative that presents their views and that of their peers in a favourable light, and that discredits the views of those epistemic cultures that dispute them. Though the epistemic cultures under study in my research are different, it seems reasonable to posit this epistemic tribalism phenomenon as existing in other cultural relations in the field, in this instance, the claim of a connection between being a culture member and being representative of that culture would be further bolstered.

3. Open to discussing science studies ideas

Due to the nature of the prompts used in the interviews, we needed to have good reason to think the participants would be open to discussing 'non-scientific' components to science and

[55] McIlroy-Young, Leopold, and Öberg, 'SCIENCE, CONSENSUS, AND ENDOCRINE-DISRUPTING CHEMICALS'.

how these might affect their work. Drawing primarily from personal experience and discussions with fellow STS scholars, some scientists appear less willing to talk about the broader social/systemic issues affecting their work than others. The nature of the research meant that this was somewhat self-filtering, as scientists who weren't comfortable or weren't interested in talking about these topics wouldn't accept the interview proposal. But this criterion was still drawn from in deciding who would be worth contacting in the first place. Again, it was judged primarily by the committee member with significant knowledge of the experts in the field.

4. **Happy to engage with opposing views**

Participants must be keen and willing to engage with views they might find disagreeable. This was a straightforward consideration based on the goal of a productive and measured discussion. A potential participant's tendencies in this area were judged primarily by their written work and their understood disposition in previous public deliberations. Again, information here was drawn mainly from the committee member who has spent significant time working and interacting with other experts in the field.

5. **Don't know one another**

The participants must not know each other. It was judged as permissible if they were familiar with one another but didn't have a personal relationship. This was to avoid interpersonal dynamics affecting the data. The participant relationship was judged based on their degree of inter-citation, their working environment and the anecdotal knowledge of the expert committee member of mine.

2.2.2 - Prompt Design

There were a number of core considerations in designing the interview prompts. As with the participant selection criteria, these design thoughts were developed in conversation with my committee, guided by close consultation with the literature surrounding effective qualitative interview research[56][57].

Firstly, it was judged that the prompts should be sensitive to the direction and revelations of the conversation round to round, and so should incorporate specific, compelling, aims-relevant data points into the questioning, both spontaneously and in preparing the key prompts for the next round. This had the advantage of being more in keeping with the naturalistic spirit of brokered dialogue as originally conceived, and being in keeping with the exploratory demands of the research through permitting flexibility in lines of questioning in response to unforeseen insights.

The initial prompts were designed with maximal open-endedness in mind to stimulate the broadest and most free-associative initial data set possible – this was useful for getting the best clips for generating interesting discussion, but also for getting as full a picture of the interviewee's views at the outset as possible, the importance of this stemming from the thought that this first round of responses would be less influenced by the ideas of the other participant and the conversation direction and so perhaps a more authentic reflection of the participants pre-interview perspective.

Another consideration was that in the interests of more easily comparable data, each participant should be presented with the same set of prompts in each round. There was a temptation to use different sets of prompts for each expert, with each set designed in response to the points being made by that expert in particular. However, the need for comparable data was judged to outweigh the advantages of individually tailored questioning.

[56] McGrath, Palmgren, and Liljedahl, 'Twelve Tips for Conducting Qualitative Research Interviews'.
[57] 'The SAGE Handbook of Interview Research'.

All in all, 17 prompts were used across the three rounds. Six in round 1, three in round 2 and eight in round 3. For illustrative purposes, an example prompt from each round is displayed below:

Round 1 -

> *What factors make for better, more trustworthy evidence in evaluating the potential harms of EDs?*

Round 2 -

> *Can we address our most pressing uncertainty problems solely by improving our technique and methodology? Or are there other important issues to address? If so, what?*

Round 3 -

> *Do different experts value certain types of evidence differently? Do these different evidence-type weightings affect the reliability of the science being produced?*

The full list of prompts as put to the participants can be found in the appendix.

2.2.3 - Clip Selection

There is no strict guidance in brokered methodology regarding how best to select clips for the conversation[58]. The key thoughts advanced are that the clips should highlight the perspective of the participants and that the editing should be done collaboratively with the participants, in part to ensure their perspective is adequately captured, and to ensure they are comfortable with the clips being shown to the other participant.

58

With this spirit in mind, and following discussions with my committee regarding a number of ethical and epistemic considerations, four explicit clip selection criteria were settled on. These are numbered below with a brief explanation:

1. **The clip contains a point that is stated strongly, repeated or is judged as especially contentious/interesting**

Clips that contained points that weren't presented strongly were excluded, this was judged based on word use, tone, body language, volume and broader discussion context. Other points that were understood as being broadly accepted or standard for experts in the field were also excluded. This was judged primarily through drawing on the field knowledge of my committee.

All decisions made stemming from this criteria point were made with stimulating a data rich conversation in mind.

2. **The point made in the clip must be representative of the interviewees' views**

If a clip involved the participant making a point that they later negated, or a point that they presented as an idea for consideration rather than something they stood behind, it was excluded. This was to ensure the discussion matched the participants' views as accurately as possible.

3. **The clip contains a fully discernable point with no additional context needed**

Clips that contained points which that required significant interview context to make sense were generally avoided. This was in the interests of time-efficiency and to further safe-guard against misrepresentation.

4. **Each clip is ideally less than 1 minute, though exceptions can be made, and the total clip runtime per interview is ideally less than 10 minutes, though exceptions can be made**

This was in the interests of concision and to give the clip viewing participant maximum time to air their own ideas, so maximising the new data potential. This is because the lower the clip runtime shown to the participant, the more of the interview they'll be able to spend presenting their own views.

With these criteria in mind the total number of clips that made the final selection was 36, with a total runtime of just over 25 minutes (25:11).

2.2.4 - Analysis

For analysing the data produced after the interviews, my approach was primarily based on the suggestions of Parsons and Lavery. One important difference to acknowledge at the outset is that my analysis altogether avoided questions around (1) how participants' views change over the course of the interviews and (2) what pathways there are to moving the discussion towards a resolution. The decision to avoid these two paths of analysis was based on the tilt of my research being exploratory and probing for divergences in views rather than focused on consensus building. Despite this difference, my focus on conducting a narrative analysis informed by thematic and interactive analyses, and consistent comparison of transcripts throughout, is firmly in-line with the analytic suggestions of Parsons and Lavery[59].

With this in mind, the primary goal for my analysis was getting to the core emerging narratives. What are the central uncertainty stories each participant is presenting? And further, where do these stories overlap, where to do they come apart, what lessons and future research directions can we draw from them? Again in-line with Parsons and Lavery, the analysis as a whole may produce specific findings, but giving the participants a chance to present their perspective and be heard is the most important component of the research.

[59] Parsons and Lavery, 'Brokered Dialogue'.

To get to these core narratives, my analysis involves three distinct steps. The first involves thematic coding to decipher the type, location and degree of all the uncertainty statements being presented by each of the participants. The second is an interactive analysis, and centres on the levels of agreement or disagreement between the two participants in their responses to one another throughout the interviews. Drawing from these analyses, the third step involves characterising the core narrative story advanced by each participant, and breaking it down into an inductively coded story structure. Finally, I will draw from both of these core uncertainty stories to produce a 'meta-narrative', a similarly structured story that incorporates the two core uncertainty stories and the interactive data, considers the participant differences, similarities, the insight they provide and the future research directions they point to.

Figure 5 below shows a visualisation of the study. The two larger circles at the bottom represent the total set of interview data gathered from the participants during their three interviews. The arrows between them represent the 'interactive data', so the parts where they responded directly to one another. The two Ns emerging out of the interview data sets represent the emerging narrative advanced by the participant. And the MN circle in between those two represents the meta-narrative. To commence each section on the three-part analysis, I will lead with the figure 5 visualisation, with the part of the data being analysed in that section highlighted in grey.

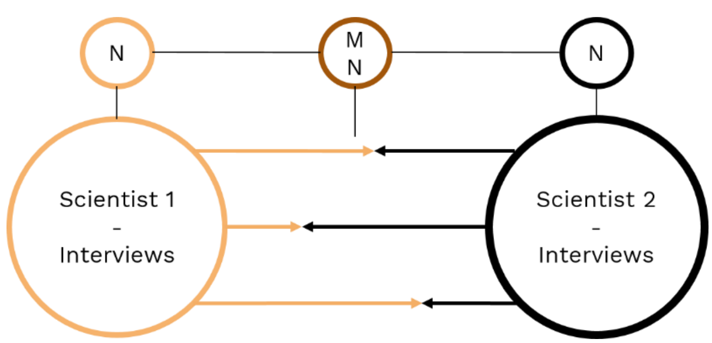


Figure 5 – V*isualisation of the data gathered during the study and its interrelation*

2.2.4.2 – Thematic

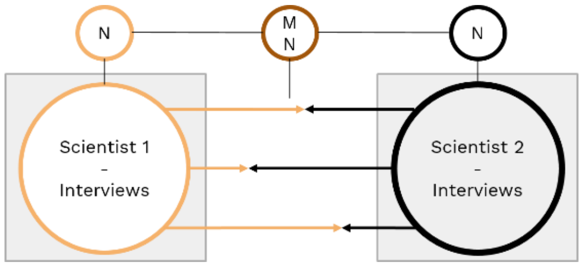


Figure 6 – *Visualisation of the study data with the interview response data highlighted in grey*

The thematic analysis involved coding views presented in the interview along three core axes:

(1) **Locus**: where in the broader system is this uncertainty being generated?

(2) **Type:** What form is the uncertainty being presented?

(3) **Degree:** What is the level of uncertainty being presented?

These three 'dimensions' were presented by Walker et al. as being the three core components attributable to uncertainty in the literature[60], and so were judged as well suited for the purposes of processing a participants' understanding of the uncertainties in the field. One additional point to mention is that the 'uncertainty statements' being analysed are understood broadly as any statement that discusses or alludes to a phenomenon that affects the certainty or uncertainty of the science being produced in the ED research context - the breadth of statements that this includes will be explored in the next section. With this extensive definition in mind, the total distinguishable instances of uncertainty pertinent statements across the six interviews came to 165.

Returning to the typology, locus formed a fairly straightforward component of the coding. Wherever the uncertainty was being presented as happening was written down. There were no

[60] Walker et al., 'Defining Uncertainty'.

set-categories to begin with, but patterns regarding where in the broader systems the participants tended to understand the uncertainty as coming from began to emerge. Drawing from this data, I developed a code that sorted the locations into six broad categories. These are presented as below, accompanied by an example uncertainty statement that was coded into the given location category:

1. **General Research (GR)** – Any uncertainty that stems from issues with the research itself

Study Example – "Of course, something that very few people appreciate, I think it used to be called the applicability domain, which is basically what animals are we talking about. Are we talking about humans, mammals, fish, invertebrates? Because there is a tendency to generally mix it and try to make extrapolations from one phylum to another where they don't hold."

2. **Human psychology (HP) –** Any uncertainty that stems from individual people's psychology

Study Example – "But once they publish it and they gain a name because of this, then they're extremely reluctant to admit that they made a mistake, even if all the evidence in subsequent years points to the fact that they got the wrong end of the stick. That is also another factor, which I think is more related to some sort of pride or ego or I don't know, it's a human trait. At the end of the day, none of us are perfect, yeah? But it is a human weakness that gets into the way of scientific evidence that is also related to social influence."

3. **Economic System (ES)** – Any uncertainty that stems from issues surrounding money, industry influence, funding or broader capitalist processes

Study Example **– "**Anyway, my point is, if you don't have a lot of money, you're going to do whatever you can in research. And then if you don't get the funding even though you think it's very interesting, as a scientist, you're not going to go and do it, it's not sexy enough to get granted"

4. **Academic System (AS) –** Any uncertainty that stems from the functioning of the broader academic system

Study Example **-** "Because unfortunately, particularly academics, are under a lot of pressure, they have lots of things to do, they work long hours, and sometimes they do a very superficial job in their research and in the papers, they don't have the time to check the data."

5. **Social Phenomena (SP) –** Any uncertainty that stems from broad social structures and dynamics

Study Example – "I believe that everybody has a different perspective and everybody should have a voice at the table, the more diversity, the better [the science]….to be honest with you, we can't carry on [in this non-diverse way]. I mean, it's really unfair."

6. **Political System (PS) -** Any uncertainty that stems from political phenomena at the local, national and international scale

Study Example – "We don't have the impression as researchers that things are moving. And I think the reason for that is because we don't think the government take [ED research] seriously."

Type was less straightforward to code. The literature on how best to categorise uncertainty in complex systems is still very unsettled. Despite a number of compelling and intuitive typologies, no single one has emerged as preferred. The typology I used, and the one touched on in the introduction, is inspired by a 2017 Van der Sluijs et al. typology which has recently been used in EU documents by the Science Advice for Policy by European Academies (SAPEA). This typology was drawn from partly due to the use-momentum and the institutional recognition, but also because it turned out to be a strong fit for the data produced.

Understanding uncertainty again as ‘any deviation from the unachievable ideal of completely deterministic knowledge of a given system’, the four-part typology is presented and briefly described below:

(1) **Technical**: Deviations resulting from inappropriate technical choices or errors/mistakes

Study Example - “Basically, there are students that, you know, give [their professor] [faulty data] and they just take it for granted. They never go back to ask for the Excel spreadsheet, you know, or whatever. They don’t check, basically step by step, how these results were created. And then they proceed with the publication”

(2) **Methodological:** Deviations resulting from inappropriate methodological choices or mistakes

Study Example -“Another methodological factor, of course, is to have a proper experimental design with appropriate controls, you know. Particularly some information on the colony, on the genetics, particularly if it is suspected that a lot of inbreeding, that can help you. I want to see environmental enrichment. I don't like to see very stressed animals participating in experiments because they affect the data.”

(3) **Epistemic**: Deviations resulting from inappropriate or insufficient knowledge contexts

Study Example - “For me, within the area of human health, the biggest issue is to have good epidemiological studies that are actually supporting the findings”

(4) **Societal**: Deviations resulting from people, groups, their interactions and broad social processes

Study Example - “[Diversity] is very important to me, like in my lab, I make sure I have men, women, and then different sexual identities, it’s very important. And they’re right because according to what you learn and experience and where you’re from, it’s going to be a different set of ideas that you’re going to bring to the table”

A point to note here is that though an uncertainty statement’s type and location can be related, e.g. types that fell into the General Research location were more frequently methodological uncertainties than other types of uncertainty, I understood it as important to present these dimensions separately because each type of uncertainty *can* be present in any of the locations. For example, in general research, there were methodological uncertainties, but there were also ones pertaining to human interactions (societal), ones related to faulty epistemic reasoning (epistemic) and some involving things like specific ineffective/inappropriate equipment (technical). Though there are correlations, one dimension involves the actual nature of the uncertainty phenomena (type), while the other represents the outer, generative context (locus) – these are both different in concept (i.e. we can conceive of them separately), and as my results would support, different in practice.

For judging the degree of uncertainty expressed in a given uncertainty statement, a 5 part ordinal scale ranging from minor to critical was employed. This was judged intuitively drawing from statement features like language use, tone, emphasis, body language and conversational context. The full scale can be seen in figure 6 below, going from weakest to strongest:

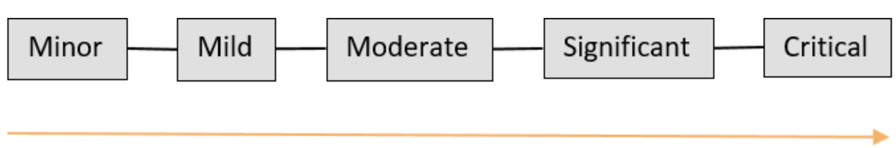


Figure 7 – *5-part ordinal scale used to judged uncertainty statements severity/degree*

Two examples of the degree coding at different ends of the scale and the reasoning behind them are illustrated below:

'Critical' study example -

> **"**Well, obviously, if it's funded by the industry, it's not going to be trusted. Well, not by me. Not by me. Zero. Zero. And it can it can be like a friend of mine who conducts the research. I will not trust it**."**

Here the force of the language points to the idea that this statement could be judged as 'critical' – e.g. turns like specifying and repeating the trust level as 'zero', and explaining that this stance doesn't change even if they know the person well. This was accompanied by a slight increase in voice volume and hand gesticulation, along with increased pauses, which I understood as emphasising the statements importance. Reflecting on these considerations as well as drawing from my real-time holistic impression, this statement was judged to have a degree rating of 'Critical'.

'Mild' study example -

> "Some places it might be possible [to conduct mass monitoring], but in *participant's country* it is just not possible. So what are we doing? And there is a lot of equipment to do all these analyses, it's creating a lot of chemicals as well. Right? So at some point, it has to be logical."

The force of the language here is certainly a little less than in the previous example, but still reads as reasonably strong. However, this is just part of the story. In the interview, the point was made in a laidback way with a relaxed tone of voice and limited gesticulation, it was advanced with the feel of being more an observation or real-time musing rather than a strongly held opinion. Though its status as being less in degree or severity was clear judging from my reflection during the interview, on re-visiting it, it was judged that the occasional use of a rhetorical questions might move it from a 'minor' rating to a 'mild' rating.

With the three dimensions and my thematic coding approach delineated and exemplified, I will close this section with an example of an uncertainty statement from each of the participants with a full demonstration of how they were coded, including the uncertainty type, degree and location. The examples were chosen as they were coded differently on each of the dimensions, so hopefully giving the reader a broad sense of the coding process.

Scientist 1 – Study Example

> "[We need] Fundamental research on invertebrate species, lower trophic organisms, enough with the fish, okay? If you want to revisit fish, improve your models. Three species, with the same reproductive strategy, when you have 35000 species, you can choose whatever you like, it's a crime, its convenience, it's not science***"***
>
> **Locus –** *General Research*
>
> **Type –** *Methodological*
>
> **Degree –** *Significant (4/5)*

Scientist 2 – Study Example

> "Universities are pressuring us to be in the media because they don't want to talk about me. They want to talk about their name right?...they don't care about me, they just want their name. So it's their indirect way of getting publicity. It's part of the game."
>
> **Locus –** *Academic System*
>
> **Type –** *Societal*
>
> **Severity –** *Mild (2/5)*

After this process was repeated across the 165 statements, I started the interactional analysis.

2.2.4.3 – Interactional

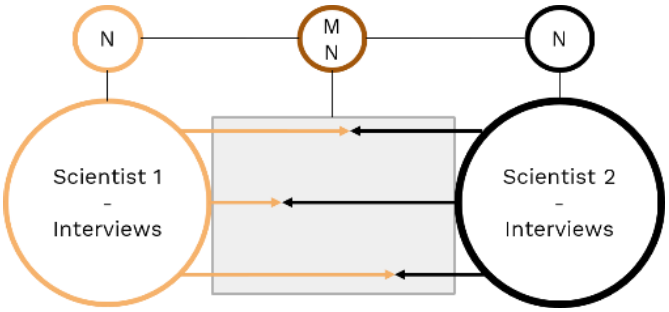


Figure 8 - *Visualisation of the study data with the interactive data highlighted in grey*

The interactional analysis focused on individual interactive instances - these were defined as any moment when a participant responded directly to a point made by the other participant. These are distinguished from moments when the participant is responding to a prompt advanced by me, and from times when they are thinking out loud in way that can't be easily linked to either a prompt or a clip from the other participant. Moments when interactive instances seemed to occur but the participant response wasn't immediately following a clip being shown have been ruled out as their status as interactions fall into a grey area. Further, in instances where a participant made two points in a clip, and the other participant responded to both points, this counted as two interactive instances.

With this in mind, there were 37 individual interactions in the final data set. The data analysis involved a straight forward two-part code which first logged the (1) concordance-type, and then (2) the degree to which those concordance-type dynamics were present. Concordance-type refers to the following three categories of possible interaction:

Agreement: The participants' concur; their views are aligned in proposition and in emphasis

Disagreement via emphasis: The participants' views are consistent with one another, but they stress the importance/unimportance of different things

Disagreement via inconsistent position: The participants' views are inconsistent with each other, their views contradict one another or otherwise substantially diverge

Degree refers to the degree to which they agree/disagree within an above concordance-type category. Degree was judged utilising a similar 5-part ordinal scale as the uncertainty degree in the thematic analysis, with a minor tweak in the strongest category from 'critical' to 'total' to reflect the different form of degree being measured. Again, this was judged intuitively drawing from the content of the interaction, as well as word use, tone, body language, emphasis etc.

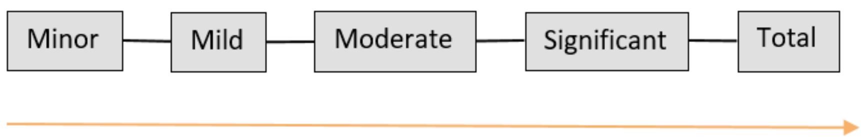


Figure 9 - *5 part ordinal scale used to judge the severity/degree of the concordance type in a given interactive instance*

Below are three examples of interactive instances from the study, presented and briefly explained. All three are coded along the two dimensions of concordance-type and degree, as in the actual coding. These examples have been chosen as they cover the three concordance types and represent different degrees, so helping to illustrate the system through varied examples. The 2nd and 3rd examples are especially useful as they help demonstrate the difference between the two types of disagreement (via emphasis and via inconsistent positions) which might be tricky to distinguish without example.

Interactive Instance *Example 1* –

S2: "I think the best is to have the disciplinary teams, obviously. It's a bit like Facebook. I think science is like Facebook. If your friends and all the people in your field and everyone thinks that way, that's what you think. And then that reinforces your own beliefs. But then if, finally, you join this group with all these other ideas, people understanding things differently, then you're like, oh! You're learning and you see things that you never considered before"

S1: “I couldn’t agree more. And that's exactly because it's a complex system. It's one of those areas where it benefits greatly from different approaches.”

Concordance-type*: Agreement*

Degree: *Total (5/5)*

This interactive instance sees Scientist 2 discussing the virtues of interdisciplinary in the ED context, mentioning how it can break you out of your bubble and help you see things in novel ways, with Scientist 1 agreeing wholeheartedly. This interaction was very straightforward from a coding perspective because the concordance type and degree was explicitly addressed by Scientist 1 in their response (“couldn’t agree more”). Their tone and body language also supported the *total agreement* assessment as they were pleased that Scientist 1 had brought this up.

Interactive Instance *Example 2 -*

S1: “I would break those stupid silos of like as if human is not an animal. This is freaking me out…The proof of this is that now Zebra fish is used as the human model!”

S2: “The endocrine system has evolved in different ways. And this is exactly what is fascinating for a comparative endocrinologist and toxicologist, when you apply these chemicals, how not only to pin the differences in the things we share, but the things that we don't share, because they are important.”

S1: “…..Well, you know, it's like is the glass half full or half empty?”

Concordance-type*: Disagree via emphasis*

Degree: *Significant (4/5)*

Here we see each scientist presenting views about how similar/dissimilar human endocrine systems are to animals. Both agree that there are differences and similarities, neither is advancing a position that contradicts that of the other, but they are both highlighting the importance of different components of the conversation. Scientist 1 is highlighting the differences, Scientist 2 is highlighting the similarities. This example is especially clear as Scientist 1's final comment explicitly references the fact this is a disagreement in emphasis when they suggest that each Scientist is focusing on different halves of the glass. In this example, significance degree rating was judged primarily from tone, with both participants clearly acknowledging the views of the other, but communicating through an assertive tone that they are unlikely to change their mind in this instance.

Interactive Instance Example 3 -

S1: "The government understand EDCs as more like an affect, than a chemical. This is a big difference in ideology and it lowers the importance of the topic"

S2: "I just don't think they are different to other toxic chemicals. They're definitely part of a general problem, but how much Endocrine Disrupting Chemicals are themselves, indeed, a very special category. Only time will tell."

S1: "That was my point in when I was saying that it's kind of a bit of a different category, due to these low dose effects. We need a different kind of model"

Concordance-type: *Disagree via inconsistent positions*

Degree*: Moderate (3/5)*

This interactive instance sees the participants present views that are mutually incompatible. Scientist 1 says that EDs are understood by the government as an effect, not as a chemical class in themselves. Explaining this is a problem as they argue it lessens the importance of the topics. Scientist 2 responds to this idea specifying that they don't think that EDs are their own category of chemicals, at least not on current evidence. Scientist 1 then maintains they should be considered a different category, because the low-dose effects they have been linked to require a different mode of analysis. Though they are arguing for the opposite viewpoint and presenting fundamentally different understandings of EDs, this was judged as only a 'moderate' degree disagreement, because each participant couched their claims with qualifying clauses (e.g. "I just don't think" "time will tell" "kind of a bit of a different category"), and because the tone was measured and distinctly non-confrontational.

A final point about the interactive instance coding is that the individual points made in an interactive instance were coded both as part of the interaction as in the examples above, and as individual uncertainty statements for the thematic analysis. As how a comment fits into an interaction and what a comment actual asserts can be judged on separate axes, I deemed to this coding decision to be a helpful and appropriate way of maximising the usable data.

After repeating this coding for each of the 37 interactive instances, emerging patterns in the form and degree of their concordance-type came into view. The statistical breakdown will be covered in the results and discussion section.

2.2.4.1 – Narrative

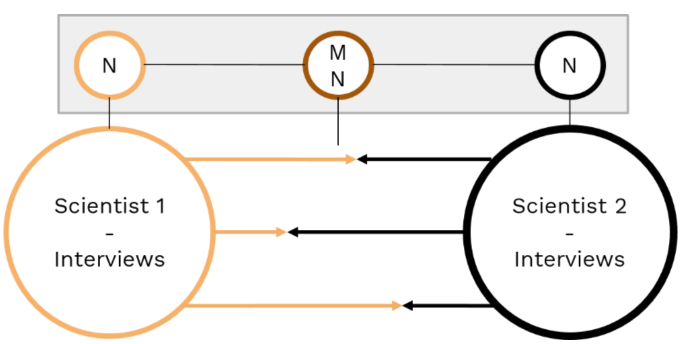


Figure 10 - *Visualisation of the study data with the emerging core uncertainty stories ('N') and meta-narrative (MN) highlighted in grey*

The narrative analysis drew from the previous two rounds of coding to inform a ‘core uncertainty story’ for each participant. This term referring to what was judged to be the central take-home message of the participant, which was then broken down into an inductively generated story structure code for presentation. To avoid hitting the notes but missing the music, a more mechanistic coding type approach was avoided in favour of a more holistic, reflective approach. The analytic decisions in this round were thus made drawing from my instincts about the data as informed by the time I’ve spent with it throughout the study.

The methodological choice to focus on deciphering a single ‘core uncertainty story’ was appealing partly in the interests of concise and impactful results, but also because both participants were keen to emphasise one through line in particular, meaning the data lent itself neatly to this kind of analysis.

After the two core uncertainty stories were chosen and written out, an inductive story code was developed as a method of sorting and presenting the stories as clearly as possible. The codes acronym spells ‘SPACE’, and breaks down as follows:

Setting – Where in the broader system is this occurring?

Plot – What is happening?

Actors/actants – Who/what is responsible or otherwise involved?

Conclusion – How will/should this be resolved?

Evaluation – What reflections do they have about it?

Once the two core uncertainty stories were sorted into the story code, the narratives could be compared and their divergences and similarities clearly presented. This will be formally presented and explored in the next chapter.

Lastly, the meta-narrative component of the analysis marks the emerging story after reflecting on the total data set, its analysis and the core uncertainty stories. The thoughts are sorted into the inductive story code as above. The meta-narrative serves less as a specific finding, and more a reflection on the findings as a whole. The meta-narrative and its generation will be explored in the results and discussion section.

Chapter 3 - Results and Discussion

3.1 - Themes

After conducting the thematic analysis along the axes of type, degree and locus for each of the 165 uncertainty statements made across the 6 interviews, a number of interesting patterns began to emerge. In this section, I will present and reflect on what I take to be the most notable observations. I will address each of the scientists' uncertainty statements in turn before discussing some similarities and differences.

A preliminary area to cover before delving into the results is the difficulties I faced in the thematic coding and what these mean for how the data should be interpreted. Reaching the final figures of both total statements and how the statements broke down into their respective categories involved and number of tricky decision junctures. These included the ambiguity of when one point ended and another began, the ambiguity of whether a repeated similar point was similar enough to count as the same point or whether it was different enough to count as a new one, and of course, the aforementioned grey area between the coding categories themselves.

Additionally, as already mentioned, the prompts themselves were designed to be open-ended and to maximise data richness within the confines of the study aims, but, due to their iterative generation in rounds 2 and 3, some prompts focus on particular types and locations of uncertainty, meaning they may skew the statistics somewhat. This skewing is particularly worrisome in terms of total mentions across the study, though may not be such a problem when comparing the scientists as they were both asked the same questions. One way of getting around the potential skewing in the analysis stage was bringing in the number of 'critical' mentions where possible, as it was assumed the participants would make it clear when they were discussing particular points that were significant, even if they didn't bring up uncertainty ideas from the same category especially frequently. For similar reasons, a crude summation of the average severity of the uncertainty statements from a given category was sometimes employed. Using statistics like these, the shape of the participant's uncertainty understanding can emerge, even with the threat of unevenly weighted questioning.

With these considerations in mind, I take it that the final figures I present in this coming section would be better understood as rough indicators rather than conclusive data points in themselves. Thus the tentative points I draw from the data are understood in this spirit.

3.1.1 - Scientist 1

After conducting thematic coding, my results showed Scientist 1 made 78 discernable uncertainty statements across the three interviews. Of these, 25 were methodological uncertainties (32.1%[61]) and 34 were societal uncertainties (43.6%). Leaving 8 as technical uncertainties (10.3%) and 11 (14.1%) as epistemic uncertainties. The breakdown of these results can be found in the graph below. A first stand out feature of this data is how much more methodological and societal were spoken about compared to the other two types of uncertainty. I understood this result as providing some indication that methodological and societal uncertainties were considered to be more important than the remaining uncertainty types, based on the reasoning that an increased number of mentions has some correspondence with understood importance. Though as already touched, this reasoning has limitations.

[61] All % to 3.d.p, meaning some % additions may add up to slightly over 100%

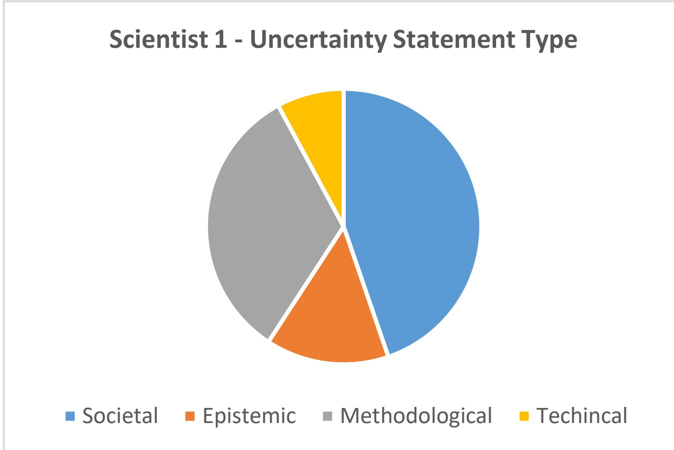


Figure 11 – *Pie chart showing the breakdown of Scientist 1's uncertainty statements by type*

Of all the uncertainty statements rated as 'critical' (the strongest severity of the 5 options), 7 of the total 15 critical statements were methodological, and 6 were societal (the remaining two were epistemic). A visualisation of this breakdown can be found below. I understood the 'critical' uncertainty statement result as providing further, and perhaps stronger, evidence that Scientist 1 understood Societal and Methodological uncertainties as the biggest contributors to overall uncertainty, as it is more difficult to dismiss the emphasis they put on a given uncertainty statement as being a feature of leading questions or influence from conversation direction.

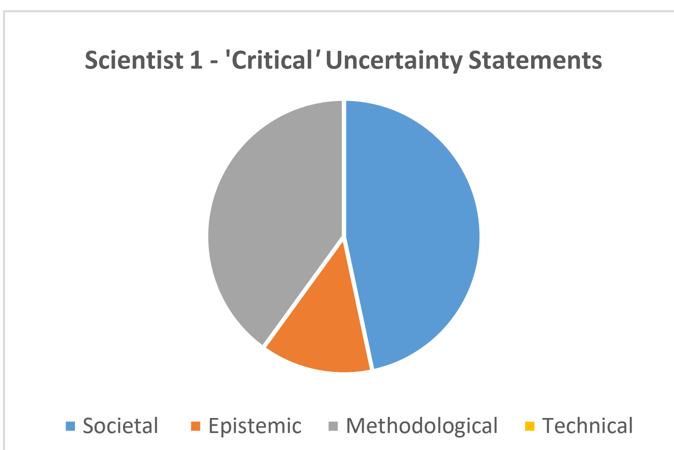


Figure 12 – *Pie chart showing the breakdown of Scientist 1's uncertainty statements by type designated 'critical' in degree*

These two data points of quantity of total mentions and quantity of critical mentions both point to the idea that Scientist 1 takes methods and societal uncertainties to be the stand-out issues in the field, and that they are roughly similar in importance.

In terms of where these uncertainties were understood as developing from in the systems, a more specific picture began to emerge. Of the 78 statements coded, 40 (51.3%) were understood as coming from general research, with a further 16 from the academic system (20.5%). Here we see the majority of the uncertainty statements were understood as emerging from the research itself, with a further 15 coming from the broader academic system. These results would suggest that for the participants, a significant portion of the uncertainty in the ED landscape stems from issues either in the research itself or associated with the broader research system (i.e. academia). This conclusion also fits neatly with my pre-coding impression from the interviews with Scientist 1, as they emphasised in several memorable moments the importance of improving our methods and research systems.

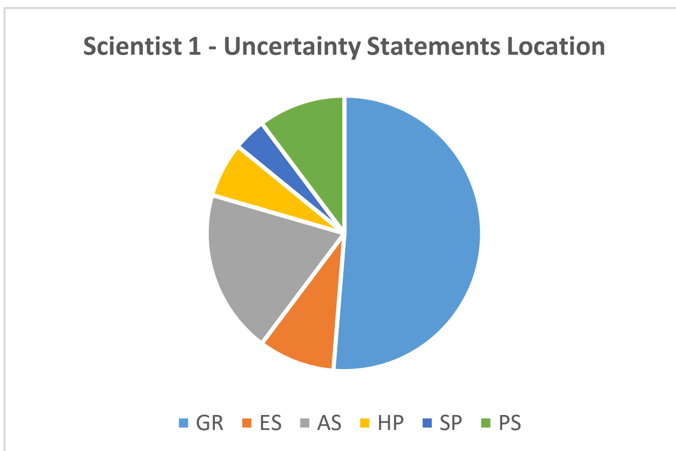


Figure 13 - *Pie chart showing the breakdown of Scientist 1's uncertainty statements by location*

One surprise the data produced compared to the pre-coding impression, however, was how much societal uncertainty was mentioned and how critical some of the associated statements were presented as being. During the interviews, societal uncertainty felt as though it was a concern but a fairly minor one compared to the methodological uncertainty concerns. In fact, the coding suggested Scientist 1 took these two uncertainty types to be of similar importance in the role they play in the broader field uncertainty.

Another interesting pattern I noticed in the data was that Scientist 1 decreased the number of 'critical' uncertainty statements they advanced across the process. Interview 1 involved 8, Interview 2 involved 5, and interview 3 involved just 2. It's difficult to draw anything too concrete from this observation, but one thought it might suggest that pertains to the original conception of brokered dialogue, is that throughout the conversation with the other participant, Scientist 1 may have gradually and instinctually approached the interviews in a manner that left more room for conversation, and so consciously limited the force of their points as each interview went on. If so, this could be understood as an indicator of the kind of cooperative attitudes that dialogue can foster.

3.1.2 - Scientist 2

Scientist 2 made 87 uncertainty statements across the three interviews, with a notable 55 (63.2%) coming from societal uncertainties. This dwarfed methodological at 15 (17.2%), epistemic at 13 (14.9%) and technical at 4 (4.6%). The breakdown can be noted in the pie chart below. Drawing on the reasoning employed in the previous section that suggests a correspondence between frequency of mentions and perceived importance, we could suggest that societal uncertainty is a clear contender for the most important of the four uncertainty types.

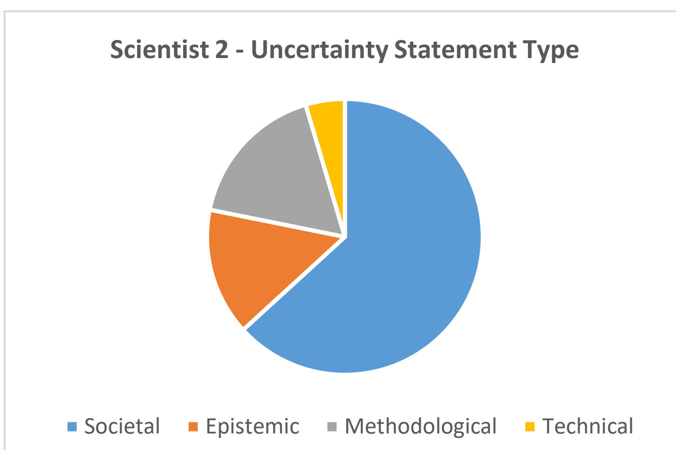


Figure 14 - *Pie chart showing the breakdown of Scientist 2's uncertainty statements by type*

Societal uncertainty standing out in this way is accentuated by the fact that 12 out of 14 critical uncertainty statements were societal (the remaining two were epistemic). The breakdown can be seen in the pie chart below. Again, drawing from the assumption that increased quantity of critical mentions has some correlation with how important the given type is held to be, this points to the idea that societal uncertainties are considered the most important uncertainty type by Scientist 2.

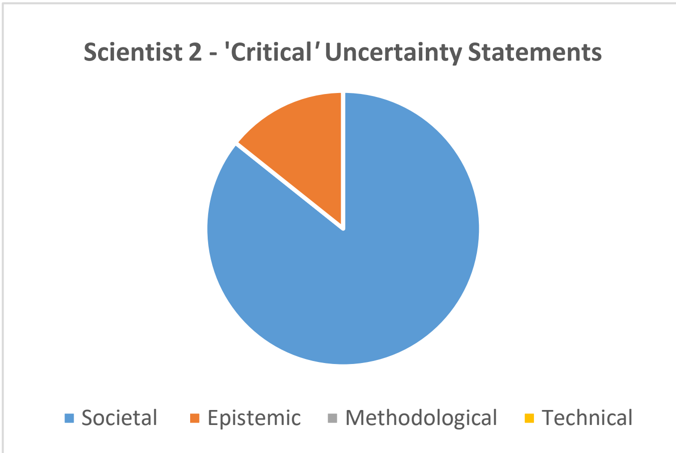


Figure 15 *- Pie chart showing the breakdown of Scientist 2's uncertainty statements by type designated 'critical' in degree*

In terms of where these (primarily societal) uncertainties are stemming from, a fairly even picture emerges, making an interesting contrast to the research and academia heavy locus of Scientist 1's statements. General research sees 29 (33.3%) uncertainties, the academic system sees 19 (21.8%), the political system sees 18 (20.7%), the economic system sees 11 (12.6%) with social phenomena seeing 9 (10.3%) and human psychology seeing 2 (2.3%). This data suggests that societal uncertainty is the primary issue, and that it permeates into all areas of the broader system.

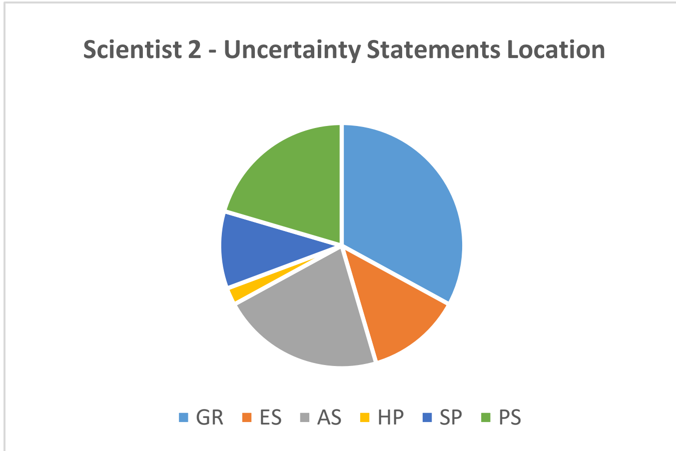
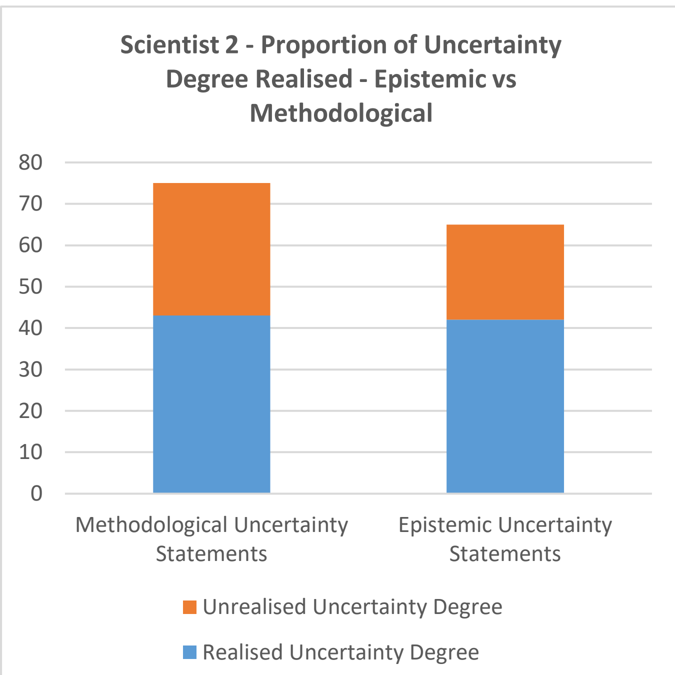


Figure 16 - *Pie chart showing the breakdown of Scientist 2's uncertainty statements by location*

Another interesting component to Scientist 2's interview data is how much importance they assign to epistemic uncertainty. Firstly, it was brought up a nearly identical amount of times to methodological uncertainty. This was a surprise in terms of my pre-study assumptions as I understood epistemic uncertainties as being much less likely to be brought up than methodological uncertainties on account of them being considerably more abstract than the more straightforward methodological uncertainties.

Relatedly, methodological and epistemic seemed to be understood as being of similar importance, this can be observed through the crude summation of the degree scores given to each of uncertainty statements made about the two types across the interviews. Adding up the total numerical degree ratings (out of 5) of each of the uncertainty statements made in that type, and then using that figure to compare against what the figure would look like if every statement in that type had been rated 'critical' (5/5), this gives us the proportion of realised uncertainty compared to potential uncertainty, or in simpler terms, the average severity of a given uncertainty type. I understood this as another statistic that could be helpful in providing some indication of how important the participant thought the given type of uncertainty was that had the advantage of being independent from frequency of mentions.

Doing this gives methodological an overall severity coming to 43 out of a possible 75 (57.3%), with epistemic coming to 42 out of a possible 65 (64.6%). These results suggest that though methodological claims were mentioned more frequently (10 more times), epistemic claims had a higher % of realised severity (or higher average severity), suggesting that though there were fewer claims made, the ones that were made were considered to be more significant. The two comparison bar charts below demonstrate these statistics, with the comparison of proportion of realised uncertainty on the left and the comparison of realised uncertainty as a % of total possible uncertainty (i.e. average uncertainty degree) on the right:



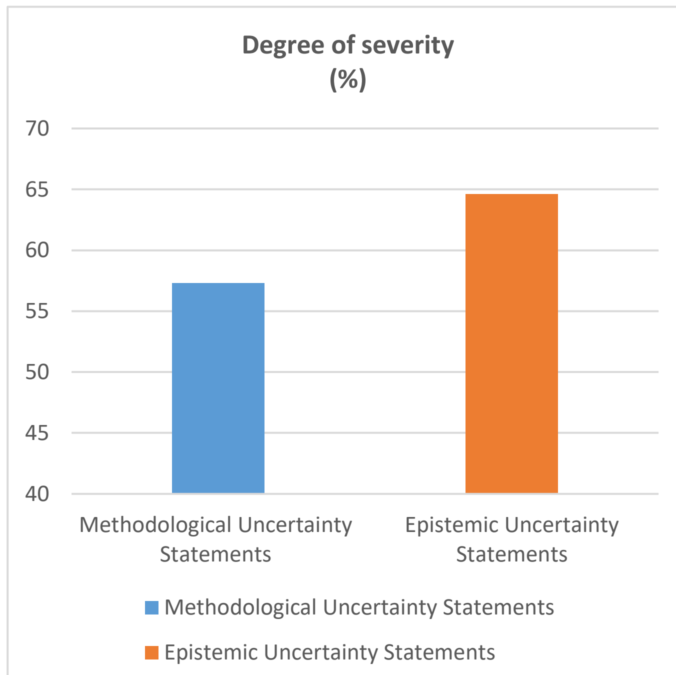


Figure 17 – *Two bar charts, the left bar chart showing the realised uncertainty degree as a proportion of the total potential uncertainty degree for Scientist 2's methodological and epistemic uncertainty statements, the right bar chart showing the same proportion statistics stated as a %*

A final component of the data that struck me was the two critical mentions of epistemic uncertainty, compared to the zero critical mentions for methodological. This observation, combined with the previous discussion demonstrating the average severity of epistemic uncertainty statements being more than with methodological statements, and societal uncertainty being the dominant uncertainty type overall (judging from frequency of mentions, number of critical mentions and average severity), the data begins to paint an intriguing picture.

Scientist 2 seems to be suggesting that the uncertainty issues with science don't lie with poor scientific practices, but with more fundamental ideas and processes concerning what kinds of knowledge are appropriate and what kind of broader structures (economic, political etc.) are best suited to promoting research success and so reducing uncertainty in the field.

3.1.3 - Comparison

When each scientist's data sets are compared side-by-side, some noteworthy similarities and differences come into view. This section will focus on illustrating and discussing some of the significant instances. A mix of example quotes and further graphs will be used to link the points to the data.

Key Similarity 1 – *Academic system causes problems*

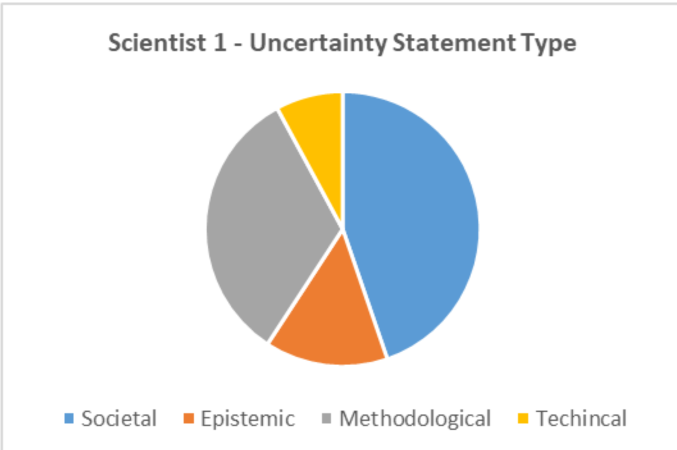
> *Example quotes:*
>
> *Scientist 1* – "Because unfortunately, particularly academics, are under a lot of pressure, they have lots of things to do, they work long hours, and sometimes they do a very superficial job in their research and in the papers, they don't have the time to check the data."
>
> *Scientist 2* – *"*Other limitations [concerning the University research context] are funding deadlines. The colleagues that are part of the project competitions. There's a lot of bias, also."

One interesting similarity is that both participants understood the academic system as being a significant generator of uncertainty. Different components of it were cited in making these points, Scientist 1 generally focused on how the system misincentivises academics, citing things like how academics are encouraged to produce a very high volume of papers that might not be conducive with rigour, and are rewarded when sensational or otherwise media-friendly results are produced. While Scientist 2 focused on the restrictions involved in the academic system, mentioning things like tight funding deadlines, low budgets and over-competition with colleagues. The consistent thread across these two lines of response was a need for significant systemic change in the academic system in order to reduce uncertainty in the ED research landscape.

Key Similarity 2 – *Societal Uncertainties are significant*

> *Example quotes:*
>
> *Scientist 1* – "We need to listen to all of these minorities better. We need to make sure that they have a voice on the table"
>
> *Scientist 2* – "I think when we are on the committee and making a decision to hire someone, to decide what's going to be the objectives, or what's going to be the experimental design of a given study, I think it's the same understanding that the diversity of opinions from different groups makes it more rich"

Another notable similarity in the data was how much both scientists understood societal uncertainties as being a core hurdle in improving reliability and reducing overall uncertainty in the field. I assumed, perhaps naively, before the study, that societal uncertainty wouldn't be something that the participants would be so keen to speak about. Thinking that they would both either consider it outside of their remit and so would bring it up less, or that they would naturally be more focused on the methodological, epistemic and technical uncertainties given that these types they encounter in their profession day-to-day. However, it was clear that both scientists understood societal uncertainties as a significant problem, and had considered, nuanced thoughts about these uncertainties, how they manifest and what could be done in the face of them. Some statistically backing of this similarity can be found below in the side-by-side comparison of the number of total number of type mentions for each scientist, although, as touched on, total mentions doesn't tell the full story. For Scientist 1, Societal uncertainties make up 43.6% of total mentions, for Scientist 2 this figure is 63.2%, in both instances they makes the most frequently mentioned type.



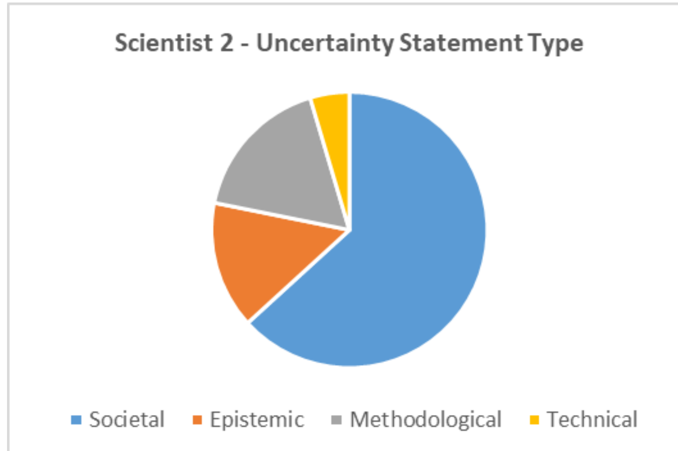


Figure 18 – *Two pie charts, comparing the breakdown of each scientist's uncertainty statements by type*

Despite this uniformly strong societal uncertainty understanding, there remains an interesting consideration in this area which I will touch on in the additional findings section concerning the potential for a degree of perceived distance between the participants and these societal uncertainties.

Finally, another thing to observe in Figure 18 above is the contrast in the number of methodological uncertainty mentions, this leads us to the first key participant difference.

Key difference 1 – *Different understandings of the importance of methodological uncertainty*

Example quotes:

Scientist 1 – "I don't disagree that we have lots of tests that could give us a very good clue in terms of what's happening. But whether this is only the potential of it happening or something that will definitely happen, that's where there is a lot of uncertainty and different evidence lies"

Scientist 2 –“Is the methodological factors where we need to improve? I don't think so. I don't think so at this point. I think we have good researchers in the field. I think people know what to do, how to do it”

The first and perhaps most stark difference between the two participants’ data sets was how differently they seemed to understand the role of methodological uncertainty in the field. Scientist 1 understood it as being one of, if not the most significant[62] uncertainties in the field. Whereas for scientist two, it was a much less substantial component of the broader uncertainty in the field. Where this idea might be most visible is in Scientist 2 advancing no critical methodological uncertainties, whereas Scientist 1 advanced 6, making up 40% of the total critical uncertainty statements they put forward. The breakdown of the critical mentions are shown side-by-side below in Figure 19.

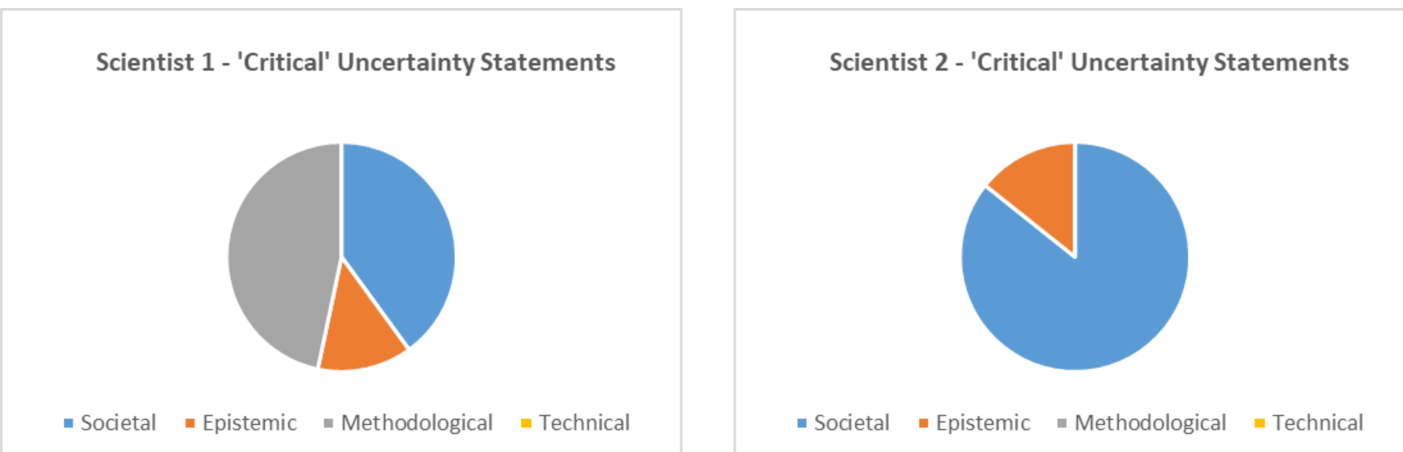


Figure 19 – *Two pie charts comparing the breakdown of each scientist’s uncertainty type by designated ‘critical’ in degree*

Further, if we add the total severity scores of all the methodological uncertainty statements made, Scientist 2’s come to 43, which is under half of Scientist 1’s total of 103. This comparison can be seen in the Figure 20 bar chart below. More dramatically, Scientists 1’s total of

[62] Judging from methodological having the most ‘critical’ uncertainty claims

methodological uncertainty mentions just from round 1 was higher than Scientists 2's total across all three interviews

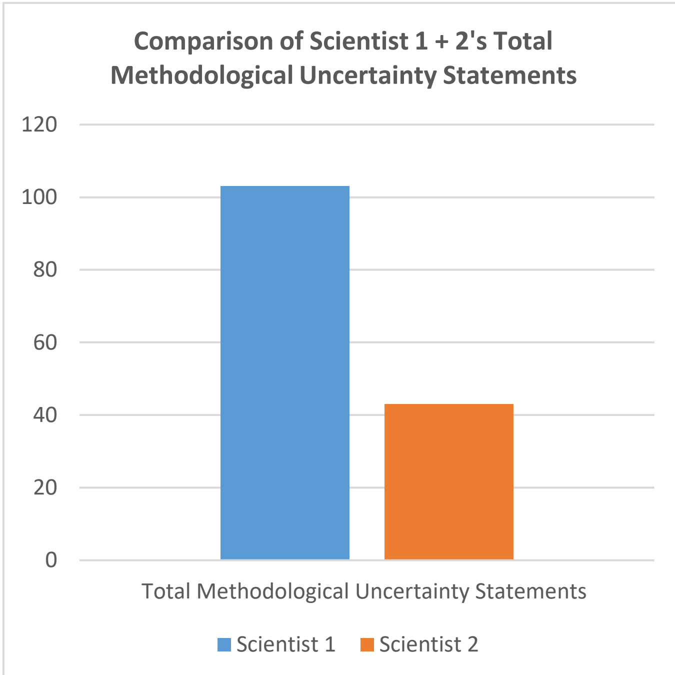


Figure 20 – *Bar chart comparing the total methodological uncertainty statements advanced by each scientist*

This difference will be explored further in the narrative analysis, but for now it's worth noting the significance of the difference and the significance of these different understandings for where best to focus our attention in advancing the ED science field, improving research reliability and reducing uncertainty.

Key Difference 2 – *Different understandings of the key loci of uncertainty*

Another key difference related to the above comes in the where the uncertainties are understood as coming from. Of Scientist 1's 78 statements, 40 (51.2%) were understood as coming from the research itself (GR). Of Scientist 2's 87 statements, just 29 (33.1%) were understood as coming from the research. Meaning that the vast majority of the places in the broader system where Scientist 2 understood the uncertainty as being located were in non-research components of the system, and that this was not the case for Scientist 1.

For Scientist 2 the political system, the economic system and social phenomena all have a significantly higher proportion of Scientist 2's total uncertainty statement location breakdown than in the equivalent breakdown for Scientist 1. This difference in concentration/dispersal of uncertainty location can be observed in the side-by-side comparison of pie charts in figure 21 below:

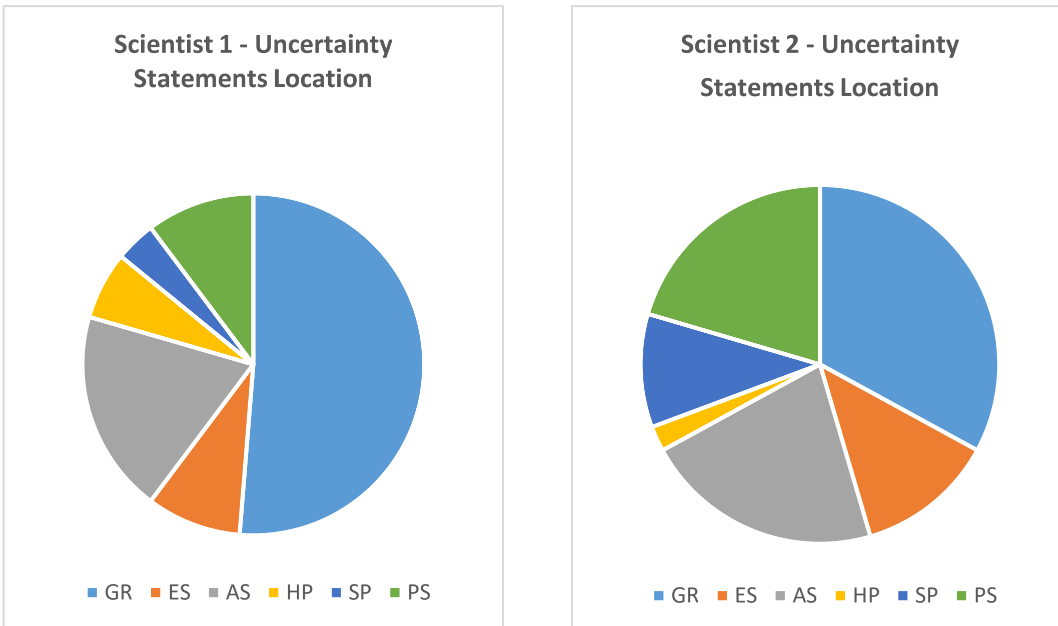


Figure 21 - *Two pie charts comparing the breakdown of each scientist's uncertainty statements by location*

A further point to make here is that of the 6 critical uncertainty statements located in the economic system that were advanced across the interviews, 5 of those came from Scientist 2. This marked over a third of Scientist 2's total critical uncertainty statements, and nearly all of these referenced the influence of industry actors in some way. This point will be touched on again in the narrative analysis

Further differences

Drawing from the data, Scientist 1 and Scientist 2 seemed to have different understandings of the significance of technical uncertainty. Though both mentioned it the least often and assigned it the least severity, if we add the total severity scores of each Scientist's technical uncertainty claims, Scientist 1's come to 27, whereas Scientist 1's come to 15. Scientist 1's score being nearly twice as high suggests that technical uncertainties were perceived with different degrees of importance across the participants.

An interesting last difference I would like to mention is Scientist 1's slight emphasis on human psychology as a source of uncertainty, and Scientist 2's slight emphasis on social phenomena as a source of uncertainty. Scientist 1's ratio of mentions across these areas is 5:3 human psychology over social phenomena, while Scientist 2's ratio across these two areas was 2:9. A visualisation of this ratio can be found in Figure 22 below, as taken from the comparative location pie charts above. Though I think the small figures here preclude any firm claims, the discrepancy does raise the idea that scientists could understand broader social structures as being the locus of uncertainty problems, whereas others might trace those same uncertainty to issues to individual human psychology. This is a significant framing distinction as it has the potential to affect the most appropriate response

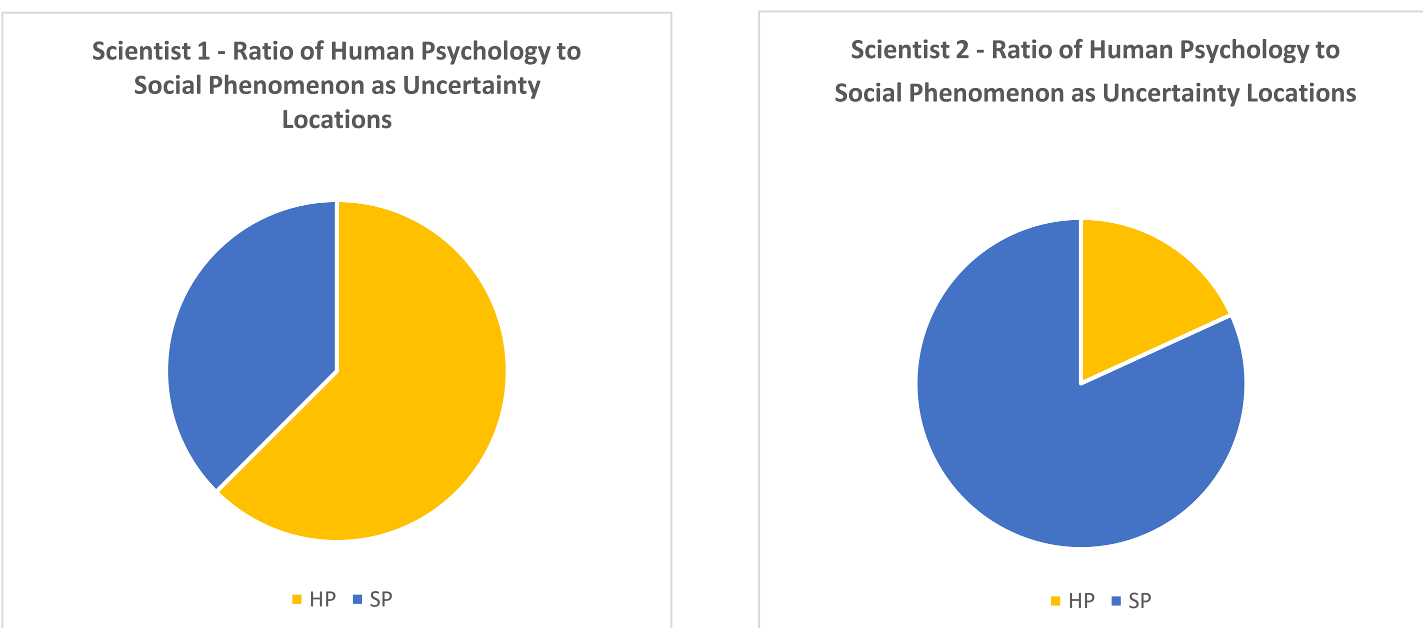


Figure 22 - *Two pie charts comparing the ratio of each scientist's Human Psychology and Social Phenomenon located uncertainty statements*

A specific example of this phenomenon in action could be Scientist 1 arguing that over-production of research papers (to the degree that quality is compromised) might stem, in some instances, from individual scientist's egos as they try to make a professional name for themselves. On the other hand, Scientist 2 discussed the same problem (over-production of papers) as relating to broader social processes like how young, untenured academics are under structural pressure to get funding and better job security. Here a similar situation is framed differently, one frames the issue as internally generated, and the other frames it as externally applied. The importance of the fact these issues can be framed different is that each framing may call for a different set of responses in dealing with it.

3.2 - Interactions

The interactive analysis, as delineated in the methods section, focused on the individual interactive instances between the two participants. In what follows, I will first cover the statistics produced by the coding to reveal a broad breakdown of the levels of agreement and disagreement throughout, before giving examples what I take to be notable interactive instances. Discussion will be embedded throughout.

Emerging Interactive Picture

There was a total of 36 interactive instances across the 6 interviews (all contained to rounds 2 and 3 by nature of the methodology). 15 were characterised as an Agreement, 9 as Disagreement Via Emphasis (DVE) and 12 as Disagreement Via Inconsistent Position (DVIP). A further statistic to cover at the outset is the accumulative degree score for each type. Agreement comes in at 49, DVE at 22 and DVIP at 32. These statistics are visualised in turn in the two pie charts below:

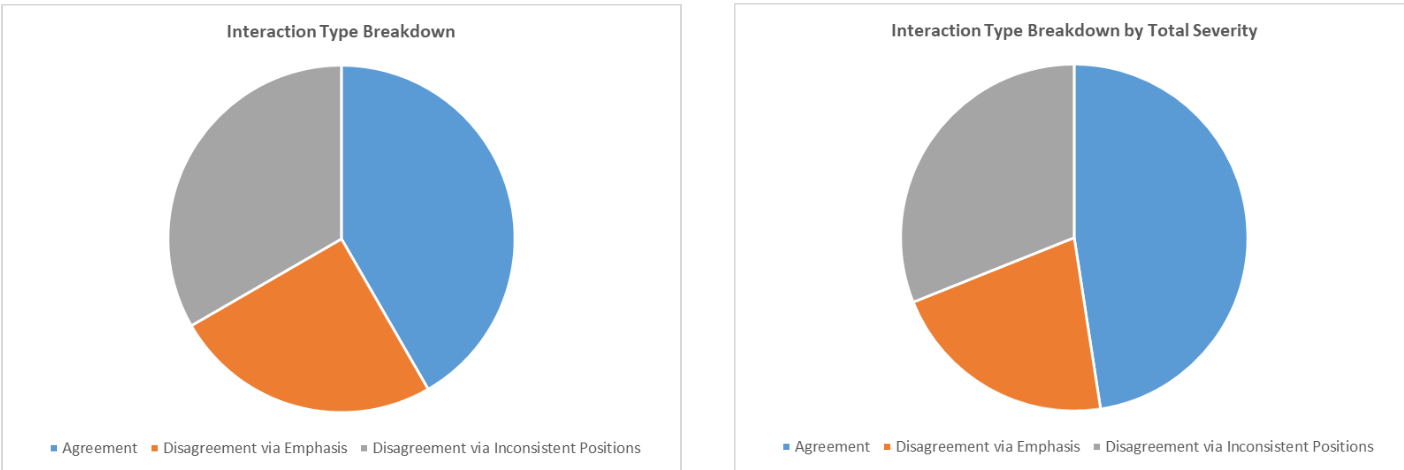


Figure 23 - *Two pie charts, left pie chart showing the breakdown of the interactions by type, the right pie chart showing the breakdown of interactions by type's total severity*

The largest of the concordance types, in terms of both frequency and accumulative degree score, is agreement. Making it, by a fairly clear margin, the dominant concordance type emerging from the coding. A further statistic that supports this comes from the realised potential of statement severity i.e. average severity, calculated as a % of the severity score compared to what the score would be if every comment made of that type was maximally severe (similar to the statistic used in section 3.1.2). I understand this as forming a rough representation of the average intensity of a given concordance type. Here, agreement is 65.3%, DVE is 48% and DVIP is 53%. Here again, agreement comes out on top.

Though agreement is the dominant concordance type, it's notable that taken together, the different types of disagreement make up the majority of the interactive instances and the accumulative accordance-type severity. So although agreement reigns as the dominant concordance type, it is outweighed by the two forms of divergence recorded throughout the interviews.

These thoughts and statistics combined point towards a general picture of minor but frequent disagreements between the two participants on the discussions around uncertainty in the ED field. Perhaps not a surprising find given the divergences in uncertainty understanding that the thematic data suggests, but still a significant finding against the backdrop of the study aims.

Moving onto illustrative examples, I will cover some of the key agreements, before moving onto notable DVEs and DVIPs. What counts as a key interaction is judged by the degree to which they agree or disagree, with more severe instances of a given concordance type understood as more important.

Key Agreement 1 – *The importance of diversity*

One key agreement was the importance of diversity in the field for reducing uncertainty and increasing reliability. This was understood by both participants as an ethical imperative and also as an epistemic one. They cited diversity in broad terms, both mentioning gender, race, age and nationhood – arguing that all are vital for the progression of the field and reduction of scientific uncertainty through increased numbers of perspectives reducing the chance of research blind-spots.

This came up twice across the interviews and in both instances the level of agreement was judged to be 'total' (5/5).

Interaction exert:

> **S2:** "I believe that everybody has a different perspective and everybody should have a voice the table. The more diversity, the better it is."
>
> **S1**: "Yeah, absolutely. I'm on all those committees. And it's very important to me, like in my lab, I make sure I have men, women and different sexual orientations, different countries, and it's very important. And they're right because according to what you learn

> and experience and where you're from, it's going to be a different set of ideas that you're going to bring to the table”

Key Agreement 2 – *The importance of interdisciplinary work*

Another key agreement was on the importance of interdisciplinary teams and communication in improving the science and reducing uncertainty. Both participants agreed that there wasn’t enough of this at the moment and that it was something that needed to be urgently addressed. This level of agreement was also judged as ‘total’ (5/5).

Interaction exert:

> **S2: “**I think the best is to have the disciplinary teams, obviously. It's a bit like Facebook. I think science is like Facebook. If your friends and all the people in your field think that way, that's what you think. And then that reinforces your own beliefs. But then if, finally, you join this group with all these other ideas, people understanding things differently, then you're like, oh! You're learning and you see things that you never considered before”
>
> **S1**: “I couldn’t agree more. And that's exactly because it's a complex system. It's one of those areas where it benefits greatly from different approaches.”

Key Agreement 3 – *The need for increased data transparency*

The participants strongly agreed on the need to be more transparent with data. Both agreed that there is a need for researchers to publish all their data, where possible, and for this to be as normalised as possible. This was also judged to be an instance of ‘total’ (5/5) agreement.

Interaction exert:

S1: “And now the funding agencies are moving into showing and publishing all the raw data. So soon anyone will basically be able to go and redo the stats of every single project. ”

S2: “It won't prevent everything…but its a very good idea, is an excellent idea. ”

Key Disagreement Via Emphasis 1 – *What is reasonable ambition in the breadth of study subjects*

A key disagreement via emphasis came when Scientist 1 suggested that we need to do fundamental research on a much greater variety of species at different trophic levels and with different reproductive cycles etc. Scientist 2 responded by agreeing that this is the case in an ideal world, but suggesting that we need to be realistic, and given the tools and resources available, we’re doing the best we can presently. Scientist 1 then responded by saying they ‘half see the point’ but that they aren’t saying we should do things more expensively, just better. I understood this as a disagreement in emphasis as both scientists agreed on what we should do, in ideal circumstances, to improve the certainty in the science. Where they came apart was where they chose to draw the line between realism and idealism, and so where our research priorities should and shouldn’t fall. This degree of disagreement via emphasis was judged as significant (4/5).

Interaction exert:

S2: “Fundamental research on invertebrate species, lower trophic organisms, enough with the fish, OK? If you want to revisit fish, improve your models. Three species with the same reproductive strategy, when you have 35,000 species and you can choose whatever you like, it's a crime. Its convenience is not science.”

S1: “I agree with her, in the perfect world where money would not be a constraint, politics would not be there, economical issues would not be there, the reality of scientists is that we don't have a lot of funding. Yes, it's convenience, because that's the species I have in my lab and I'm interested in pushing the fundamental understanding of EDCs. I'm going to use the model I have because, you know, there's a difference between what's the best, even for science, and the reality, right? We all have limitations."

S2: "It's an issue, of course, but I'm not suggesting necessarily to use more expensive models, I'm just saying use different models. So you build up the knowledge, you know. They're not necessarily all inconvenient or difficult to source."

Key Disagreement Via Emphasis 2 – *How to approach industry influenced research*

A key DVE that received a 'significant' (4/5) came when Scientist 2 stated in certain terms their distrust for industry funded research. Science 1 then responded by distancing themselves from Scientist 2's strong position, but conceded that they would also be initially distrustful of a study funded by industry. This was understood as a disagreement via emphasis as it seems they approach industry papers with a similar and compatible distrust; they come apart in the degree to which this distrust is held.

Interaction exert:

S2: **"**Well, obviously, if it's funded by the industry, it's not going to be trusted. Well, not by me. Not by me. Zero. Zero. And it can it can be like a friend of mine who conducts the research. I will not trust it…they are allowed to change the rules of the game, which I don't agree with."

S1: "I think, in my own interview, I also said that the industry by definition, are less trustworthy, because they do have an agenda, they make these chemicals they sell them, they make profit out of them. And although I don't take such a military attitude, because I think that there is a responsible industry too, I wouldn't necessarily trust something from industry straight away either.

Key Disagreement via Inconsistent Positions 1 – *Appropriateness of inter-phylum extrapolation*

A first disagreement via inconsistent position comes in Scientist 1 discussing a tendency in the literature to extrapolate the result of an ED study from one phylum to another when there isn't enough evidence to warrant such a move. Scientist 2 responded by arguing that this is actual often good practice and well-justified, as there is lots of endocrine system overlap across phylums. Though there is a sense in which this is a disagreement via emphasis (like the similar interactive instance used as an example in the methods section), we find an inconsistency here in Scientist 1's assertion of a tendency to over-extrapolate vs Scientist 2's assertion that this over-extrapolation is not an issue. How problematic or not they find this phenomenon is where we see the inconsistency.

Interaction exert:

> **S1:** "Of course, something that very few people appreciate, I think it used to be called the applicability domain, which is basically what animals are we talking about. Are we talking about humans, mammals, fish, invertebrates? Because there is a tendency to generally mix it and try to make extrapolations from one phylum to another where they don't hold."

> **S2:** "So I do agree with them that we have to be careful in doing generalisations, but at the same time, I don't think we should not make generalisations because we don't have the data, or let's not make a rule or a regulation because we don't have data for a turtle, you know? The endocrine system is very well conserved. If it's present in birds, in mammals and in fish, amphibians are in the middle. So most likely we could use the data from one group to the others….I would say the opposite, I would say we should do more amalgamation"

Key Disagreement via Inconsistent Positions 2 – *The nature of academic incentivisation*

Another key DVIP came when Scientist 1 argued that a key generator of uncertainty in the ED scientific field comes from the way academics are assessed, arguing that the system incentivises poor research. Scientist 2 disagreed and argued that the system does emphasis high output, but that it also emphasises high quality. Scientist 2 also countered Scientist 1's idea that academics sometimes don't check their work as much as is appropriate due to sensational results are rewarded in the system by arguing that Academics have a strong ethics and that this isn't really a problem at the moment. This disagreement was

Interaction exert:

> **S1**: "Yeah, well, I think it starts from the way academics are being assessed. So basically they're under pressure to produce papers that are under pressure to have impact. And sometimes, I mean, some of them even admitted it publicly, they make up data even. I'm not suggesting that this is happening to a great extent. Very few people will fall for this, but many will not check the quality of the data. And they would be more than happy to follow a sensational result, even if it's just a mistake."
>
> **S2**: "But the constraint was to do good quality papers. Many good quality paper, not just many papers….I think that academics have strong ethics."

3.3 - Narratives

3.3.1 - Participant Narratives

After conducting the thematic and interactive analyses, and after much reflection on the data as a whole, the core uncertainty stories of the respective participants began to emerge. This through line, as covered in the methods, was then integrated into an inductively generated story code designed to present each core narrative as clearly as possible. This code broke down as S.P.A.C.E, a reminder of what this acronym stands is below:

Setting – Where in the broader system is this occurring?

Plot – What is happening?

Actors/actants – Who/what is responsible or otherwise involved?

Conclusion – How will/should this be resolved?

Evaluation – What reflections do they have about it?

With a reminder of the narrative analysis methods delineated, what follows is the results of process:

Scientist 1 – Core Uncertainty Story – *The Faulty Academic System*

Setting – Academic Research Institutions

Plot – A combination of weak methodologies and a misfiring academic system which isn't set-up to encourage best research practices produce a dearth of effective research. This is the core generator of uncertainty in the ED scientific landscape

Actors/Actants - Academics, research methods, the broader University system, funding, publicity, status

Conclusions – There needs to be wholesale changes to the academic research system. This includes changing how academics themselves are incentivised, increasing the diversity of those academics doing the science, more thorough data checking and data transparency, more real-time monitoring and a much wider scope of test subjects

Evaluation – There is a lot that we still don't know, and making these changes to academics and academic research will be the key to getting to the level of certainty we need to start affecting real change

Scientist 2 – Core Uncertainty Story - The Corrupting Industry

Setting – Chemical Industrial Complex

Plot – Industry influence in research is a core generator of uncertainty. Industry plays by different rules and produces research that serves its interests, muddies the water and casts doubt when other research runs against their interests. They are the biggest hurdle to advancing the scientific conversation presently

Actors/Actants – Chemicals industry, lobbyists, poor regulation, non-industry complacency, profit

Conclusions – Some research changes like breaking the silos between human and animal research will be helpful, but ultimately we need drastic regulatory changes to reduce and contain industry influence as much as possible

Evaluation – We know quite a lot, we have generally strong methods and we're doing a good job given the confines. The hurdle between us and the necessary consensus is industry – if we can deal with this, we can make the long-overdue changes

3.3.2 - Meta-Narrative

Building on the above, we can generate a meta-narrative to tie the results together –

Meta-Narrative - The Diverging Uncertainty Understandings

Setting – ED Research Landscape

Plot – Two ED scientists, selected on the basis that they were judged to be part of and broadly representative of different epistemic cultures, have differing understandings of the uncertainty in their field. Scientist 1 understands the core uncertainty issue to be related to research methods and broader issues with academia. Scientist 2 understands the core uncertainty issues to be associated with larger structures around the science, the biggest issues of all coming from the influence of industry in the field.

Actors/Actants – Scientist 1, Scientist 2

Conclusions – There's a need for increased communication across cultures. And there's also a need to review the efficacy of the academic system in the ED research context, as well as the influence of the industry on the certainty/uncertainty in the ED science landscape.

Evaluation – I think this divergence between these two scientists is significant enough to support the notion that there are diverging epistemic cultures in the ED context. Primarily because, despite the significant overlap and many instances of agreement, both scientists located the core uncertainty issue in different places and partially downplayed the core issue of the other participant. Aside from this, the civility and nuance of the conversation gives me hope that continued cross-culture communication is viable and productive; all we need to do is provide more opportunity for it to occur.

3.4 - Additional Finding

Aside from the data and analysis already presented, and following from the point made in 'Key Similarity 2' regarding the understood importance of societal uncertainties, there was an interesting result I felt important to include but that didn't easily fit into the three-step analysis approach or the resultant core uncertainty stories.

In the preliminary conversations I had with other experts in the lead up to the research, there was a recurring response to my questions along the lines of these topics being best discussed in social settings with alcohol. As well as occurring multiple times in off-record discussions in the lead up to the study, this fairly specific image cropped up unprompted three times during the interviews themselves, advanced by both participants. For illustration, the quotations from the study are below:

- "But again, that's another bottle of wine discussion"
- "We can talk about that over beer for a long time"

- “I do actually, quite often [talk about the broader factors that affect science’s reliability], but usually at the pub rather than at the lab”

It’s difficult to make much of this result at first, given that these sorts of phrases are employed in day-to-day life in a variety of contexts and their meaning is very general and roughly equivalent to “this is a conversation for a more casual setting”. However, I think there is more to glean from this result, so, drawing from recent developments in psychoanalytic qualitative analysis[63][64], and following psychoanalysis’ ‘interpretive’ philosophy[65], I will explore some potential implications of this pattern and what it might tell us about how the participants perceive, either consciously or unconsciously, the kinds of topics we covered in our conversation.

I list and explain some potential ‘reads’ of this result below:

1. *These conversations are interesting but ultimately tend towards frivolity. Their potential un-seriousness keeps them in the casual, social realm, and outside of the professional sphere.*

This interpretation draws from the associations of alcohol with fun and unserious environments. Thus, suggesting the conversation is one to be had in these settings is understood as linking the nature of the topics involved in these conversations with such unseriousness. Though, anecdotally, this read does seem to apply to some scientists when discussing science studies ideas, I understand this read as being the least likely of the four in this instance

2. *These conversations are important, but the participants perceive a certain distance between themselves and the topics being covered. Perhaps the conversations are to be taken seriously, but they are outside of their remit and so, if discussed by them, better to do so in*

[63] Holmes, ‘Using Psychoanalysis in Qualitative Research’.
[64] Stamenova and Hinshelwood, *Methods of Research into the Unconscious*.
[65] Kernberg, ‘The Four Basic Components of Psychoanalytic Technique and Derived Psychoanalytic Psychotherapies’.

a relaxed, amateurish manner rather than with any potential implied expertise or responsibility.

This interpretation understands consigning the study's topics to the drinking setting not as undermining their seriousness, but as an admission of non-expertise. Here the scientists might be acknowledging, or at least not commenting on the topic's seriousness, instead only communicating that they would only be able to discuss this in the manner interested amateurs might talk about any topic. This one seems possible, but both participants touched on the importance of scientists engaging with these ideas, which makes this read also unlikely.

3. *These conversations are somewhat taboo or otherwise generally not spoken about. The intimate audience more common in relaxed social setting, as well as the fact these conversations would be off-record, suggest that these discussions could be somewhat controversial and so best discussed in a private setting loosened by alcohol.*

This interpretation draws from three components to drinking environments: (1) the inebriation and resultant lower inhibitions, (2) being in a relaxed, intimate setting and (3) being 'off-record'. These three aspects all permit discussion of more taboo topics than a formal interview would, and so by the participants suggesting the conversation would be better had in those environments, they might be implying that these topics are themselves taboo. Given the controversial nature of the discussions being had, this seems possible, but their general willingness to discuss things throughout the interview makes me understand this read as unlikely also.

4. *These conversations are best had in a non-confrontational setting. These topics need to be discussed, but their contentious nature requires that it be done in as relaxed a setting as possible.*

This interpretation draws on the association of drinking environments with friendliness and open-mindedness. It suggests that these conversations are important, they are qualified to have them, and the topics aren't taboo, but because of the contentious nature they should be had in a way that would involve minimal tension and antagonism. This is the reading that I take to be most likely judging from my experience in the interviews.

This analysis, though carefully considered, is of course highly speculative. The truth could be a mix of these, or, of course, none of these. Thus I present it not as a formal part of my thesis results, but rather to stimulate discussion and perhaps provide some thoughts for future research directions.

3.5 - Study Reflection

3.5.1 - The Broader Picture

Before getting into the specifics about the successes and shortcomings of the study as a whole, it will be helpful to discuss the findings of this research in context.

In the literature on the endocrine disrupting expert deliberation, the expert groups are sometimes split into two broad camps[66]. In the first group, experts consider endocrine disruptors to be a novel category of toxic substances[67] which pose particular threats to the endocrine system that can't be captured in conventional toxicology studies, as such they tend to recommend a precautionary management strategy as the default. In the second group, experts argue that, on current evidence, endocrine disruptors appear as a form of toxicity like any other, thus they contend thresholds for adverse effects can be established and that the chemicals themselves can be used provided they are handled appropriately and exposure is limited. On top of this, there are a number of other distinguishing features that have been used in the

[66] McIlroy-Young, Leopold, and Öberg, 'SCIENCE, CONSENSUS, AND ENDOCRINE-DISRUPTING CHEMICALS'.
[67] Zoeller et al., 'A Path Forward in the Debate over Health Impacts of Endocrine Disrupting Chemicals'.

literature to imply differing expert groups roughly along these lines, such as their understanding of whether or not rigid weight-of-evidence protocols are currently possible in the ED decision making context (the first group arguing they aren't, the second group arguing they are)[68]. As touched on in the context of my own analysis, these sorts of differences in framing, reasoning and values make these groups natural fits for the application of the epistemic culture concept.

Though it's not an exact fit, Scientist 2 seems to suggest ideas more in line with the first epistemic culture, where Scientist 1 suggests ideas more in line with the second epistemic culture. An example indicator of this split can be seen in how the scientists in this study understood how EDs should be categorised, with Scientist 1 suggesting they don't have special status compared to other harmful chemicals, where Scientist 2 argues they should be understood as their own category due to the possibility of low-dose effects.

Working from these epistemic culture assignments, we can see an interesting connection between this work and that of McIlory-Young's in my lab[69]. Her focus group work suggests that the two groups characterise one another along the lines of character archetypes, e.g. the 'Activist Scientist' who's personal agenda is that of environmental activism, with this biasing the science they conduct[70]. To build on this from the perspective of my core narrative results, we might understand each participant as presenting archetypes of 'shady industry agents', and 'ineffective science practitioner', with the former being a character who clouds the science in favour of promoting industry interests, while the latter marks a character who, due to the shortcomings of the academic system and ineffective methodologies, is struggling in their bid to provide robust research on the dangers of EDs.

[68] Clahsen et al., 'Understanding Conflicting Views of Endocrine Disruptor Experts'.
[69] McIlroy-Young, Leopold, and Öberg; McIlroy-Young, 'Chemical Controversy'.
[70] McIlroy-Young, 'Chemical Controversy'.

The ‘shady industry agents’ would be a neat fit in the second narrative, similar to McIlory-Young’s ‘invested industry’ and ‘shady scientist’ archetypes. The ‘ineffective science practitioner’ doesn’t fit as neatly in McIlory-Young’s results, as the activism accusation in the ‘Activist Scientist’ archetype is narrower than the haphazard, publicity minded, broadly misfiring researcher advanced in Scientist 1’s core uncertainty narrative. However, despite this misalignment, these ideas are not at odds with one another as both advance the thought that some university-based scientists are conducting ED research non-optimally and thus present a hurdle in the advancement of the broader ED science field.

From these parallels, we can see how the two core narratives my study has produced further develop the idea of different epistemic cultures engaging in narratives that understand other parts of the research system in broadly distrustful ways. One insight, first sketched in McIlory-Young’s work[71], and brought out especially clearly in this research, is the idea that scientists involved in these different cultures might understand different institutions as being more or less trustworthy than scientists from other groups. Scientist 1’s distrust being more contained to academic institutions and their research quality, and Scientist 2’s distrust being more contained to industry, and their general influence on the field.

In my research, I’ve understood this lack of trust to be linked to where in the system the core uncertainties are understood as being generated, whereas McIlory-Young understood the lack of trust in terms of narrative characters and the traits they’re understood as having. In either case, the epistemic cultures at hand (whether the first or second narrative, or more nuanced permutations) exhibit a degree of distrust directed at institutions in the broader system. This distrust is a feeling that we shouldn’t ignore if we want to advance the conversation and improve

[71] McIlroy-Young.

the science, both in terms of the mutual understanding of those practicing, and in terms of the quality of the eventual research being produced.

3.5.1 - Study Strengths and Limitations

This study's novelty has prompted a consistent reflection on what it does well, and the areas where it could be improved for anyone hoping to pursue similar lines of inquiry. I will cover the most important of these thoughts here.

A first strength of the study comes in the extended time periods spent with the participants (nearly 3 hours in both cases). This allowed for an extensive data set which permitted an in-depth analysis of their perspectives. Less concentrated interviews formats wouldn't have been as successful here.

An additional strength more specific to the chosen methodology was the insight dialogic analysis provided on the ins and outs of the inter-culture dynamics. There were a number of ideas and understandings that would have remained uncovered if a more conventional isolated interview style was employed.

Finally, though it wasn't explicitly measured, the discussion format seemed to build a degree of understanding between the two participants. This is of course a happy side-effect in an area of scientific impasse like the ED scientific landscape.

Aside from these strengths, there were a number of limitations. A first one comes in the study's founding thoughts. Specifically, that the scientists under study (1) are likely to come from a particular epistemic culture, and (2) are likely to be representative of it. Though I've argued there is good reason to advance these, the fact remains that these premises are not conclusively established. This is an important analytic vulnerability in my study because it leaves room for other phenomena to account for the differences in understanding. For example, the understandings exhibited throughout the interviews could have been informed by the scientists' individual values, rather than the more collective-values framing the epistemic cultures concept advances. This wouldn't be totally destructive in terms of study insight, as values diverging and influencing uncertainty understandings would still be important information, and could still be mapped and understood in a grouped fashion, but the framing of the deliberation as being culture-orientated and the associated insight would be undermined.

The promptive brokered dialogue format, despite the strengths already mentioned, led to some moments of stilted dialogue, repeated topics and instances of miscommunication that wouldn't have occurred in a face-to-face dialogue. Though this would not have been possible anyway given the Covid-19 research context, and there was perhaps some interesting data points that would not have been revealed in a more head-to-head set-up, the constant civility and open-mindedness of the participants made me question the utility of the brokered component of this dialogic research.

A final point to mention related to the analysis is that a lot of time was spent coding the data - though this did reveal some interesting components to the participant responses that may not have been possible otherwise, given that my research was focused on highlighting cultural perspectives and gauging core narratives, it might have been a better use of time to have coded less and used that time to introduce extra experts from the respective epistemic cultures into the interview process, to broaden and bolster the data set.

3.5.2 - Key Takeaways

There is a notable core divergence in understandings of uncertainty in between the two experts, and this supports the notion that they do belong to different epistemic cultures and so, *a fortiori*, that different epistemic cultures exist in the ED scientific landscape. Despite lots of agreement, there were consistent disagreements throughout, sometimes on fundamental lines (e.g. how to define EDs themselves). The difference in core uncertainty stories saw differences in the understood dominant uncertainty type (Scientist 1-Methodological and Societal, Scientist 2-Just societal) and in understood location of the uncertainty (Scientist 1-primarily stemming from research shortcomings and issues with academia, Scientist 2-primarily coming from the process over-and above the research, primarily stemming from industry actors).

3.5.3 - Future Research Directions

In terms of research directions my study results point to, I take there to be three standouts. These are numbered and explained below:

1. *Epistemic Cultures in the ED field* - Research on epistemic cultures in the ED scientific context, both in terms of exploring for further evidence of their existence, and, provided the picture develops as it has done so far, in attempting to map their perimeters and features.
2. *Encouraging Dialogue in the ED field* - Increased attempts to encourage inter-group dialogue, both as a research technique and also to help foster the communicative and co-operative environment needed to advance the ED field beyond its current stalemate.
3. *Research focused on the issues raised in core uncertainty stories* – Further research on the effects the academic system and the industry have on uncertainty in ED science landscape.

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Appendices

Appendix A. Interview Questions

N.B. In the spirit of the exploratory nature of this research, space was for left in the interviews for spontaneous questions and prompts following from points made by the participants. However, the core conversation starter questions that were posed to both participants in each round are listed below:

Round 1

1. What factors make for better, more trustworthy evidence in evaluating the potential harms of EDs?

2.a. Are social factors relevant to how the potential harms of EDs should be studied and assessed? If so, can you give an example?

b. Are there others in your field who would respond differently? If so, how might they respond?

3.a. What methodological factors might improve the trustworthiness/reliability of evidence in evaluating the potential harms of EDs? Can you give an example?

b. Are there others in this discussion who might answer differently? If so, how?

4. Given these factors, how might we move forward?

Round 2

1. Can we address our most pressing uncertainty problems solely by improving our technique and methodology? Or are there other important issues to address? If so, what?

2. To what extent is the standardization of data gathering and assessment a benefit to the reliability and trust of EDC science, and to what extent is it a hindrance?

3. As expert judgement plays such a central role in the evaluation of chemicals, does it matter who these experts are, beyond having expertise in the subject matter? If so, why and what other competencies and considerations ought to be weighed when selecting expert panel members?

Round 3

1. If 0 is totally in the dark about the potential harms of ED chemicals, and 10 is total knowledge about every aspect. Where would you guess we are at the moment?

2. Do different experts value certain types of evidence differently? Do these different evidence-type weightings affect the reliability of the science being produced?

3. If there is a dose-response relationship, is it essential to be able to reproduce this relationship in different studies (whether monotonic or not)?

4. In your opinion, how much uncertainty in the field results from miscommunication, misinterpretation or terminological ambiguity? I.e. uncertainty from ineffective communication between people, rather than from methodological error or equipment imprecision etc.

5. Can different value judgements or biases in the problem formulation be a source of uncertainty?

6. Do you understand profit-based motivation as a generally positive influence on the ED science field, a negative influence, mixed influence or neutral? Why?

7.a. Do you talk to your colleagues or students about the kinds of things we've been discussing in these sessions? (i.e. about broader contexts surrounding science) Why, why not?

b. How seriously do you find these topics are taken in ED scientific deliberation more broadly?

Appendix B. Raw Data

Thematic Analysis - Scientist 1

Types of uncertainty	**Number of individual statements** *By round then total*			**Total score on severity by round +** *Total critical mentions of type/total critical mentions*		
Technical	2	2	4	7 *0/8*	8 *0/5*	12 *0/2*
Total	8			27 *0/15*		
Methodological	10	6	9	44 *4/8*	26 *3/5*	33 *0/2*
Total	25			103 *7/15*		
Epistemic	3	4	4	12 *0/8*	15 *1/5*	13 *1/2*
Total	11			40 *2/15*		
Societal	11	15	8	45 *4/8*	42 *1/5*	28 *1/2*
Total	34			115 *6/15*		

Round	**Location**		
Round 1	GR 15	ES 2	AS 5
	HP 2	SP 2	PS 0

Round 2	GR 11	ES 3	AS 6
	HP 2	SP 0	PS 5
Round 3	GR 14	ES 2	AS 5
	HP 1	SP 1	PS 3

Thematic Analysis - Scientist 2

Types of uncertainty	**Number of individual statements** *By round then total*			**Total score on severity by round +** *Total critical mentions of type/total critical mentions*		
Technical	0	2	2	0 *0/4*	8 0/5	7 0/4
Total	4			0/14		
Methodological	2	11	2	7 *0/4*	29 0/5	7 0/4
Total	15			0/14		
Epistemic	6	4	3	19 *0/4*	10 1/5	13 1/4
Total	13			2/14		
Societal	26	17	13	85 *4/4*	62 4/5	49 3/4
Total	55			12/14		

Round	**Location**		
Round 1	GR 5	ES 4	AS 8

	HP 0	SP 6	PS 11
Round 2	GR 15	ES 4	AS 7
	HP 1	SP 3	PS 4
Round 3	GR 9	ES 3	AS 4
	HP 1	SP 0	PS 3

Interactive Analysis

	Agree	**DVE**	**DVIP**
Scientist 1 - R2	4	3	3
	3-5-5-5 17	3-2-2 7	1-3-3 7
Scientist 1 - R3	3	2	4
	3-5-3 11	2-2 4	3-2-1-3 8

	Agree	**DVE**	**DVIP**
Scientist 2 - R2	4	0	3
	3-1-3-5	0	2-4-3

	12		9
Scientist 2 - R3	4	4	2
	1-3-2-3 9	4-4-2-2 12	3-5 8