TRAINEE TEACHERS' UNDERSTANDINGS OF NEWS STORIES ABOUT SCIENCE: BEYOND IDEAS ABOUT UNCERTAINTY

by

JOHN ROBERT KIRKMAN

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College of Social Sciences
University of Birmingham
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ABSTRACT

This study explores how science and history trainee teachers, who have different amounts of higher education in science, respond to news reports about science. In semi-structured interviews, using researcher and reader selected articles, readers were asked about the likelihood of veracity of knowledge claims and also their reactions to what they read.

The thesis reports a range of heuristics which served to increase, or decrease, epistemic distance and so make the reader more or less willing to accept scientific claims as true. The quality of participants' responses to news stories was also examined by using concepts maps to identify the extent to which ideas were interconnected. Concept maps were found to have a networked structures for both groups of participants, however, there was limited evidence for participant use of 'ideas *about* interconnectedness', thus there was limited evidence of epistemic thinking. The veracity of news stories is largely indeterminate for the non-expert reader given the limited information contained in the story and so readers' multiple understandings are emphasised. Overall, there was not much difference between the two groups of readers.

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ABBREVIATIONS

A-level	General Certificate of Education Advanced Level or GCE Advanced Level
AS-level	General Certificate of Education Advanced Subsidiary Level
A2-level	General Certificate of Education Advanced Level (usually completed in the second year of the qualification)
AQA	The Assessment and Qualifications Alliance
CASE	Cognitive Acceleration through Science Education
GCSE	General Certificate of Secondary Education
HEI	Higher Education Institution
Hi	History
IaS	Ideas about Science
ITE	Initial Teacher Education
NoS	Nature of Science
PGCE	Post Graduate Certificate in Education
PgDipEd	Post Graduate Diploma in Education
QTS	Qualified Teacher Status
Sci	Science
SL	Science Literacy/Scientific Literacy
SPU	Science for Public Understanding GCE Advanced Level Qualification
SSI	Socio-scientific issues
URL	Uniform Resource Locator (Web address)

CHAPTER 1: INTRODUCTION

1.1 Introduction

Existing research within science education that explores how people respond to news reports about science have often been within the context of socio-scientific issues (SSI) and evaluating information which will later be used in SSI decision making (Sadler, 2004). The approach has thus taken a somewhat narrow view of evaluation as not all scientific knowledge is associated with such an issue. Research from an information studies perspective (Brand-Gruwel and Stadtler, 2011) has explored how people undertake searches on the internet, judge the credibility of websites and solve problems. This research has adopted a more generalist position and has sometimes neglected the role of specific disciplinary knowledge. Other research has paid particular attention to uncertainty (Norris and Phillips, 1994; Norris et al., 2003), a perspective that could limit readers' thinking. Further, other researchers have explored what experts say about reading news stories (McClune and Jarman, 2010) rather than examining what people actually do when they read news stories. The research in this thesis seeks to address some of these issues in the context of post graduate teacher training.

In this research the goal is to examine postgraduate trainee teachers' understandings of news reports of science, with a particular focus on relationships between advanced scientific education and these understandings. One goal of this study is to make some recommendations about how teacher educators might help trainee teachers to improve their critical reading of news reports of science, which in turn could help trainees to work with their pupils in this area. A further goal is to explore the nature of these understandings.

News reports cover a wide range of topics associated with science: from contentious issues, such as the safety of nuclear power where expert opinion is divided, to more individualistic contexts such as in the selection of consumer goods. News reports, as a genre, are written to be accessible to the reader but also to present something that is newsworthy and that will keep the reader buying a newspaper or visiting a website (Jarman and McClune, 2007). Thus a news story requires a different kind of approach to reading and understanding than a textbook, for example (Mallow, 1991).

One goal of science education in schools is to provide pupils with some tools for autonomous evaluation of science they encounter in their everyday lives, including in news stories (Norris, 1995a; Millar, 1996). This might be broadly described as scientific literacy, a research area that has generated much interest recently (see Robert, 2007 for a review). While there is not an agreed definition of the term there has been much attention internationally on devising school curricula which have the goal of preparing people to be able to engage intelligently with science, even though they are not going to be practising scientists. The body of work on scientific literacy is relevant to this research as news stories are one aspect of science that is encountered in everyday life.

1.2 The researcher and origins of the thesis

This research has its origin in my experiences of teaching Science and Physics in English secondary schools for more than a decade. Gradually my own conceptions of the nature of scientific knowledge changed as I became aware of uncertainties associated with the knowledge I had previously accepted as unproblematic. In my more recent roles as teacher educator, I noticed a variety of perspectives on the certainty of scientific knowledge among the trainee teachers I worked with. I also became increasingly interested in curriculum design

and content, in particular the shape of a curriculum that claims to develop students' scientific literacy.

This thesis follows on in a somewhat tangential way from my MA thesis which was entitled "Pedagogy and the Nature of Science: What do teaching strategies 'say' about science?" (Kirkman, 2005). My concern then was that trainee teacher's actions in the classroom gave the impression that science was a body of knowledge that was unquestionable and authoritative in nature In other words, that any uncertainty present in science knowledge was omitted from teaching. A particular concern was that practical work was often related to the "discovery" of scientific ideas in science lessons, an approach which I felt dishonest. Pupils could leave lessons with the impression that scientific explanations naturally 'fell out' of observations. In Woolnough's terms this is 'stage-managed heurism' (1991, p.4) and contrast to views such as those of Lewis Wolpert in his book 'The unnatural nature of science' (1992) where science is seen to be far from intuitive.

My reading led me to explore personal epistemologies (for example, Baxter Magolda, 1992) and how college students became more questioning of authority as their studies progressed and less accepting of a 'right answer' with respect to knowledge. Completing a conversion diploma in Psychology after my MA in Educational Studies fed into the process because the differences between psychology and physics as a discipline became apparent. For example, in psychology texts almost all knowledge claims are accompanied by author names, something that is absent from most physics text; there is a difference in the epistemologies of these two subjects (Hofer, 2000).

Finding the Mortimer and Scott (2003) perspective on interactive teaching give me insight into how a teacher can engage their pupils in learning canonical knowledge in their science

lessons, while remaining 'true' to science as a discipline. It shows that it is possible to engage with an authoritative body of knowledge that is potentially very dry to learn. In this approach to teaching, the teacher opens up a topic using a 'dialogic' approach, drawing upon students' ideas. Later they close down the dialogue between students and the teacher and bring in an 'authoritative' perspective on the topic under discussion. As a consequence of these insights, issues of uncertainty became less problematic for me.

However, a further issue was emerging: the 'new' Key Stage 3 and 4 National Curriculum (QCA/Crown, 2007a; QCA/Crown, 2007b). I felt that it represented a significant change in curriculum content, a radical change in philosophy, but that teachers I worked with, and I as practicing teacher at the time, mainly carried on with what we were doing before. The curriculum documentation shifted the focus away from substantive scientific content towards How Science Works, which can be described as practical skills with a basic insight into the philosophy of science. Alongside this shift in emphasis away from learning substantive content, there was a philosophical change in focus. Great emphasis was placed on the view that pupils should not be primarily learning science that is a preparation for further qualifications, but that they should be learning science that would allow them to engage with science in their everyday life. With the criticism that this was 'pub science' appearing in the press (Critics attack new science GCSE, 2006), I became increasingly interested in what sort of science knowledge is needed for someone who will be engaging with science as a citizen, for example responding appropriately to articles that appear in the news. An implication of this thinking is that there are certain things that could be learned in school which are transferable to a different situation or context, things that are, at least to some extent, content-transcendent (to use Norris's 1997 term).

My motivations for undertaking this study are complex. A significant motivation is the expectation within my institution that academic staff should have a doctoral qualification. Another motivation is that I would like to establish a research profile and a PhD is a step in this direction. When I embarked on this study I had been studying part-time for four years and as such, scholarship had become part of my life. I am also interested in developing my own teaching as a science teacher educator. I am hoping that the findings of this study will allow me to better prepare trainees to read a news report about science, and understand more about the epistemologies of scientific knowledge.

Working as a teacher trainer based within a Higher Education Institution (HEI) is my second career with school teaching being my first. My principal role is teaching and administering the Science: Physics Post Graduate Diploma in Education (PgDipEd) (formerly Post Graduate Certificate in Education, PGCE). I have been in this role for around 7 years in total and part of my work has been to visit trainee teachers while on placement in secondary schools. During these visits I am expected to observe lessons and offer feedback. Thus, while no longer teaching within secondary schools myself, I am in close contact with school-based partners.

In my work as a teacher educator news reports are raised infrequently within university based sessions and occasionally I will observe lessons where trainee teachers make use of news reports in their teaching. It is not a core part of the role; however, helping trainees to become familiar with contemporary pedagogic approaches and the school curriculum is part of the role. Reading news reports is an example of what a teacher in school might do to help students engage with science as part of their everyday life, and so it is relevant to trainee teachers and teacher educators.

My reading of related literature suggested that that were limitations in studies that asked readers to explore the quality of science in the news. This topic, thus, became the focus of my research. The research strategy was emergent in design and consisted of three main phases. Initially I conducted a pilot study with four participants to identify suitable news stories and find how many stories would be appropriate to examine during an individual interview. The pilot study led to a first phase of 26 interviews where readers were given the same four news stories to read during interviews. Also during these interviews participants were asked to complete a questionnaire where they gave some information on their educational background. Further, the questionnaire asked readers about their views on the likelihood veracity of the scientific knowledge claims given in the news story headlines.

During analysis of the first phase interviews it became clear that participants' responses were not limited to discussion of the truth, or veracity, of scientific knowledge claims. Thus, the first phase interview approach appeared to restrict the breadth and depth of readers' responses. I made the decision to open up the interviews to allow participants the opportunity to talk more widely about news stories. In this second phase of interviews, which involved a different cohort of trainee teachers during a different academic year, I undertook individual preliminary interviews to obtain information about readers' educational background. The preliminary interview was also to explain to participants that I wanted them to identify news stories which they would read and bring to a second interview. At the second interview for each participant I asked questions which allowed, as much as possible, for readers' spontaneous responses. In Figure 1.1 I have summarised the three empirical components of the study.

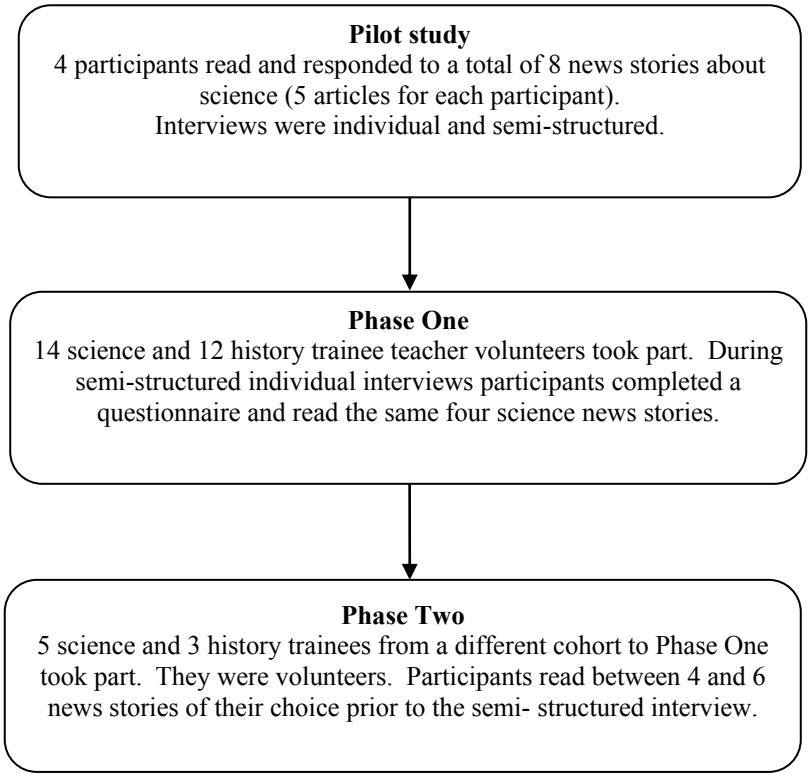

Figure 1.1: Flow diagram to show the three phases of empirical data collection.

This study is interpretivist in nature and so I am, as the researcher, the main research instrument. My experience, understandings, interpretations and insights are central to this study. Unlike research in positivist traditions I have not attempted to strive for objectivism or to check my judgements with measures such as inter-rater reliability. Instead, issues of bias take on a different hue within the interpretivist paradigm. Within this paradigm it is my experience, knowledge and humanity that *allow* situations to be understood (Carson et al., 2001) rather than getting in the way of analysing and reporting findings.

1.3 Participants and research setting

The University of Birmingham is a large Russell group university in the Midlands of the United Kingdom. It has around 18,000 undergraduate students and 8,000 postgraduates. Within the School of Education there are a larger proportion of postgraduates than within the

wider university. Teacher education courses within the University of Birmingham are highly rated in the Good Teacher Training Guide (Smithers, 2012) and also by Ofsted (2011; 2013).

The context of this study is initial teacher education (ITE) and therefore there are two sites of interest – the HEI teaching room and the school classroom or science laboratory. These places are where trainees learn *about* the school context and where trainee teachers gain their practical experience respectively. The teacher training and school contexts are closely related as the latter is the topic of study for the former. These two locations represent my own main workplaces both historically and currently.

All participants were PGCE/PgDipEd students at the University of Birmingham. The course is a 36 week long and leads to the award of Qualified Teacher Status (QTS). It is also taught at Masters' level and successful students will leave the course with 120 credits, most of which are at Masters' level. The trainees have a range of backgrounds and these are described in more detail later in this thesis. All have at least an honours degree. There are two groups within this study: those who are completing a course in science teaching (with a specialism in biology, chemistry or physics) and those who are training to be history teachers. The general guide is that participants' first degrees contain at least fifty percent of the subject they are training to teach. Having two contrasting groups allowed comparisons to be made about their uses of scientific ideas. At the time of the research I had established working relationships with some of the trainees, especially the science trainees. The research was done following the main assessment period on the course so as to avoid potential conflict of roles as tutor and researcher.

The responses of trainee teachers to news reports are interesting for two reasons. The first reason is that they represent people who one would be expect to be competent readers, after

all they have studied science to at least school level and have studied to at least undergraduate level. I suppose they might be considered a 'best case' when compared to a wider group of people from society. Thus responses are suggestive of what is possible or achievable. Secondly they will, if they are not already, be teaching within a school curriculum that is, at least in part, intended to further pupils' literacy, whether this is scientific literacy as described above or more general literacy. While the relationship between teachers' actions and their practice is not straightforward (see Lederman, 1999, for example) it is important to know how trainee teachers themselves interact with media reports because it has some bearing on what they do in the classroom.

1.4 Related research

The topic of this study lies at a confluence of research about SSI, scientific literacy, personal epistemologies, decision making, teacher education, the nature of science and critical thinking. Each of these fields is substantial in size and will be examined in more detail in Chapter 2.

Research that is very closely linked to this study includes the research undertaken by Korpan and others in 1997 where they asked first year undergraduates to read especially constructed articles and writing down what other information they would need in order to decide if the key points were true. Further, Kolstø (2001) researched 16-year old school pupils' views on the trustworthiness of scientific information given in preparation for discussing an SSI. Zimmerman et al. (1998) explored what factors influenced readers' credibility rating of fictional short news reports. Furthermore, the work of Norris and Phillips (1994) and Norris et al. (2003), where school and university students make judgements about the certainty of

knowledge claims, was influential to this work, especially the key finding that readers tend to demonstrate a certainty bias and read claims as being more certain than suggested in the text.

1.5 Research aims and questions

The main aim of this study is to examine educated readers' responses to popular news reports about science. A further aim is to look at any relationships between advanced study of science, such as a first degree, and these understandings. Thus in this study the explanandum, the thing I am trying to explain, are any differences in understandings or approaches taken by readers, and a hypothesised explanans, the thing that explains any differences, is the readers' science qualifications (Luker, 2008). A significant theme for the study is the extent to which prior learning can be generalised to a new context. Another broad area of interest is how people draw upon epistemological understandings about the nature of knowledge, in particular knowledge of science.

The research questions for this study are:

- What heuristics are used by readers when they reason about the quality of science published in the media? Are there differences in heuristic use based on readers' formal education in science?
- To what extent do readers integrate what they read about science in the media with other knowledge? Is there any relationship between the extent of integration and readers' formal education?
- How do readers understand news reports of science? Are there differences in the understandings of readers with advanced formal education in science and those without?

1.6 Overall strategy

The design of the study was emergent with each stage being dependent on the previous stage. There was a pilot study which informed the first main phase of data collection. The lessons learned and the limitations identified from the first phase were used to inform the second phase. The analysis was emergent too and not planned *a priori*. In qualitative research it is recommended by Robson (1993) that a theoretical framework should be established at the start of a study. In this study, however, the two analytical frameworks used in chapters 5 and 6 emerged late in the study. I have tried to be careful to identify the influences that led to these analytical frameworks. However, they have come about as a culmination of reading of previous research, from repeated reading of interview transcripts and from multiple attempts at identifying suitable analytical approaches, so some influences may not always be clear.

The primary source of evidence for the study is from 34 individual semi-structured interviews where participants talked about four (or so) news articles about science. Further evidence came from emails, face to face and telephone communications which was mainly to arrange the interviews and answer any questions about the research. Within the interviews the questions asked were intended to explore how the trainee teacher had gone about reading the article and the understandings they had of the articles. There were also questions intended to get both basic and more in-depth background information about the participants and other contextual details.

Broadly, the main strategy for analysis throughout the study is comparison. The comparisons have been made between individual units of data, categories of data and previous findings. The strategy has similarities with a constant comparative approach (Glaser and Strauss, 1967). However, I have not followed a specific method. Furthermore, constant comparative methods

are often associated with Grounded Theory and I would want to deny that my research has discovered any underlying theory (Thomas and James, 2006); instead my view is that the comparative approaches adopted here have helped develop explanations for the data.

1.7 Glimpse of the methodology and analytical approach

The two main empirical phases of the study have different methods. In both phases I used individual semi-structured interviews and genuine media reports of science that appeared on news websites. In the first phase I selected the news reports, partly because they are short and relatively easy to read in a limited timeframe. In the second phase participants selected articles on two main criteria: that they were about science and that they were of interest to them as the reader.

The goal of the research strategy was to set up a situation where participants encounter a media report and describe their thinking about the content of the report. In the first phase the readers encountered the news story for the first time in the interview and were asked about their initial reactions. In the second phase the readers had selected the article and bought it along to the interviews; thus it would be expected that they would have read the news story for the first time prior to the interview. In all interviews, some questions were kept deliberately broad to allow the reader to respond in a range of ways. Prompts and probes were used to try and obtain deeper responses. Thus each interview, even in the first phase where all readers looked at the same articles, was different.

Interviews were audio recorded and transcribed. The first phase data was analysed by using what might be described as a data filter. The data filter allowed the identification of parts of the text where there was a coupling between a cue and a conclusion. This is described later in Chapter 4, but briefly I was looking for things that made the reader more or less confident in

the knowledge claims they had read. An example would be that some readers identified information about the scientific methods used in reported scientific research that made them more willing to accept what they had read. For the second phase data I used two analytical approaches. The first was to produce concept maps for the interview data and look for evidence of how the reader had made links between those ideas found in the news story, and other ideas. The second was to identify a number of themes from the data and explore these themes and relationships between them for individual readers.

1.8 Original contribution to knowledge

Some previous research about understandings of news reports of science has focussed on issues to do with certainty, understanding evidence or critical reading. The main contribution of this study is to show that a broader view of reading about science, one that moves beyond ideas about certainty of knowledge, is necessary to account for the wide range of responses to news stories articulated by participants. Furthermore, when embarking on this study I was working within a broadly generalist position, akin to the generalist position adopted by some critical thinking writers such as Ennis (Moore, 2004) where critical skills are seen to be able to be applied to wide ranging situations. I did not know this at the time, however, as this has become clearer in retrospect. It can be seen in Chapter 4 that I was pursuing a rule based approach to understanding and judging certainty of knowledge claims. As the study progressed it became clear that while some 'rules' could be identified, such as a large sample size makes readers more confident in research findings, when to use these 'rules' was not clear from the findings. Moore rejects a generalist position about critical thinking but suggests students learn what Barnett (2000) calls 'increasingly sophisticated relativism' (in Moore, 2011, p.272). Similarly, in this study, Chapters 5 and 6 describe participants'

understandings of news stories and the links that they make to other ideas. These understandings are not rule based but complex and interconnected.

In this study I have made use of concept maps as a means of identifying the links that participants make between ideas. As far as I know concept maps have not been used in this way before. Furthermore, the use of in-depth semi-structured interviews to explore responses to news stories is not something that has been widely reported in the literature. There has been much philosophical discussion in science education literature about the potential for intellectual independence for the layperson (Norris, 1995a; Grandy, 1995; Norris, 1995b). Generally it is denied that this is possible and the best that non-scientists can hope for is being able to make a judgement about the epistemic authority of the scientists. This study gives a somewhat more optimistic perspective and emphasises that readers can respond to news stories using a wide range of ideas. These ideas include those present in the story, but may also include ideas from other sources, including from readers' prior learning or ideas that are generated by the reader themselves.

1.9 What is not included

Criticisms of some research in the field of public understanding of science and scientific literacy have included what has been called a 'deficit model' of scientific knowledge (e.g. Irwin, 1995). Briefly this is where researchers have identified ignorance of, or inability to apply, scientific ideas. In this study I was keen to avoid a situation where the focus is on what is not known and not understood. I now adopt the assumption that it is not useful to say that a response to a news report of science is 'wrong' or 'incorrect'. It is my view that the situation is not this simple. Thus I have tried to avoid judgements about the "correctness" of

participants' ideas. I am more concerned about what readers have been able to do rather than what they have not been able to do, the focus is thus on their understandings.

1.10 Thesis overview

I have structured this thesis such that Chapter 2 offers a review of relevant literature and offers a rationale and explanation of the research questions. Chapter 3 is devoted to methodology and there I seek to explain and justify my research strategy. I made the decision to separate discussion about the data collection strategy and writing about my approach to analysing the data. The reason for this was that the approach to analysis emerged during the research and understanding the approach to analysis is an important part of understanding the analysis. Following the advice of Thomas (2009) I integrated the findings, analysis and discussion. Chapter 4 gives the approach to analysis, the findings, the analysis and discussion for the first phase interviews. Chapter 5 is concerned with ideas about interconnectedness based on interviews from the second phase. In Chapter 6 I am also concerned with the second phase interviews but use a thematic analytical frame with two themes; the first is about readers' understandings about knowledge, the second is about the loci of knowing. In Chapter 7 I draw a conclusion, discuss implications and make some recommendations.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This study is concerned with experienced readers' understandings of news stories about science with a particular emphasis on the relationship between formal science education and these understandings. In part it addresses the question: How can a non-expert understand the science they read in the news when they have little, if any, substantive knowledge of the article content? This is an important question because school, college or university courses deal with only limited specific disciplinary knowledge and the extent to which that can be transferred to new contexts can have consequences for the reader. For example, important personal and professional decisions may be made based on their understandings of the science they encounter in the media.

The specific site of this research is university-based initial teacher education (ITE) but the context of secondary schools is also relevant as trainees are preparing to work in that context. Trainee teachers' own approaches to reading and making sense of news stories may inform their own classroom practice. This is further justification for examining this question. Implications from this study will include possible developments in ITE programmes that would better equip trainee teachers to respond to news reports and possible pedagogic strategies that trainee teachers can use with the pupils they teach (see section 7.5).

In this chapter I will set out the research questions for this study and give a rationale for these questions. The first two questions are about readers' use of heuristics, or rules of thumb, as they reason about the quality of scientific knowledge. How philosophers and others have

written about judging the quality of scientific knowledge is relevant here, with a particular emphasis on 'certainty' (section 2.4). Ideas about reasoning and decision making are also relevant to this research question (section 2.5). The associated findings, analysis and discussion can be found in Chapter 4.

The second two questions are concerned with how readers integrate what they read in news stories with other ideas. As background for this question I draw upon literature about critical thinking (section 2.6) and introduce the idea of 'interconnectedness', a concept that will ultimately be used to produce the analytical approach described in Chapter 5.

Towards the end of this chapter in section 2.9, I set out to review other empirical studies which have explored how readers respond to media stories. In some ways discussion of these empirical studies need to be read in parallel with the other sections in this chapter; however, I decided that sections 2.2-2.8 offer a useful background and have therefore put the review of empirical studies near the end of Chapter 2.

The final two questions are broader in nature and are concerned with readers' *understandings* of the science news they read. The rational for these questions draws upon much of the discussion in this chapter including the personal epistemology literature, which is concerned with attitudes or dispositions, rather than specific skills or concepts.

2.2 Expertise and the critical non-expert

The uncritical acceptance of knowledge claims that invoke science as a warrant can disadvantage the individual and a society more widely (Thomas and Durant, 1987). Furthermore, efforts to engage citizens in decision making in relation to SSIs relies on access to reliable scientific information (e.g. Sadler, 2004). In order to be able to critically read scientific information an individual needs to have some sort of intellectual independence, or at

least the avoidance of uncritical acceptance, from the authorities, or individuals, who are making the knowledge claims. However, the potential for intellectual independence for the non-scientist with regard to the evaluation of knowledge claims has been discussed at length (Norris, 1995a; Grandy, 1995; Norris, 1995b; Norris, 1997) with Norris claiming that the "goal of intellectual independence as it is espoused traditionally in science education is not reachable" (Norris, 1995b, p.223). Norris's argument is that it is rational to defer to scientists' expertise and that learning *who* the experts are is important for the non-scientist. The "Hardwig limit" (Hardwig, 1991; Norris, 1995b) is the point at which someone with some scientific knowledge is no longer able to evaluate studies because they are too specialist and they must accept on trust what scientists tell them.

Recent work by Bromme and colleagues (2008; 2010) raises interesting questions about what they describe as the 'division of cognitive labour' and how students understand *who knows what* and *who to believe (*Bromme et al., 2010). Further, Harris (2001, in Bromme et al., 2010) offers a critique of the Piagetian tradition which suggests that it emphasises the role of first-hand experience in child development and underplays the role of adult testimony. Harris showed that even very young children reason from premises they have received from others rather than from the personal experience which the Piagetian perspective might suggest. Even if the points made by Norris (1997) and Bromme et al. (2010) are accepted, and knowing who to believe is recognised as being important knowledge for evaluating science, media reports remain especially challenging. This is because there is the potential for scientists to be misquoted or misunderstood. Thus this places emphasis back upon the readers' critical capacities.

2.3 Knowledge for reading news stories: the Nature of Science

Readers of news stories about science are likely to encounter a wide range of scientific topics, some of which they will have little if any substantive knowledge. Being able to interpret media reports of science and to evaluate them appropriately cannot depend only on knowledge of the world or *science explanations* (Millar, 2008). For many news stories, if any scientific knowledge is drawn upon it is likely to be more general in nature. More general ideas of *knowledge about science* (Millar, 2008) or to use associated language, ideas about the Nature of Science (NoS), may be used. Thus the specific content of science studied at school or at university, such as in covalent bonding or bending moment diagrams, is unlikely to be directly useful, except in a limited number of circumstances.

In section 2.3 I build on the assumption that a part of formal education likely to help readers understand a news report of science is that which is associated with NoS or scientific enquiry, for the reason that it is generalised enough to apply to a wide range of contexts. Firstly I am interested in the secondary school science curriculum, important because all trainee teachers will have studied science at school, but also because trainee science teachers will be teaching in schools themselves. Secondly I explore how university and college curricula may help readers, including looking at studies with university and college students, graduates and trainee teachers as participants.

2.3.1 Secondary school science

There has been agreement for some time that it is important that during their schooling pupils learn something about the NoS (e.g. Lederman, 1999). An illustrative list from science education literature can be found in Abd-el-Khalick et al. (1998) who suggest that scientific knowledge is: tentative; empirically based; subjective; involves the invention of explanation;

is socially and culturally embedded; distinguishes between observations and inference; and involves the relationships between scientific theories and laws. Not all agree with such a list, however; Wong and Hodson (2009) conclude, from their questionnaire and interview study of scientists, that "there is no single set of NoS elements, static with time and fitting all disciplines and contexts." (p.123). However, it is this sort of generalised knowledge that offers some potential to help readers understand news stories that are on a topic outside of their expertise.

Since the earliest National Curriculum (DES/Welsh Office, 1989) there has been a strand (often known as Sc1) which includes reference to "fair tests" and "variables" where students are expected to learn something about scientific inquiry. However, this has contained only limited reference to the contents of the Abd-el-Khalick et al. (1998) lists. Some of the youngest participants in the present study may have been taught science based on the National Curriculum document for England "Science Programme of study for key stage 3" (QCA/Crown, 2007a). This includes "Key concepts" and "Key Processes", the terms that have been adopted to describe components of scientific knowledge which relate to NoS and the processes and practices of science. The National Curriculum also has reference to generating and testing theories, evaluating evidence, scientific explanations and morality. Furthermore, this strand of the curriculum includes the control of variables, risk assessment, taking measurement, analysing and communicating data. At key stage 4 the vocabulary used within National Curriculum documents (QCA/Crown, 2007b) to describe content related to NoS changes to "How Science Works" (p.221). At this level, focus shifts towards understanding relationships between data, evidence, theories and explanations. Pupils are also expected to learn about how "how uncertainties in scientific knowledge and scientific ideas change over time" (p.223). These ideas about scientific inquiry potentially offer readers

other general tools with which to examine news stories. Even with a national curriculum, it is not possible to know what trainees have learned in school. Some authors (Mellado, 1997; Bartholomew et al., 2004) have claimed that science teachers' own schooling is typically devoid of reference to such science epistemology.

There are also potential problems with the way science is presented in school. If students only encounter scientific knowledge in school that is not really contested they may come to see that all science has the same status and is certain and infallible. Millar describes this as an "epistemological danger" (1989, p.54). These dangers may come from pedagogic strategies as well as the type of knowledge encountered. Strategies or approaches used by teachers may imply that all scientific knowledge is as secure as most school science knowledge (Kirkman, 2005). A further example is the use in school science of rubrics for writing up practical investigations: Title, Prediction or Hypothesis, Apparatus, Method, Results and Conclusion (Jenkins, 2007). In these approaches, students make a prediction or hypothesis based on theory, make a deduction as to what observations would confirm that hypothesis and then collect empirical data. The use of such rubrics may intentionally, or unintentionally, teach students about 'the scientific method' (Jenkins, 2007) and the hypothetico-deductive model, both of which are challenged by philosophers of science (Feyerabend, 1978). From a pedagogic point of view, such approaches may limit students' vision of the breadth science and their understanding of how scientific knowledge enters the public sphere.

2.3.2 Undergraduate study and teacher training

In their work with undergraduates, Ryder et al. (1999) found that all students in their study thought that "knowledge claims could be proved absolutely" (p.212) and indicated that empirical research was the basis for such proof. Further, they tended to downplay the social

aspects of scientific work. This demonstrates that even at undergraduate level, students' understanding of the nature of science is somewhat limited.

One might expect that science trainee teachers would have a better conception of the nature of science than those whose degrees are within other disciplines. However, there is research to suggest that academic background is mainly unrelated to conceptions of NoS (Lederman, 1992). Furthermore, it has been found that philosophy students scored more highly than professional scientists or science teachers in one particular study (Kimball, 1968 in Lederman, 1992).

Within England there is not an explicit curriculum for trainee teachers to learn about NoS. Many studies have explored teachers' conceptions of NoS (see Lederman, 1992 and Mellado, 1997 for summaries) and most concluded that both primary and secondary teachers had inadequate conceptions. Work with college students and trainee teachers has shown that personal conceptions of the NoS are independent of 'cognitive variables', 'socio-personal variables', 'gender', 'science subject being taught', 'in-service professional training' and 'years of service' (Abd-el-Khalick and Lederman, 2000, p.671). Abd-el-Khalick et al. (1998) found that, even with sufficient personal knowledge of NoS, trainee teachers actual planning and teaching contained few references to this part of scientific knowledge, thus emphasising a complex relationship between personal knowledge and teaching practices. Lederman (1999) similarly concluded that teachers' experience, intentions and perceptions of students all contribute to classroom performance regarding NoS, in addition to personal knowledge.

Taken together these points signal a complex relationship between personal knowledge of NoS, its acquisition and its use. Therefore, it would be surprising to find a simple relationship between teachers' knowledge of NoS and how they understand media reports of science. The

points made above about the influence of knowledge of NoS on classroom performance may extend to its influence on understandings of news stories: there may be other factors which influence understandings other than personal knowledge.

2.4 Philosophical perspectives on quality of scientific knowledge

Readers of scientific news stories face particular challenges when trying to judge what they read because the scientific ideas have been interpreted by journalists who may or may not be experts in science, and are adapted for a general audience (Jarman and McClune, 2010). For example, some news stories possess the narrative of a melodrama (Jacobi and Schiele, 1993), which makes interpretation challenging. This second order presentation of information is thus removed from the researcher and scientific community. Philosophers of science have also faced difficulties with how to go about judging the quality of scientific knowledge, thus it might not be surprising if trainee teachers find it challenging.

The criteria for judging quality is strongly linked to the perspective of those judging quality. For example, 'empiricism' held the view that knowledge can only come from experience (Godfrey-Smith, 2003) and that an observer should put aside prejudice and bias. A significant criticism of empiricism, however, was that observations are always theory-laden and that it is not possible to look at evidence without preconceptions (Morick, 1980).

More recently, logical positivism was an important movement in the twentieth century; a central tenet was that a sentence, or claim, could only have meaning if it could be verified by observation (Godfrey-Smith, 2003). The Verification Principle (Ayes, 1936), for example, holds that for a statement to be true it either needs to be analytic, that is logically necessarily true, or able to be shown to be true by empirical methods. Thus within logical positivism analytic knowledge could be held *a priori*. Popper (1989) adopted a different perspective in

his conceptions of falsification, where tentative theories are accepted and then held up to the possibility that they will be falsified. In this perspective there is no need to start with observation, instead, induction is replaced by prediction based on theory. The prediction is tested and the theory potentially falsified. A theory will only survive if it stands up under pressure and it is not falsified. In falsification there is the clear signal that all scientific knowledge is tentative and, therefore, uncertain although some theories may have been tested more frequently and are thus more robust under potential criticism. Thus, this process of testing and falsification can be considered to be a test of quality of scientific knowledge.

While there is not a single definition of the 'hypothetico-deductive' model of scientific method, it is generally used to describe a view of science in which a conjecture is set up, observational predictions made, then tested and the theory either receives support or is refuted. It is sometimes equated to Popper's falsification (Kind and Kind, 2008). Miller (1994), however, has suggested that Popper's approach is actually "hypothetico-destructive" (p.110) to demonstrate that Popper does not emphasise the confirmation implied in the hypothetico-deductive model but the falsification aspect. Implicit in the above discussion of Popper's falsification is that science will progress as theories are found to be false by empirical work, and the surviving theories are accepted. Kuhn (1970) posits another mechanism by which scientific knowledge progresses, that of the revolution. In 'normal science' (p.10), according to Kuhn, scientists work within a paradigm sharing common language and practices. However, there are potentially different and incommensurate paradigms in direct competition and at times of crisis, for example when an anomaly is identified, a revolution can occur with an associated paradigm shift.

There is ambiguity in Kuhn's work about the nature of progress in science, and thus how to identify the quality of scientific knowledge, however. Those working within the prevailing paradigm would be optimistic that they have made progress in replacing the previous paradigm, but this is not something that can be viewed as an indicator of progress. Kuhn's (1970) efforts to explain progress in terms of the problem solving power of paradigms are also problematic as science is, even from the perspective of a lay observer, able to solve increasing numbers of problems, and as it has made progress according to this measure, it must be building on what has gone before. This is incompatible with Kuhn's incommensurability of paradigms (Godfrey-Smith, 2003). Thus, as Kuhn does not offer means to distinguish 'normal' science from what replaces it, he does not offer a way of judging the quality of scientific knowledge (Kind and Kind, 2008).

According to Lakatos et al. (1978), competing "research programmes" (p.4), similar to Kuhn's paradigms, are either progressing or degenerating. While degenerating programmes may be just about keeping up with handling anomalies, progressing programmes are extending their scope of their research as well as handling empirical difficulties. Thus for Lakatos, progress can be seen within programmes as well as when one programme gradually replaces another. Feyerabend (1978) was critical of Lakatos's failure to indicate when a scientist should move posts from a degenerating programme to a progressing one. This implies that the criteria for deciding which of the programmes is working with more certain knowledge would become clear over time but in the short term it would be impossible to distinguish which programme was establishing better quality scientific knowledge.

A potential criterion for identifying whether knowledge claims are to accepted or not is whether they have been obtained by following scientific methodology. The 'hypothetic-

deductive' method mentioned above is one example of this approach. Feyerabend (1978), however, was dismissive of the scientific method and emphasised that science is an 'anarchistic enterprise' (p.2) and that scientists should be free to be creative and unencumbered by reason. While Feyerabend endorses the 'principle of proliferation' (p.335), where people are encouraged to develop new ideas, he does not explain how it is possible to distinguish between multiple and varied ideas.

Returning to the perspective of philosophers of science, Cartwright (1999) has emphasised the distinctiveness of different scientific domains. She, for example, used the term "dappled world" in the title of her book to emphasise that these domains are incommensurate. The implication here is that what counts as knowledge within each domain is different and incomparable. Thus, what counts as acceptable knowledge in one domain is different to another. This perspective adds further to the difficulties of lay readers of science as they try and decide which knowledge claims to accept or to reject as it suggests that there is not one set of criteria that could be adopted to help in the decision making process.

The discussion above indicates that deciding on the quality of the scientific knowledge that appears in the news may not be straightforward. At a more basic level, one way of framing responses to news stories would be to try and decide whether the contents of the story are scientific. Deciding whether something is scientific or not has been described as the 'demarcation problem' (Laudan, 1983). Fuller (2007), in his revisiting of the demarcation problem, suggests that Laudan's (1983) paper "The demise of the demarcation problem" contributed to the general view that science was what scientists do, thus challenging the usefulness of the science/non-science distinction when judging quality.

In a study examining the views of two practising scientists, Yore et al. (2006) report that the scientists made use of terms describing both uncertainty and certainty in their publications. However, one of the scientists felt that the public would not understand. The scientists in Yore et al.'s (2006) study had experience that other scientists in their field still promoted "traditional realism" (p.125) language where there was an expectation that terms like "truth" and "scientific method" (p.126) would still be used in writing about their work. However, these other scientists did make use of hedges such as "the data support, suggest or indicate" (Yore et al., 2006, p.133) when writing for lay audiences.

Some ways in which those within science education research have looked at the quality of scientific information and scientific sources are described in section 2.9. Of particular significance to this study is the approach adopted by Norris and Phillips (1994) and Norris et al. (2003), Ratcliffe (1999) and Christensen (2009). They explored participants' views about 'certainty' of scientific knowledge with a general sense that 'certain' means 'true'. However there is ambiguity with the term because it could mean either how sure the researcher, or reader, or wider scientific community are that a claim is true.

Further to the point above about whom it is that is certain, the word 'true' is also problematic. Godfrey-Smith (2003) points out that in striving for accurate representations of the world some people have made use of linguistic concepts of truth to describe the relationship between theories and reality. He goes onto explain that more recently ideas about scientific models as a means to represent reality have become more influential and that when looking at models, ideas about 'truth' do not really apply. Godfrey-Smith (2003) aligns himself to Horwich (1990) and other post-modern thinkers who have put aside these issues of truth in

relation to linguistic representations or models. Instead they use the term "truth" (or "veracity") to indicate that people agree or disagree.

In order to try and adopt a specific definition in this study I will use 'likelihood of veracity' to signal whether an individual participant agrees with what they have read or not. Thus I have adopted a similar meaning to Horwich (1990), but with a focus on the individual perspective. If a reader were to state there was a high 'likelihood of veracity' this would be taken to mean that the reader strongly agrees with the statement and accepted the model that was being described as an accurate representation of reality. In other words it is the readers' view of the probability that a claim is true.

2.5 Reasoning, decision making and epistemic distance

In the introduction to this chapter I explained that the first two research questions are concerned with how trainee teachers reason about the quality of scientific ideas. In this section I will give further background to these questions and look at how other researchers have described *reasoning*. I have two motivations for this. Firstly I wish to build on the discussion above about knowledge of NoS and discuss reasoning capacity as a further possible means to understand news stories. Secondly, I want to explore how researchers have viewed progression in reasoning, in other words I am interested in differences between simple and advanced reasoning.

It is useful to distinguish between reasoning which has been observed or evidenced, and reasoning which is normative. Information on the former can be obtained, for example, by observing how young people, scientifically literate adults or scientists reason. The latter is concerned with the kinds of reasoning students *should* undertake. Normative reasoning can

be criticised as emphasising a deficit model of scientific literacy (Irwin, 1995) where the focus is on what people are unable to do and what they should be able to do.

2.5.1 Learning reasoning

The CASE project (e.g. Adey et al., 1989; Adey and Shayer, 1990) was informed by the work of Piaget and gives a further perspective on scientific reasoning. The series of 30 lessons is designed to lead to cognitive development including the furthering of pupils' reasoning ability in, for example, understand the effect of variables and ratio. Each lesson is built on the same five pillars of CASE. One example of these pillars is the concept of "cognitive conflict". Pupils are presented with scientific ideas which are likely to be incompatible with their existing thinking, and this process, so the argument goes, will lead to changes in pupils' thinking. Pupils undertaking this course have been shown to make gains which extend beyond the immediate context. The CASE conception of reasoning is useful here because it describes reasoning patterns. These patterns include, for example, variables; classification; proportionality; inverse proportionality; probability and correlation.

The CASE list adds to the ideas mentioned in previous sections about NoS as part of the school curriculum potentially useful to readers of science news stories. Further, Kuhn et al. (2008) suggests three aspects of scientific thinking that pupils should encounter. The first is the control of variables; the second is being able to understand the effect of multiple variables, and thirdly understand something of the epistemology of science. Chinn and Brewer (1993), however, focus their attention on relationship between variables and causal, inductive, contrastive, analogical and impossible causal links. The three perspectives described above have in common a concern for variables and relationships between them.

Also adopting a normative approach, Giere (1997) described a course intended for undergraduate students not specialising in science. The approach is significant because it makes explicit reasoning which may otherwise not be emphasised. For example by distinguishing causation from correlation. Giere uses case studies to illustrate this reasoning. It becomes apparent in this approach that the knowledge needed to reason in the way described by Giere cannot be represented as declarative propositions; instead this reasoning is a sort of skill that needs to be practiced. However, this approach has been criticised for being oversimplified (Ratcliffe, 1999).

Amsel et al. (2008) suggest a mechanism for the development of scientific reasoning in the context of a task which examines ratio. Their dual process account posits that two separate cognitive systems develop in tandem. The first is the experimental processing system which is automatic and requires little effort. The second is analytic processing which is cognitively demanding and more formal in operation.

2.5.2 Describing reasoning

In the previous section I raised some examples of normative reasoning that appear to be relevant to understanding news stories. In this section I will discuss research which is concerned with describing *how* people have reasoned in certain circumstances. Previous relevant research concerned with reasoning has tended to be in the research area of NoS or SSIs. Thus it is necessary to extrapolate from these areas.

In an attempt to characterize school students' reasoning about NoS, Leach et al. (1997) propose a framework. First, *phenomenon-based reasoning* is where the distinction between explanation and description are blurred, and enquiry into scientific phenomena is thought to make things happen. Second, in *relation-based reasoning* pupils are able to distinguish

between evidence and explanation but relationships between variables are misunderstood. Correlation, for example, is interpreted as causation. Third, *model-based reasoning* involves the use of explanation which has a coherent system of theoretical entities. The study found that *relation-based reasoning* was the most common. The three parts of the framework are not seen to be hierarchical and therefore are not able to contribute to discussion on progression in scientific reasoning. The reasoning indicated here was derived, in part at least, from asking pupils in interviews to decide if questions were scientific in nature and so does not necessarily apply to reasoning within particular scientific disciplines. It is thus a domain-general analysis and does not take into account differences *within* science.

A range of researchers have drawn upon 'informal reasoning' in the context of socio-scientific issues (Dawson and Venville, 2009; Kolstø, 2006; Sadler, 2004; Sadler and Zeidler, 2005). Johnson and Blaire (2012) quote a broad definition for informal reasoning:

> Informal reasoning is the reasoning carried on outside the formal contexts of mathematics and formal logic. It involves reasoning about cause and consequences and about advantages and disadvantages or pros or cons of particular propositions or decision alternatives (p.134).

Informal reasoning has been used to describe reasoning that does not have an inevitable outcome and conclusions may change as new information becomes available. Sadler (2004) claims that it offers a superior description of reasoning in the context of SSI.

Further, Sadler et al. (2007) view reasoning, in the context of SSI, as a theoretical construct with four practices: recognising complexity; adopting multiple perspective; issues continue to be subject to inquiry; and exhibit scepticism. For Sadler et al. these four practices are seen as necessary for considering socio-scientific issues. The extent to which these practices might be useful when evaluating science as found in the media is uncertain. However, Sadler et al.'s

approach offers a methodology including a hierarchy of reasoning, and therefore it is a mechanism for exploring the development of reasoning. For example, participants engaging with socio-scientific issue demonstrated their reasoning in "complexity" at one end of an ordinal scale by offering a simple solution and at the other end of the scale by offering tentative solutions based on a range of opinions. Compared to Leach et al. (1997) the role of evidence in Sadler et al.'s framework is less obvious.

In a further examination of socio-scientific issues, Sadler and Zeidler (2005) identify three patterns of informal reasoning: rationalistic (use of reason and logic), emotive (care based e.g. sympathy and empathy) and intuitive (affective moral reasoning). They found that participants relied upon combinations of the patterns. This patterning emphasises that facts, reason and logic are not the only influences on reasoning. This point suggests a limited role of subject knowledge when reading news stories (explored in section 2.9.5).

Although the discussion above is not specifically about how readers respond to news stories, the types of reasoning described offers some potential explanations for what might happen with news stories. For example, reasoning about SSI and critically reading news report have in common that scientific ideas are involved and reasonable people may disagree about the final outcome.

2.5.3 Decision making and heuristics

In an everyday sense heuristics are 'rules of thumb' which guide action. Other definitions include probabilistic generalisations (Thomas, 2007), educated guesses and way of solving problems. Heuristics are described by Simon (1990) as "…methods for arriving at satisfactory solutions with modest amounts of computation." (in Shah and Oppenheimer, 2008, p.207). Thus they do not lead to optimal solutions but to adequate ones. An everyday

example of a heuristic is if the sky is clear blue then there is no need to carry an umbrella. However, there are circumstances where this heuristic could leave someone wet. Within psychology, heuristics have been identified in decision making research (Kahneman et al., 1982).

Decision makers use heuristics as effort-reduction strategies to simplify their reasoning process (Shah and Oppenheimer, 2008). However, they have been thought to hinder decision making (e.g. Maeyer and Talaquer, 2010). More recently it has been suggested that they can result in more accurate decision making compared with more comprehensive reasoning strategies, in cases, for example, of low predictability and small samples (Gigerenzer and Gaissmaier, 2011). Thus while heuristics are often associated with the dual-process models, where processing can be either slow and laborious (analysis) or fast and frugal (heuristics) (Evans, 2008), they are also associated with situations where information is limited and thus processing is necessarily simplified.

One particular example of a heuristic is the Satisficing Heuristic (Simon, 1990; Gigerenzer, 2008) where a person searches through alternatives and selects the one which has a value above an aspiration level. This heuristic, like others, can be phrased using an "If…then…" rule formulation: <u>If</u> value above aspiration level <u>then</u> select item. A further example is the Recognition Heuristic:

> If one of two objects is recognized and the other is not, then infer that the recognized object has the higher value with respect to the criterion (Goldstein and Gigerenzer, 2002, p.76).

Heuristics also form part of Hilligoss and Rieh's (2008) framework for credibility assessment in information studies. They suggest that heuristics offer a way of finding and evaluating information rapidly. They give the example that "an official source is a credible source"

(p.1480) and suggest that participants would continue in their research unless they came across something which challenged that heuristic.

After some thought about heuristics and the If... then… structure I have come to the conclusion that there are similarities with research on argumentation. It is claimed that argumentation is necessary for scientific progress and learning about science (Erduran et al., 2004). Much argumentation research builds on work by Toulmin (2003) who suggests a scheme for the analysis of arguments that focuses on claims, warrants and grounds. However, put simply an argument is an assertion accompanied by justification (Kolstø, 2006; Toulmin, 2003). I have not drawn explicitly on argumentation work in this study but future work in this areas may benefit from further comparisons.

Sadler and Fowler (2006) tested a 'threshold model' as possible a relationship between argumentation quality and content knowledge. In the context of genetics they asked three groups with varying formal education to respond to scenarios. Sandler and Fowler found that those with advanced genetics knowledge produced better quality arguments but undergraduates in other subjects and high school students produced inferior arguments. This finding is interesting because the study identified a link between specialist subject knowledge and responses to presented material.

2.5.4 Decision making and certainty

Kahneman and Tversky (1982) distinguish two sources of uncertainty: external uncertainty, which is located outside of a person, and internal certainty, when an individual does not know. For external uncertainty, thinking is about "*the* probability" (p.516), rather than "*my* probability" (p.516) in the case of internal uncertainty. A further way of considering this distinction is to think of the distinction between nobody knowing and an individual not

knowing. For each source of uncertainty Kahneman and Tversky (1982) give two modes in which a decision maker can operate. For external uncertainty the singular mode is when decisions are based on a single case, for example, a particular sun bed leading to cancer. In external uncertainty in the distributed mode probabilities are explored with the case seen as part of a wider set of cases, for example, this sun bed leads to cancer because all sun beds cause cancer. Kahneman and Tversky (1982) suggest that people would rather operate in the singular mode.

Internal uncertainty refers to personal knowledge, and reasoning can be in the direct mode, where decision makers rely on intuitive responses. One can imagine a response to a news story as an exclamation of "nonsense" or "I don't believe it" when an individual is operating in this mode. In contrast in the reasoning mode there is an examination of the evidence and a weighing of arguments, the response is justified. The distinction offered here between internal and external uncertainty is an useful reminder of differences between private and public knowledge.

2.5.5 Epistemic distance

As discussed in section 2.2, Norris claims intellectual independence is unobtainable for the non-expert; in other words, we are dependent upon those with epistemic authority. However, a case can be made for students understanding a 'spirit' of intellectual independence; that is adopting an attitude towards knowledge which is questioning and not passive. Norris (1984) offers a list with some potential epistemic responses to knowledge claims:

> Appropriate scientific attitudes consist in withholding judgement when there is insufficient reason to judge, doubting when there is reason to doubt, believing cautiously when there is reason to believe cautiously, believing strongly when there is reason to believe strongly, and believing without doubt when there is reason to believe without doubt. (p.494)

Norris's list, however, does not give details of situations when such reactions might be appropriate, thus identifying such examples is an area for future research.

Chinn and Brewer (1993) list a similar set of responses to anomalous data that include rejection, holding it in abeyance, ignoring and reinterpreting. Such a set of responses to scientific claims can be hypothesised in response to scientific claims that appear in news stories. It would, however, be counter-productive for school pupils or others to be overly critical or even dismissive of knowledge claims. One challenge, then, is to know *when* to be critical. For example, with regard to information sources it would be generally unhelpful to students to critically examine a science textbook, however, an advertisement about hair care product or breakfast cereal could usefully be critiqued.

Norris and Phillips (1994) usefully distinguish between fallibility and uncertainty. They suggest that all scientific knowledge is fallible but it is not all uncertain. Such a distinction is useful as some scientific knowledge is uncontentious in practice but still retains the potential to be superseded. There is often very good reason to believe scientific ideas and as a science teacher, I would not want the students I teach to group together all science knowledge because some is very tentative and other knowledge is secure.

Further, Norris (1997) suggests that a suitable goal for non-scientists would be to be able to establish an appropriate "epistemic distance" (p.253) between the scientific content and the knower, with no distance suggesting that the they believe what they hear and large distances indicating they are sceptical. Similarly, Bergstrom et al. (2006), working in the field of cognitive psychology, raise the question of whether information is tagged with a "creedal state" (p.532) such as probable or possible, or whether information is "quarantined" (p.532)

until its truth becomes clear. While this project will not focus on researching such "states" the idea that someone may hold knowledge tentatively is useful here.

Norris (1997) suggests that *evidence* and *sources of knowledge* are possible means to creating epistemic distance. He also suggests that the applications of scientific knowledge are a possible means of creating epistemic distance, in this case he suggests that scientists are not particularly expert. The idea of epistemic distance offers potential as a means to understand and explore readers' responses to new stories. In this study I will use this concept to identify a range of factors that could lead to changes in epistemic distance. These responses fall into two main categories: those that increase epistemic distance and those that reduce epistemic distance. An example would be that if a finding had been subject to peer review then a reader might be willing to reduce the epistemic distance between themselves and the claims to knowledge. They would then be more willing to believe what they had read.

There are precedents in previous research where problems are simplified to binary constructs. Murray-Prior (1994, 1998) draws on personal construct theory to simplify decision making processes about price and attitude to risk. The farmers in this study thought of price as being either high or low. In a similar way it is reasonable to suggest that when looking at epistemic distance it might reduce the problem to looking only at things that serve to increase or decrease epistemic distance.

A broad research topic emerging from the above discussion, and the discussion in section 2.8 about how researchers have explored the quality of the science encountered in the news, is to explore how readers use heuristics to reason about the quality of the science they encounter in their everyday lives. This leads to the first pair of research questions:

What heuristics are used by readers when they reason about the quality of science published in the media? Are there differences in heuristic use based on readers' formal education in science?

2.6 Critical Thinking

Pithers and Soden (2000) in a review of literature point out that 'good thinking' is commonly a goal of education and an expectation of employers. They claim that in research literature, 'good thinking' is linked to critical thinking. However, defining critical thinking is not straightforward. A key challenge for researchers has been the extent to which critical thinking is generic (Moore, 2011). Ennis (1987) adopts the position that thinking skills are mainly independent of subject disciplines. He, like others (e.g. Beyer, 1985), have put together lists of these skills. McPeck (1981) in contrast sees critical thinking as much less general and transferable:

> Just as rules of particular games do not necessarily apply to other games, so certain principles of reason may apply within certain spheres of human experience, but not in others. (p.72)

Bailin (2002), in the field of science education, also rejects the skills based conception of critical thinking and instead defends a normative approach which has, in common with the discussion of evaluation above, a focus on criteria. For Bailin the identification of such criteria must be within specific contexts.

Further, Moore (2013) undertook to ask 17 academics what they understood by critical thinking. He identified seven definitions in their responses which included: judgement; scepticism; simple originality and rationality. What emerged from this study was that the meaning of 'critical thinking' is subject to disagreement:

> Along with seeing critical thinking as a term having multiple meanings, the interviews suggested that it is also a contested notion. This was evident in a number of quite divergent, even incompatible, accounts by informants – for example, in the different views expressed about whether critical thinking is at heart an 'evaluative' mode, or a more 'constructive' one; or whether the term necessarily entails the adopting of an ethical and activist stance towards the world; or how much being critical involves a logical and rational outlook (p.519).

From a different perspective, the Critical Thinking GCE A-level course (OCR, 2013) adopts the following definition of critical thinking:

> Critical Thinking is the analytical thinking which underlies all rational discourse and enquiry. It is characterised by a meticulous and rigorous approach. As and (sic) academic discipline, it is unique in that it explicitly focuses on the processes involved in being rational. (p.4)

The OCR approach is skills based, in line with the Ennis (1987) perspective, and includes, among others, the following elements: credibility; plausibility; vested interests; neutrality; and rational decision making. The course includes the expectation that students will look at news stories and follow arguments:

> Candidates will be presented with a wide range of material based on articles found in newspapers, journals, books and magazines, including diagrams, images and statistical data. They will also be expected to sift passages of argument from articles which, in themselves are not argument, and to follow a train of reasoning even though this may not be technically an argument. (OCR, 2013, p.19)

Thus this conception of critical thinking is associated with the reading and understanding of news stories and offers other ways of looking at the quality of the science in the articles.

The discussion above adds to previous discussion in this chapter which explores the extent to which conceptions of generalised knowledge and skills are useful in the context of responding to media stories. In his recent work on critical thinking, Moore (2011) begins to articulate the inadequacy of prescriptive approaches to critical thinking involving a range of skills in our

“highly complex and dynamic world” (p.272). Drawing on Barnett (2000), Moore suggests in critical thinking students do not require a range of skills but an understanding of complexity and indeterminacy. Moore also draw upon Williams’s (1983) perspective that words have such a range of meanings and usage that trying to specify their precise meaning is less useful than being aware of this range.

One goal of this study is to explore the extent to which formal education in science can be generalised to topics that have not been specifically studied. The critical thinking literature described above, including Moore (2011), offers some insights. The concept of “interconnectedness” described in the next section is a further exploration of how readers may be able to reason and think about scientific areas outside of their formal education.

2.7 Interconnectedness

In section 2.7 I will try to explain what I mean by ‘interconnectedness’. At the end of this section I will set out the second two research questions which are about how readers integrate what they have read with other ideas.

2.7.1 The crossword metaphor

Interconnectedness, in this study, is how people link ideas they encounter with other ideas, including their existing knowledge. In some ways it echoes with a Piagetian perspective where phenomena are experienced within "the systematic framework of existing judgements into which the observer pigeon-holes every new observation" (Piaget, 1929, p.33, in Solomon, 1994, p.4). This constructivist perspective emphasises that readers understand and interpret what they have read through the ‘eyes’ of their experience.

Interconnectedness should not be conflated with “connectionism” (Klein, 2006) which uses a network as a model of the mind. Within that model, found in cognitive psychology, there are

nodes and connections between nodes which permit inputs and outputs. A number of writers have suggested that making links is important in science education. Elliot (2006, p.1245), for example, writes of the goal of linking "scientific theory" to "the real world". Furthermore, Norris and Phillips (2003) have discussed "interconnections among […] elements of content, their sources, and their implications" (p.236). Zimmerman et al. (2001) endorses links between science, technology and society. Kolstø et al. (2006) discuss making connections between data and claims as found in argumentation warrants. My notion of interconnectedness is inclusive of, but broader than these. It also includes links between knowledge gained in other contexts or constructed 'in the moment'.

Biggs and Collis's (1982) SOLO (Structure of the Observed Learning Outcomes) taxonomy which is associated with learning objectives and outcomes, makes use of an idea similar to connectedness. It includes the category *relational*. For Biggs, a "relational response is conceptually integrated within its given context" (1979, p.387). For Biggs, the taxonomy is hierarchical and the relational category is level four out of five levels of understanding, thus this sort of connectedness is valued in Biggs and Collis's scheme. The multi-structural outcomes described by Biggs and Collis (1982), where a learner has several ideas on a topic, is similar to the spoke concept map structure outlined below.

The notion of 'interconnectedness' was in part inspired by the crossword metaphor that Susan Haack (1993) uses to explain her theory of foundherentism. The metaphor is borrowed from Haack but her theory in science epistemology is not concerned with the thinking of an individual, so the application is quite different. Within the crossword metaphor, when applied to the context of reading news stories, some of the crossword entries are filled in but on reading a news story it may be possible to add further entries. In these new entries there are

letters in the answers that are shared, these shared letters count as useful checks for the puzzle solver. Similarly when reading news reports a reader may come across familiar ideas and the extent, or otherwise, they fit in with their current thinking serves as a check on the knowledge claims. I am assuming here that the private connections will fit somehow into a wider, external set of interconnected ideas.

It follows that knowledge *of* 'interconnectedness', compared to its *use*, would include how ideas come about and how they are checked and integrated into other private or public knowledge. Thus knowledge of interconnectedness includes ideas about peer review, knowledge of experts and expertise, and ideas about status of knowledge and how knowledge comes about. It also includes references to the wider scientific community and indications of how that might function. Furthermore, it includes knowledge of reporting, news production and news stories.

2.7.2 Concept mapping

Concept mapping (Daley, 2004; Hay and Kinchin, 2006; Kinchin et al., 2000; Kinchin and Alias, 2005; Novak, 1990a) can be used to visually represent understanding and to explore hierarchy, complexity and conceptual development. Briefly, in concept mapping propositions (two concepts with a linking phrase between them) are joined together such that concepts only appear once on the map and so can have multiple links between them. Concept maps are commonly used as a metacognitive tool that can facilitate meaningful learning (Novak, 1990b), however, they have been used in science education for purposes of assessment (McClure et al., 1999; Prosser and Trigwell, 1999). They have been used in research during interviews (Rye and Rubba, 1998) and some researchers have endorsed their use in analysis of data (Daley, 2004; Kinchin et al., 2010; Novak and Musonda, 1991).

Specifically, Novak and Musonda (1991) used the approach for the analysis of complex interview data and more recently it has been used, in the context of nursing, to evaluate critical thinking (Daley et al., 1999). However, these approaches to analysing the data were quantitative and made use of scoring systems. Kinchin et al. (2000) pointed out that in such analysis information is lost and judgements are made about whether links are valid or invalid, when all links could potentially be useful. Kinchin et al. (2010) trialled the use of retrospective concept mapping as a tool for analysing interview data and suggested that the gross structure of maps gives a check on interview quality, with better quality interviews having concepts that form interconnected networks. They also suggest that concept maps offer a means of summarising and reducing data, moreover, it is a form of coding which can help identify further lines of enquiry. Further, Daley (2004) suggests that concept maps can be used to identify interconnections between concepts.

Some concept maps are highly networked with a large number of concepts and multiple complex links between concepts, some maps however, are much less interconnected and there is evidence of propositions anchored into a network with only one link. As mentioned above, Hay and Kinchin (2006) and Kinchin et al. (2000) suggest that analysis of the gross structure of concept maps may overcome some of the difficulties associated with quantitative analysis. They identify three gross structures: chain, spoke and network. They argue network structures are stable when amended and are associated with meaningful learning. Chain and spoke structures are less stable if errors are identified and are associated with more surface learning.

Kinchin and colleagues suggest that the three gross structures reveal different levels of understanding, with spoke arrangements showing the lowest level and networked maps

showing deep understanding. The gross structure of the concept maps produced in the analysis in this study offer a means of exploring the 'interconnectedness' of the ideas raised by participants. Linking the concept map analysis to the crossword metaphor, where the clues cross over and act as checking and stabilising points, further helps to define the notion of interconnectedness. Table 2.1 summaries some ideas about the crossword metaphor and concept mapping.

	Crossword metaphor for critical thinking inspired by Haack (1993)	**Kinchin et al. (2010) concept map for analysis of interviews**
Crossovers	Crossovers are where two words cross at right angles and where there is a shared letter.	Concepts themselves can be part of two (or more) propositions, thus each concept occurs only once in a concept map and shows how propositions are connected.
Correctness	In a crossword, a word needs to fit in the space and shared letters need to fit into multiple words. Thus there are clues to whether the answer is correct but these are not entirely reliable and sometimes more than one word could appear to fit a space.	The map itself does not highlight whether reasoning is correct or not, but needs interpreting.
Meaning of spokes	Words in a crossword with one shared letter only are checked in only one place. Thus there is less certainty associated with an answer.	Kinchin et al. argue concept maps arranged as spokes that are not hierarchical and show with little understanding of process. New concepts can be added without implications for the rest of the map.
Meaning of chains	In a crossword chains do not occur.	For Kinchin et al., chains are problematic because there is a single linear sequence of understanding, which may imply a hierarchy which is not correct.
Meaning of crossword with multiple crossovers/ network	In the case of a fully completed crossword there are multiple answers which fit with one another in a complex network. Each crossover counts are a check or an anchor.	For Kinchin et al. deep understanding is reflected in the hierarchical and integrated representation in a completed concept map.

Table 2.1: Comparing the crosswords metaphor with concept maps

If the idea of interconnectedness as described here is applied to news stories about science then it would follow that a critical approach to reading a news story would draw upon all kind of ideas that may be relevant and that may help make sense of the text. Thus points raised are

likely to come from a wide range of different places. These may include formal study; interests; personal circumstance; previous/current work; previous reading; and on the spot reasoning, for example. Thus it follows that a desirable outcome for a response to a news story would be one where there are multiple and interconnected links between concepts in a concept map produced from the response. If there are concepts that are arranged around a single idea in a spoke formation then there are few crosschecks on knowledge. These might be described as factoids, which are isolated and disconnected facts. These factoids, or 'spokes' are associated shallow learning and they do not demonstrate evidence of processing or comparing ideas; instead they suggest recall and restatement. In contrast a networked concept map is evidence of drawing upon a wide range of ideas that are linked and provide cross checks on knowledge.

2.7.3 Metacognition

Kitchener (1983) proposed a three-level model of cognitive processing for people working on ill-structured problems. The problems under consideration are those where the situation is unclear with contradictory perspectives or evidence, and thus similar to reading news stories. In this model cognition includes processes such as reading, writing or perceiving. Metacognition is concerned with individuals monitoring of their cognition, in other words it is about using strategies and monitoring the use of the strategies. The final level is epistemic cognition, which is described in the next section.

Similarly Kuhn (1999) makes links between cognitive development and critical thinking. Like Kitchener, Kuhn associates critical thinking with higher-level processes: metacognition rather than cognition. Also in a similar vein to Kitchener, Kuhn suggests three forms of second-order cognition: metacognitive, metastrategic, and epistemological. Here

metacognition makes use of declarative knowledge; however, epistemological thinking includes more general philosophical points such as answers to "How does one come to know?" (p.18).

Metacognition according to Kitchener (1983) involves the use of strategies and monitoring of the use strategies. It is distinct from cognitive processes such as perceiving, reading and writing. One metacognitive strategy might include making links between ideas. Thus, this suggests that the notion of interconnectedness is associated with metacognition. It would follow from these ideas that a networked concept map can be evidence for metacognitive activity. I will try and support this claim using three arguments. First, concept mapping is known as a tool that helps to develop understanding as new concepts are fitted within existing knowledge framework (Kinchin et al., 2000). Concept mapping has also been used, with some success, to try and promote metacognitive development (Linder and Marshall, 1997, in Case and Gunstone, 2002). Further, Nesbit and Adescope (2006) point out that doing concept mapping activities is more likely to result in metacognitive activity. Thus these points indicate the usefulness of concept maps in promoting metacognition and offer support to a relationship between metacognition and concept mapping.

Second, a network of integrated concepts can demonstrate metacognition because concept maps give evidence of checking having taken place. Metacognition, as described in literature, draws on a range of strategies including strategy monitoring and checking cognitive processes. Pintrich (2002), for example, highlights that strategies for completing tasks, knowledge of effectiveness and knowledge of self are metacognitive in nature. The interconnectedness of concept maps can be seen as manifestations of the metacognitive processes of checking and monitoring.

Thirdly, I appeal to an indirect relationship, that both networked concept maps and metacogntion are associated with meaningful learning. Kinchin et al. (2000) argue networked concept maps show meaningful learning. There is also substantial amount of work that supports the idea that metacognition facilitates learning, for example, Chmielewski and Dansereau (1998) found in experimental settings that training in mapping was associated with better recall (see White and Frederiksen, 1998, which includes a longer list that supports this point).

2.7.4 Epistemological thinking

The third level of Kitchener's (1983) model is epistemic cognition or 'knowing about knowing'. In other words it is concerned with the nature of knowledge and how knowledge is justified. Epistemic cognition includes three elements: limits of human knowing; certainty of knowing and criteria of knowing. For King and Kitchener (2001):

> …epistemic cognition is the foundation of critical thinking when individuals are engaged in ill-structured problem solving. (p.38)

Similarly Kuhn (1999) uses the expression *epistemological thinking.* In her scheme there are two aspects of *epistemological thinking*: general philosophical and personal. The general philosophical includes "How does anyone know?" (p.18) while the personal includes "What do I know of my own knowing?" (p.18). While metacogntion is about strategies, conscious or unconscious, that the reader uses, epistemic cognition includes thinking and reasoning about the nature of knowledge. Both metacognition and epistemic cognition in this context offer the potential to identify generalised criteria used by readers as they read and respond to news stories.

2.7.5 Expertise revisited

I would suggest that there are parallels between the metaphor of intersecting crossword entries and the idea of corroborating testimony. Almassi (2009) analyses Eddington's scientific expertise and challenges the notion that his findings from observations of the deflection of starlight by the sun in 1919 were uncritically accepted by those in the scientific community. Almassi suggests that the findings of Eddington could be crosschecked by those with expertise in observational astronomy but without specialist expert knowledge of general relativity. Similarly, although readers of news stories may not have specialist knowledge of the area under consideration, their general specialist knowledge can serve as a useful check. It would follow that drawing upon expert testimony, or others' expertise, are a legitimate part of a response to a news story. Supportive of this point is the work of Hardwig (1991) and Norris (1995a, 1995b) which is about accepting what others say being a rational strategy in certain circumstances. It should be noted, however, that there is a distinction between experts' knowledge (about gravity near black holes or genome sequences of the Bactrian camel, for example) and generalised knowledge about experts (such as which professional bodies are have stringent entry requirements). It is that latter that is a focus of Norris's thinking.

The preceding discussion suggests that it is worthwhile further exploring ideas about interconnectedness, particularly possible relationships between formal education in science and the extent to which readers integrate what they read with other ideas. Thus the next two research questions are:

To what extent do readers integrate what they read about science in the media with other knowledge? Is there any relationship between the extent of integration and readers' formal education?

2.8 Perspectives on beliefs about knowledge: Personal Epistemologies

The beliefs about knowledge found through personal epistemology research are a further possible way of exploring how readers understand news stories; literature in this field has also provided a theoretical background for some of the empirical studies into reading science news that are described in section 2.9. However, in a similar way to critical thinking research, it includes debates about the extent to which findings are specific to a field or more general in nature. Thus, it is not easy to know the extent to which findings can be applied to the reading of news stories, or the extent to which the topic of a news story influences the outcome.

Literature on personal epistemologies (Baxter Magolda, 1992; Hofer, 2000; Hofer, 2002; King and Kitchener, 2001) focuses on individuals' beliefs about knowledge, including certainty of knowledge. It relates to the "ways of knowing" (Hofer, 2002, p.3) that are operating when we are learning or dealing with knowledge. Central to this field are a number of theoretical models that have been established from longitudinal empirical work (e.g. Perry, 1970). The instruments used to identify these ways of knowing vary; for example, to categorise participants in her "epistemological reflection" model, Baxter Magolda (1992) collected data from extended interviews with the participants and placed participants into four broad categories. Conversely Schommer's (Hofer, 2002) pen and paper instrument allocated each individual to five un-tethered dimensions. What the models have in common, however, are developmental stages where individuals are seen to follow an idiosyncratic trajectory

away from the perception that knowledge is certain and secure to a more subjective view (Hofer, 2002).

Examples of categories describing early stages in development are *absolute knowing* (Baxter Magolda, 1992) or *pre-reflective knowing* (King and Kitchener, 2001). In these categories there are only right or wrong answers and students would find it difficult to explore ideas that seem contradictory. They may also assume that the writer of textbooks or media reports is an authority figure who is to be believed. Trainee teachers, as postgraduates, are less likely to have characteristics of these early stage categories, but for school students it is likely.

Kuhn's (2009) analysis of her study undertaken at a train station highlighted differences in responses between college students and the public. She suggests that the public were interested in actual answers and it seemed that, for them, a decision was better than wavering. College students, however, were less interested in a final answer and seemed to be more interested in the process of decision-making. Kuhn, therefore, identifies avoiding undue certainty in one's judgement as being an important reasoning skill. The implication here is that training can lead to greater propensity to hold knowledge as uncertain. However those attending a college course represent a broad category, when college students are a heterogeneous group.

Hammer and Elby (2003) reject the conception of personal epistemologies as trait like and suggest a framework of "fine-grained, context-sensitive resources" (p.53). Different resources can be activated in different contexts (Hammer and Elby, 2003; Rosenberg et al., 2006). People reading media reports of science may, therefore, evaluate claims using one set of resources rather than another. It is possible, then, that their most effective scientific critical faculties may not be engaged during a particular learning activity. The resource view of

personal epistemologies suggests that one reason for failure to successfully solve science related problems may be because the reader has not operated within an appropriate epistemological framework. It follows that a teacher, or researcher, under certain circumstances, may be able to intervene to encourage pupils, or other participants, to switch to a different more productive epistemology (Rosenberg et al., 2006). This viewpoint is more positive than assuming that epistemological beliefs are fixed and stable at a developmental stage. It is also useful because it accounts for some of the variability seen in pupils' knowledge in different fields.

In a similar vein Stathopoulou and Vosniadou (2007) contrasted distinct perspectives on physics knowledge:

> students who view knowledge as a collection of simple and discrete pieces of factual information, rather than as a complex system of organized and re-organized theoretical concepts, are more likely to "early foreclose" their critical thinking in the process of learning without considering alternative views. (p.277)

It is conceivable, then, that a similar mechanism to the one described here is operating for those reading news reports with a scientific component. The presence of short statements and fragments of text within media reports may actually reinforce this propensity for "early foreclosure" and the bypassing of critical processing.

The personal epistemology research examined above involves domain-general beliefs, however, Hofer (2000) points to the need to consider more domain-specific beliefs. Hofer (2000) claims that first year college students in science tended to see knowledge as more certain and unchanging than students in psychology. Also students in science tended to rely on the expertise of others more than students in psychology who would tend to justify their

knowing with first-hand experience. This finding suggests that there may be differences in the thinking of students in different disciplines.

The discussion in this section examines one approach to studying 'knowing'. There is strong evidence from this field that individual perspectives on knowledge are developmental in nature: as people mature, they hold knowledge as more tentative. Thus it might be expected that experienced readers will demonstrate features of a relativistic view of knowledge However, there are difficulties inherent in this approach. For example, whether the different studies draw upon the same cognitive capacity and the extent to which personal epistemologies are domain specific.

2.9 Readers' responses to media reports of science

2.9.1 Overview of Empirical Studies

Over the last two decades, there have been a significant number of studies undertaken where participants have responded to news articles or web-based media. In this section I will build on reviews by Sadler (2004) and Brand-Gruwel and Stadtler (2011) who examine areas overlapping with the present topic. Table 2.2 gives a summary of the key studies I identified during the period October 2008 to July 2011. These were identified from various web and database searches and from following up references within articles. They are primarily from research in science education. They have in common that participants engage with a report from a media source, mainly about science, and some sort of response is required. Some articles were excluded, for example, Boush et al. (1994) examined responses to generalised beliefs about advertisements and did not require responses to specific adverts. Jarman and McClune (2009) was similarly excluded because it asked young people about the source of

information they had previously used rather than engaging with actual content as part of the study.

It can be seen that participants have been presented with fictitious reports of science (Gray and Mill, 1990; Korpan et al., 1997; Korpan et al., 1999 and Zimmerman at al., 1998), newspaper and magazine reports (Gray and Mill, 1990; Ratcliffe, 1999; Norris and Phillips, 1994; Norris et al., 2003; Ratcliffe, 1999; Yeaton et al., 1990), news video (Christensen, 2009) or internet material (Halverson et al., 2010; Kienhues et al., 2011; Kolstø, 2006; Rieh, 2002; Mason et al., 2009; Mason et al., 2011). Participants have included graduates (Gray and Mill, 1990; Kolstø, 2006; Ratcliffe, 1999), undergraduates (Kolstø, 2006; Korpan et al., 1997; Norris et al., 2003; Ratcliffe, 1999; Yeaton et al., 1990; Zimmerman at al., 1998), school-aged pupils (Kolstø, 2001; Norris and Phillips, 1994; Ratcliffe, 1999) and scholars (Rieh, 2002). Studies have generally included relatively small numbers of participants, typically less than 100 (Halverson et al., 2010; Norris et al., 2003; Zimmerman et al., 1998; Yeaton et al., 1990, being exceptions).

As might be expected, a range of data collection strategies have been utilised including semi-structured interviews (Christensen, 2009; Gray and Mill, 1990; Kolstø, 2001), focus group methodology (Dodds et al., 2008; Christensen 2009), participants asking questions or requesting information (Korpan et al., 1997; Korpan et al., 1999), producing a written response (Kolstø et al., 2006; Ratcliffe 1999; Zimmerman et al., 1998) and answering questions on what they have read (Norris and Phillips, 1994; Norris et al., 2003; Yeaton et al., 1990). Research within information studies has made use of 'think-aloud' commentaries while conducting web searches (Rieh, 2002)

2.9.2 Indicators of quality of science used by researchers

Readers have been asked to examine a range of different features, which I will call quality indicators, when they read news reports. They have been asked about plausibility (Korpan et al., 1997; Korpan et al., 1999), credibility (Zimmerman at al., 1998), trustworthiness (Kolstø, 2001; Kolstø et al., 2006), certainty (Christensen, 2009; Norris and Phillips, 1994; Norris et al., 2003) and validity (Gray and Mill, 1990). They have also been asked to decide if an inference from the report is correct (Ratcliffe, 1999). For Yeaton et al. (1990) the focus is on the readers' understanding of articles' content.

The words listed above give different perspectives on quality. At this stage I think it is useful to include a summary of my own reflections on the meanings of some of the key terms, these are included as a starting point for discussion:

> Validity carries a sense of whether the study is actually examining what it claims to examine. Trustworthiness places the focus on the source material rather than the content, giving a sense of whether it can be relied upon. Plausibility suggests an individual response along the lines of 'it seems reasonable'. Certainty has been discussed above but carries a sense of confidence, or probability that a claim is true. Credibility has a similar meaning to trustworthy in that the focus seems to be on the source and whether that source can be seen as worthy of trust. (My own reflections.)

Table 2.2: Summary of empirical studies where participants respond to scientific information

Author(s)	**Date**	**Type of media**	**Partici-pants**	**Age of sub-jects**	**Theoretical/ literature background**	**Conception of quality of scientific source or information**	**Methodological approach**	**Findings and conclusions**
Bråten et al.	2011	7 different information sources	128 under-graduates	Mean age 22.2	Information problem solving	Trustworthiness	Participants read texts and completed topic knowledge and trustworthiness questionnaires	Textbooks and official documents were judged as more trustworthy than newspapers.
Christensen	2009	News video	28 young adults	18-26 years, 19 were 21 years or youn-ger	Socio-scientific issues and previous research.	Responses to uncertainty in scientific knowledge where people are disagreeing.	Focus group watching of news report about mobile phones with discussion. Individual semi-structured interviews.	Formal science education does not provide an understanding of science that will prepare young people to respond adequately to contested science.
Gray and Mill	1990	3 constructed abstract, 2 based on published articles	48 biology graduates; 48 English graduates	no infor-mation	Reasoning and judgement.	Validity: recognition of missing control group information.	Abstracts had missing control group information. A cued approach was used to indicate how readily participants recognised this missing information.	Biology students required fewer cues but performance not significantly different to English on the less scientific texts. Critical abilities were relatively domain specific.
Halverson et al.	2010	Websites	129 university students enrolled in biotechnolo gy course	Univ-ersity stud-ents	Discussion of information and scientific literacy; criteria for evaluation.	Identified from study.	Written assignments on stem cell issue using prompts to critique.	11 types of website used e.g. mass media websites. 11 criteria used by students including credibility and accuracy/completeness. Undergraduates found it difficult to evaluate online resources and needed prompts.

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Author(s)	**Date**	**Type of media**	**Partici-pants**	**Age of sub-jects**	**Theoretical/ literature background**	**Conception of quality of scientific source or information**	**Methodological approach**	**Findings and conclusions**
Kienhues et al.	2011	Web information (15 websites for each of the two interventio ns)	100 German medical students (84% female; not medically related students	Avera ge 22.6 years	Epistemic beliefs at different levels (discipline related and topic specific).	Medicine-related beliefs.	Pre/post test experimental design with three groups. Completed epistemic belief questionnaire. 30 minute web search to answer questions on cholesterol.	People in conflicting group showed more advanced topic-specific beliefs than those in the consistent group. Both intervention groups showed more advanced medicine-related beliefs. Engagement with web information has potential for developing epistemic beliefs and decision making.
Kolstø	2001	Teaching sequence (including conflicting information from different sources)	22 pupils	16 years	Socio-scientific issues and previous research.	Trustworthiness is when information and knowledge claims were sufficiently reliable to aid decision making.	Teaching sequence and group discussion followed by individual semi structured interviews (40-60 minutes). Inductive analysis on transcribed interview.	Evaluations based partly on empirical evidence, but mostly on rather superficial contextual information. Four resolution strategies for who and what to trust: reaction (acceptance of claims; evaluation of statements) and focus (acceptance of source; evaluation of source).
Kolstø et al.	2006	Participants selected articles found on the internet	89 students in teacher education	Un-known	Critical thinking, nature of science and role of trust.	The number of different criteria for evaluation used by participants. Quality of application of the criteria.	Pairs of students evaluate trustworthiness of science related claims in the self-selected articles.	Students made use of a wide range of criteria other than that related to content knowledge in their evaluations. Three areas were: empirical/theoretical adequacy; completeness of information; social aspects of source.

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Author(s)	**Date**	**Type of media**	**Partici-pants**	**Age of sub-jects**	**Theoretical/ literature background**	**Conception of quality of scientific source or information**	**Methodological approach**	**Findings and conclusions**
Korpan et al.	1997	4 fictitious news briefs	60 University students	Range 17-38 years; Med-ian 21 years	Scientific literacy; evaluation of research.	Plausibility judgement. Ability of participants to ask a range of good questions.	7 minutes allowed to rate plausibility of reported research and request information needed to determine if conclusions were true.	Most requests related to how research done and why results occurred. Few details requested for what found and who/when conducted. Three tentative dimensions that influence information requests: plausibility; typicality; personal familiarity.
Korpan et al.	1999	4 fictitious news briefs	34 non-university; 24 1st year Psychology students; 24 4th year English students; 24 4th year Psychology students	Univ-ersity and non-univ-ersity mat-ched for age	Builds on Korpan et al., 1997; scientific literacy.	Plausibility judgement. Ability of participants to ask a range of good questions.	Participants rated articles on plausibility and typicality. They then listed questions needed to establish if reported conclusions were true.	Questions focussed on how the research was conducted and why results had occurred. The types of questions were constrained by text characteristics. Theory questions were asked by all but methods questions only asked by 4th year psychology students.
Norris and Phillips	1994	Popular reports of science in magazines and newspapers	91 high school students	Grade 12	Epistemological beliefs; reasoning; science epistemology; pragmatic meaning.	Identifying the certainty, status and role of scientific statements.	Students read 5 reports and answered 75 questions requiring them to interpret the pragmatic meaning of the reports. They responded on the degree of reported certainty and decided on the status and role of statements.	Students overestimated the reported truth of statements within the reports. No more than one half of students accurately understood the scientific status of statements (e.g. if one thing influences another; what was observed; what ought to be done etc.)

Table 2.2: Summary of empirical studies where participants respond to scientific information

Author(s)	**Date**	**Type of media**	**Partici-pants**	**Age of sub-jects**	**Theoretical/ literature background**	**Conception of quality of scientific source or information**	**Methodological approach**	**Findings and conclusions**
Norris et al.	2003	5 popular reports of science in news magazines and newspapers	380 university students	2nd/3rd year university students	Scientific literacy; building on Norris and Phillips (1994); Reading.	Identifying the certainty, status and role of scientific statements.	Students read 5 reports and answered 75 questions requiring them to interpret the pragmatic meaning of the reports.	Certainty bias shown in rating statements as true. Self-assessments of knowledge, interests and reading difficulty explained almost none of the variance in performance. Generally held inflated views of own performance. Interpretation did not vary much depending on amount of science education.
Ratcliffe	1999	New Scientist articles	56 pupils; 35 students; 29 graduates	Pupils 12, 14 and 17 years; graduates 22-35 years.	Scientific literacy; evidence/ theory relationship; reasoning.	Deciding if things are known for certain.	Written response to question under test conditions about certain/uncertain elements. Written response to incorrect inference from the article content.	Majority could distinguish between established facts and areas of uncertainty. 40% recognised problem of extrapolating from insufficient evidence. Signs of evaluation of evidence in all age groups, with graduates able to see detail in limitations of evidence. Only pupils drew upon personal experience.
Rieh	2002	Web	15 x scholars	Adult	Conceptual model of judgement; information quality; cognitive authority.	Information retrieval: selecting information readers want. Information quality and cognitive authority (trustworthy, topical.	4 tasks requiring Web searches (Information Retrieval). Web searches recorded along with "think-aloud" commentary. Subsequent discussion of the recordings in an interview.	People relied upon information quality (good, accurate, current, useful, important), cognitive authority (trustworthy, credible, reliable, scholarly, official, authoritative), topical interest, aesthetic appeal, affective aspects and general expectation when deciding what to look at.

Table 2.2: Summary of empirical studies where participants respond to scientific information

Author(s)	**Date**	**Type of media**	**Partici-pants**	**Age of sub-jects**	**Theoretical/ literature background**	**Conception of quality of scientific source or information**	**Methodological approach**	**Findings and conclusions**
Yeaton et al.	1990	Health related articles in newspapers and news magazines	144 university students	82% betwe en 18 and 25 years	Media related	Correct application of results. Understanding of article and ability to recognise correct and incorrect application of study results. Elements of recall.	Students read 5 reports and answered questions intended to test their understanding.	Rate of reader misunderstanding approached 40%. Inadequate understanding of the reports of health research at time of initial exposure.
Zimmer-man et al.	1998	Fictitious news briefs which have been adjusted to vary their plausibility and typicality	128 University psychology students	Median 19.4 years	Scientific literacy	Credibility rating of conclusions	Fictional newspaper reports. Participants read news briefs and rated credibility on Likert scale. They then wrote a justification of their rating.	Students often cited personal beliefs in justifications. Quality of information about the methods used in the research only affected credibility rating when news briefs were typical of natural/physical sciences.

2.9.3 Findings from empirical studies

There is significant evidence that people generally accept as true scientific statements presented to them (Dodds et al., 2008; Kolstø, 2001; Sadler 2004) or exhibit a 'certainty bias' (Norris and Phillips, 1994; Norris et al., 2003). Norris and Phillips (1994) conclude that even the high achieving students in their study were not able to interpret news briefs and obtain an appropriate understanding of the authors' meaning. A follow up study (Norris et al., 2003) with university students led the authors to conclude there was generally no relationship between the amount of science previously studied and successful interpretation of popular reports. Furthermore, Norris et al. (2003) found that university students handled the binary constructs of truth and falsehood better than grey areas where their interpretative powers were more limited. The use of multiple choice statements, however, meant that the outcome of evaluations were available to the researcher, but not the process. The methods adopted in the present study, in contrast focus more on the process of reasoning than the outcome.

From their work on socio-scientific issues (SSI), Kolstø et al. (2006) found a range of criteria used to evaluate claims:

- Quality of references
- Consistency of argument
- Face validity of argument
- Compatibility with own theoretical knowledge
- Completeness of references
- Completeness of an argument
- One-sidedness of the presentation
- Possible underlying interests
- Personal value-related qualities
- Authors' or cited experts' competence

- Level of professional recognition
- Level of expert agreement

These criteria were identified in evaluations completed by adult science education students who were well qualified in science subjects and who had selected their own articles to critique. It is clear from the list that quality of argumentation in the articles was important.

Kolstø (2001) used inductive analysis to identify four 'resolution strategies' (p.882) which 16 year old pupils used to evaluate the trustworthiness of the information they used in decision making about socio-scientific issues. Classifying these evaluations, Kolstø (2001) arranged "resolution strategies" for judging information on two orthogonal dimensions. The first dimension was "reaction" and the two categories within that were "acceptance" and "evaluation". The second dimension was "focus" and the two categories emphasized attention to the content of the statement or the authority (source) of information. Given that pupils had multiple resolution strategies it follows that some pupils' strategies fell into all the quadrants of the dimensions. This analysis is helpful because it emphasises both the usefulness of the statement and its authority. However, when looking to relate the findings of this study it should be noted that they were evaluating the information given within the context of a science lesson rather than from a media source.

Tytler et al. (2001) considered that "…judgements about evidence are often central in interaction between science and public." (p.817). Sometimes scientific claims in articles are justified with empirical evidence. The role of evidence, however, appears to be undervalued by secondary and university students. In a study by Thomas (1997), Open University students were asked before and after a science course about their opinion on controversial issues. It was found that exposure to scientific evidence did little to change their positions on the issues. Furthermore, Kolstø (2001) found that 16 year old pupils, in the context of SSI, undertook

"no evaluation of knowledge claims based on underpinning empirical evidence" (p.887). Likewise Zeidler et al. (2002), in a study of attitudes to SSI, found that some secondary aged students believed that scientific evidence would be unable to change peoples' minds on an issue. The same study gave further insights into attitudes to empirical evidence; it found that pupils were surprised that scientists could interpret the same data in different ways. It might be expected, therefore, when encountering reports of science, participants could ignore evidence as irrelevant or counter the evidence with common sense reasoning (Kuhn et al., 2008). It is also likely that they would try to evaluate sources of knowledge (or communicators of knowledge) rather than the claim and the associated evidence (Kolstø, 2001).

Mason et al. (2011), in their study found that most Grade 13 students spontaneously considered their beliefs about knowledge including about the certainty of knowledge during web searches. They found that most reflections were on the source of knowledge. Mason et al. (2011) considered that spontaneous reflection on knowledge is an under examined area. Gerjets et al. (2011) found that explicit instruction about how to evaluate information during web searches yielded more responses than when the responses were spontaneous and without guidance. Taken together, these two studies point to the importance of exploring spontaneous evaluation, but also the potentially significant impact of how the data is collected.

Studies that required participants to ask questions based on the text (Korpan et al., 1997; Korpan et al., 1999) found that participants were particularly interested in the methods employed in the reported research; it was not clear from this research, however, how the readers would use this information as they did not actually go through the process of evaluation and therefore their reasoning was not explored. Kolstø et al. (2006) found that

science education students made use of information about methodological norms. However, Zimmerman et al. (1998) found that information about methods in reported research only influenced outcomes in reports of natural and physical science.

Rieh (2002) makes a similar distinction to Kolstø (2001), between information quality with facets such as good, accurate, current or useful and cognitive authority. Cognitive authority includes perspective on trustworthiness, credibility and reliability, for example. Rieh (2002) also found that participants made a predictive judgement when selecting Web pages and if expectations were not met they would move to a new page or return to a previous one. In Rieh's approach participants selected their own web pages and moved to other sites if their expectations of the web page were not met. Readers also seem to have relied upon more surface characteristics such as URL, title and web page graphics. Rieh's study is open to the criticism that participants do not use information for a purpose.

2.9.4 Methodological information

In Zimmerman et al.'s (2001) information request study they found that one third of their sample of news stories contained sample size information. In that study experts highlighted the importance of this information but only around 20% of the students in their study asked for methodological information. Korpan and colleagues (1997 and 1999), in their studies, found that requests about *how* studies were conducted were common. Zimmerman et al. (2001) summarise work by Mallow (1991) and Einsiedel (1992) who found that information on methods was generally very brief, if present. Zimmerman et al. also reported that experts highlighted the importance of, and students requested information on, research design; details of subject and nature of methods. What is not clear from this research is how important this

information is, *how* readers made use of this information and whether it serves a useful purpose.

Zimmerman at al. (1998) claim that:

> Although social context conditions may influence judgement of quality or credibility, information about the appropriateness of the scientific methods employed is probably the most critical determinant of the credibility of research conclusions (p.193)

Further, Korpan et al. (1997) goes on to suggest that "Skilled evaluation requires, among other things, knowledge about *features of research* that are correlated with the quality of the investigation…" (p.518), examples of features associated with scientific methods are control groups and sample sizes.

Other writers are not unanimous on this issue. Gaon and Norris (2001) suggest that non-experts have less capacity to critique methods, therefore they should look at the social elements of the findings:

> Although only an expert can appraise the methodological validity of evidential claims, the non-expert can, and indeed should, always ask such questions as: Does this scientific belief embody or engender any particular social hierarchy such as those based on race, on gender or on class? (p.199)

Elliot (2006), in devising a strategy to develop scientific literacy in trainee teachers, did not include methodological information, suggesting that this information is not immediately useful. Overall these disagreements point to this being something worthy of further investigation.

2.9.5 The role of subject knowledge in readers' responses

The findings from the studies in Table 2.2 indicate that in their responses to reports of science, participants used personal beliefs and other criteria not related to science content

knowledge to make their judgements (Kolstø et al., 2006; Zimmerman at al., 1998). In another study it was found that scientific knowledge was less important than might be expected in evaluations (Norris et al., 2003). There was some evidence from Gray and Mill (1990) that Biology students performed better than English graduates, but this effect was reduced for less scientific texts.

Bråten et al. (2011) exposed undergraduates to seven different information sources and asked them to rate trustworthiness and identify the criteria that the trustworthiness rating was based on. They found that newspaper reports were trusted least of all the sources by those with "low knowledge" of the topic, while those with "high knowledge" of the topic rated newspapers above an oil company publication. Participants reported the content of the article as being the most important criteria for all of the different information sources. For newspapers the criteria, in order starting with the most important were: content, type of text, publisher, own opinion, author and when published. Bråten et al. rightly pointed out that each source being represented only once was a challenge to validity. Furthermore, the *a priori* criteria for the trustworthiness rating may not have included all criteria used and this breadth of the "content" criteria suggests that a more nuanced approach might be necessary.

Bromme et al. (2008) consider it obvious that some scientific knowledge is necessary to make judgments about scientific claims. Furthermore, von Aufschnaiter et al. (2009) state that subject knowledge is an indicator whether students are likely to achieve quality argumentation. Moreover, in their study with scientifically educated women, Dodds et al. (2008) found that participants make use of their scientific background when they evaluated advertisements. However, some pupils stated their opinion that textbook scientific knowledge was not crucial in their decision make about controversial issues (Kolstø, 2001). Consistent

with this, the same pupils did not think they should make use of textbook knowledge in their argumentation justifying their decision-making (Kolstø, 2001).

2.9.6 Summary

It can be seen from section 2.9 that previous research conducted in this area has made use of a range of quality 'measures', including certainty. A key finding, relevant here, is that readers have tended to show a 'certainty bias' where they have overestimated the probability claims are true. Further, there are indications that methods used in scientific studies are of interest to readers. It also seems that readers use a range of different criteria in their thinking, with existing scientific knowledge being only one of those criteria. The implication here is that formal education in science may have a limited impact on readers' understandings.

Perspectives on personal epistemologies, and the discussion in section 2.9, suggest that 'knowing' and subject knowledge are possible areas for further exploration. This study has been emergent in design with each phase of research depending on findings from the previous phase. Findings from the research into heuristics reasoning (Chapter 4) and 'interconnectedness' (Chapter 5) was found to be somewhat too narrow to capture the richness of readers' responses. Thus the final pair of research questions are about readers' understandings and deliberately adopt a broader view of readers' responses to news stories.

How do readers understand news reports of science? Are there differences in the understandings of readers with advanced formal education in science and those without?

2.10 Statement of aim and conclusion for Chapter 2

The substantive question to which I hope to make a contribution is "How does a non-expert evaluate claims when they have little, if any, specialist knowledge in the field?" This

question is relevant in the context of secondary teacher education because science teachers cannot be experts in all scientific areas and it would be expected that they model appropriate strategies and approaches to reading media texts about science. An understanding of how trainee teachers respond to news reports of science is a starting point for developing a curriculum to help them to improve their own responses and to prepare to work with school students. A related substantive issue is the extent to which knowledge is generalised or domain-specific. It can be seen that this domain general/domain specific issue recurs in the discussion above about personal epistemology, scientific literacy, NoS and in critical thinking.

In this study I will address two broad research aims. The first is to find out how people respond to news reports of science. The second aim is to explore any distinctiveness of responses for those who have undertaken advance study in science. While there has been research done into responses to news reports there is limited understanding of what progression might look like in these responses. In other words, what are the differences between a more basic response and a more sophisticated one? One way of exploring this is to look at any distinctiveness of responses from those with advanced science education, compared to those without.

The discussion above includes some possible ways of exploring how readers approach a news report about science. Firstly by examining how they approach knowledge claims and make decisions about the likelihood of veracity of those claims using heuristics, or 'rules of thumb'. Secondly by looking at how they make links or interconnections to other ideas. And thirdly by looking more broadly at their understandings of the articles they read.

CHAPTER 3: METHODOLOGY

3.1 Introduction

In this study my aim is to find out how trainee teachers respond to news stories about science and whether there is any relationship between these approaches and their formal science education. In line with the research questions given at the end of Chapter 2, I will explore participants' responses in three ways: firstly by identifying rules known in reasoning known as heuristics; secondly by looking at how readers make links between ideas; and finally by undertaking a thematic analysis with a focus on knowledge. For each of these three approaches I will explore any differences between science and history trainee teachers, and whether their formal education is able to account for these differences. In Chapter 3 I explain my general approach including the epistemological and ontological positioning of the study. I also explain the research design, seek to justify it and explore some of its limitations.

3.2 My thinking behind this study

This study draws upon an interpretivist philosophy (Schwandt, 2000). It is not assumed that there is one 'correct' way of understanding the world or that there is an external reality waiting to be discovered. The empirical data is not simple to interpret because making sense of media reports is socially situated and context-dependent. The area is inherently complex with peoples' responses to media reports dependent upon their background, their education, their perceptions of the media and their experiences, amongst other things. Furthermore, there is no guarantee that on one day an individual response may be the same as on another day or that as the researcher I will treat each participant in the same way. Thus, I acknowledge the complex and shifting nature of interactions between media texts, participant and researcher and the potential for a range of factors to influence the evaluations undertaken

by participants. As my concern is primarily with exploring trainee teachers' reasoning with regard to media reports, nearly all my analysis is qualitative.

At all stages of my work I deny the possibility of researcher objectivity in the research process (Scott and Usher, 1996). I would, therefore, subscribe to Thomas and James' (2006) view that:

> "... a priori assumptions are uneliminable, and this fact − far from being a source of anguish − is what the qualitative researcher should expect: a priori assumptions are what make study (a) worthwhile, and (b) possible." (p.783)

I do not consider it possible, or desirable, that somehow I might be able to put aside my experience, knowledge and assumptions either to observe some external reality as in positivist thinking (Lincoln and Guba, 2000) or in the phenomenological sense of epoché (bracketing) (Hollway et al., 2007). While for some researchers pre-understandings may result in bias or prejudice, Gadamer uses the idea of "fusion of horizons" (1992, in Scott and Usher, 1996) to describe the process which takes place between the researcher and the objects of research and which results in a broadening and convergence of viewpoints. According to Scott and Usher this is a plausible alternative to objectivity.

> "By comparing and contrasting various interpretations, a consensus can be achieved despite differences – indeed because of differences." (Scott and Usher, 1996, p.21)

I consider that it is only when I seek to absorb, comprehend and make sense of my exposure to new and unexpected data, insights or perspectives that I will be able to make any claims as to my findings.

Therefore, it is necessary that I reflect upon and describe my situatedness, and my part in the research process. I began to explore this in the introduction to this thesis. I am a white,

middle class male, have been a teacher in state secondary schools for in excess of a decade and taught science up to GCSE level and physics up to A-level. I have studied Engineering, Science Education and Psychology. My research is closely tied in with my role as a PGDipEd tutor and Lecturer in Science Education within a research-intensive university. My research interests stem from deep reflections on my own secondary school teaching and that, looking back, I presented science to the classes I worked with as a body of knowledge that is epistemologically unproblematic and certain.

I am concerned that trainee teachers and pupils should not be misled by school curriculum documentation about the nature of the scientific knowledge they encounter, and that they should be able to demonstrate some sort of autonomous thinking about science, both in relation to the individual scientific claims they encounter and the status of scientific knowledge more generally. I have had these interests for some time. In my Masters' dissertation (Kirkman, 2005) I was concerned with 'honesty' or epistemological consistency between the pedagogic methods utilised by teachers and the scientific content of science lessons. I wrote then:

> "Pedagogic approaches add contexts that are potentially divorced from any social, industrial, philosophical or historical context. Consequently, a new and potentially misleading context is overlaid on the scientific knowledge being taught in lessons, and can result in science being seen as fixed, objective, definite and devoid of cultural bias." (p.87)

I consider it likely that the messages pupils, and trainee teachers, receive about science are inconsistent with a contemporary consensus view (see Abd-El-Khalick et al., 1998 for a list of items relating to the nature of science as often understood in science education) of the epistemic status of scientific knowledge and so are misleading, although perhaps not deliberately.

I suggest there are two senses in which people could be misled: in an everyday sense, and in a more epistemological sense. Norris (1995a) writes, "it matters what we claim to know" (p.211) and explains that actions are sometimes based on knowledge claims. I agree with this everyday conclusion, but Palmer (1987) writes about something different, which is less about knowledge-informed action, and more about "being":

> "...the way we know has powerful implications for the way we live. I argue that every epistemology tends to become an ethic and that every way of knowing tends to become a way of living. I argue that the relation established between the knower and the known, between the student and the subject tends to become the relation of the living person to the world itself." (p.2)

Thus, I consider it important that people are not given misinformation in the sense that Norris writes but I am also concerned with the 'lived out' sense of Palmer (1987). Knowledge from the scientific community, scientific knowledge communicated by the press, or the knowledge constructed during my research cannot be neutral or value free.

This study does not seek to identify 'laws' and then generalise to a wider population. Instead the methodology and findings contribute to 'case law' (Robson, 1993).

In summary, the Norris sense is related to social justice and empowering trainee teachers and pupils with "correct" information and the Palmer sense relates more to ways of seeing the world and relating to other people. Both point to the importance of conceptions of knowledge and knowing.

3.3 Methods of data collection

3.3.1 Approaches adopted in previous research

The studies described in Chapter 2, and in particular Table 2.1, can be classified according to the broad nature of the task undertaken by participants. The most common task was to read

an information source and then respond to it. Some studies requested that participants select the articles themselves. In others, participants were asked to make requests for further information in order to permit decisions to be made for an imaginary purpose. Each of these types of studies gives different information. For example, reading an article selected by the researcher permits comparison between responses to the same article. However, there are differences between participants that may have a greater effect on the outcome than the article type - a form of hidden heterogeneity (Luker, 2008). Careful analysis of studies in this category is thus required.

Participants selecting articles with a particular purpose in mind gives an indication of what is considered important in search criteria and affords greater ecological validity than responding to researcher determined information sources. Approaches where readers make requests for further information mean that in addition to asking directly, participants' certainty about the reliability of the content can be explored from a different angle (e.g. in Korpan et al., 1997 and Korpan et al., 1999) and detailed information can be obtained about the nature and extent of information needed to confirm a high degree of certainty. However, there is a sense that within this genre there is no closure and there is no requirement for a final judgement given the available information. As suggested in the approach used by Rieh (2002), the process of selection of information is in itself an evaluative process, one in which criteria are used to identify appropriate texts, so perhaps the distinction between search tasks and response tasks is less than might be imagined.

<table>
<tr><th colspan="3">Task undertaken by participants</th></tr>
<tr><td>Participants selected article/ information for a purpose</td><td>Participants read information source(s) and responded</td><td>Participants made requests for further information</td></tr>
<tr><td></td><td>Gray and Mill (1990)
Norris and Phillips (1994)
Norris et al. (2003)
Ratcliffe (1999)
Yeaton et al. (1990)
Zimmerman et al. (1998)
Christensen (2009)
Kolstø (2001)
Dodds et al. (2008)
Kienhues et al. (2011)</td><td></td></tr>
<tr><td>Rieh (2002)</td><td></td><td></td></tr>
<tr><td colspan="2">Halverson et al. (2010)
Mason et al. (2011)</td><td></td></tr>
<tr><td></td><td colspan="2">Korpan et al. (1997)
Korpan et al. (1999)</td></tr>
<tr><td colspan="3">Kolstø et al. (2006)</td></tr>
</table>

Table 3.1: Summary of tasks undertaken in previous related empirical studies

Different media may require different approaches in order to examine how people evaluate them. For example, the real life situation of reading a newspaper on a train without opportunity for finding additional information is different to having the opportunity to follow embedded hyperlinks in an internet article.

As in most related studies, participants in the first phase of this study were asked to read a paper copy of the media report, taking as long as they needed. Exceptions in related studies are Korpan et al. (1997) where participants were given seven minutes to read and respond, and Ratcliffe (1999) where the articles were read out loud to the group of 11-14 pupils. It is possible that in the interview situation participants would feel pressure to read the articles quickly and therefore possibly omit key points. It is important, therefore, to put participants

at ease and emphasise that they can read at their own speed. In the second phase of this study participants selected their own articles and read them prior to the interview.

Most of the studies indicated in the table required a written response of some sort. All required an individual response, except for Kolstø et al. (2006) where participants worked in small groups, and Christensen (2009) who used focus group methods, neglecting social aspects of making sense of news reports. In all of the studies participants were required to read some materials (with Ratcliffe, 1999, being exceptional, as mentioned above).

The range of different responses includes Korpan et al. (1997), who asked participants to rate the plausibility of the scientific conclusions and Zimmerman et al. (1998) who asked participants to rate their credibility. Norris and Phillips (1994) and Norris et al. (2003) asked participants to respond to multiple choice items about the reported or asserted certainty of a range of statements related to the news report. Participants in Kolstø et al. (2006) selected a scientific article of their choice and then wrote a summary "evaluating the information and argumentation included in the article" (p.639). Finally, although not used in research, Jarman and McClune (2007) suggest that a "certainty meter" (p.116) could be used as a teaching tool when examining claims in news stories.

3.3.2 Using interviews

Interviews were selected as the main method in this study because they permit an interaction between the interviewer and the participant that would be absent in questionnaire or observation methods. However, a rigidly structured interview schedule might limit the range of responses and may restrict the type of reasoning which the participant would demonstrate. Exposure to media reports within unstructured interviews is favourably comparable to an informal chat but this increases the possibility that conversations stray far from the research

agenda. Therefore, semi-structured interviews (Cohen at al., 2011) offer a compromise to these tensions and permit deeper probing and the individual treatment of participants. The approach here is consistent with the idea that "qualitative researchers are first and foremost human listeners" (Thomas and James, 2006, p.784). As my concern is primarily with exploring potential patterns or themes, a qualitative interview is more appropriate than ethnographic approaches, where the main concern is with the particular setting (Warren, 2002). However, this does not mean that consideration of the interview as a social context can be neglected. As Dingwall put it:

> "If the interview is a social encounter, then, logically, it must be analysed in the same way as any other social encounter. The products of an interview are the outcome of a socially situated activity where the responses are passed through the role-playing and impression management of both the interviewer and respondent." (1997, quoted in Fontana and Frey, 2000, p.664).

Therefore, while my analysis is mainly concerned with the content of the interview, the context cannot be ignored. In common with other researchers interested in interviews as a way of exploring how participants make use of their existing knowledge, I acknowledge that meaning is negotiated and results from interactions between interviewer and interviewee (Halldén et al., 2007; Welzel and Roth, 1998). Thus each interview will need to be interpreted as an individual social encounter.

I see the interview situation as a "directed conversation" (Pidgeon, 1996, p.89). Furthermore, I now do not see it as desirable, or possible, to control or standardise the interview content (Warren, 2002) in order to reduce the impact of variability in the social context between respondents. Other examples of factors influencing the enacted interview include the interview environment; any existing relationship between the interviewer and interviewee; use of audio recording or note taking; and respondents' conceptions of the interview situation. In

line with the interpretivist nature of this study I made use of information associated with these factors that emerged in the findings, analysis and discussion.

Consistent with the vision of the interview situation as a "directed conversation" it is desirable to make the research approach as similar to normal life as possible. However, there are potential threats to this approach. O'Halloran (2003, in Cook et al., 2009) notes that participants may read materials more carefully than they would normally. It is, for example, conceivable that in normal life participants would read a headline and the first paragraph and skim the rest. There is no real solution to this tension except that I encouraged participants to take as much from the articles as possible, which is something that is interesting in itself because it reveals something about what is possible in analysis. A further issue is related to the motivation to read media reports. Fogg et al. (2003) point out that readers without deep motivation assess websites only on superficial features. Presumably, volunteer participants, as in this study, were willing to undertake the activities requested by the interviewer; however, it was necessary to examine the data to see if there was evidence to the contrary.

While the interview may be of some benefit to the interviewee to help develop their thinking about news stories, their time commitment was limited to no more than one hour for each interview as this represents the maximum time that participants could be reasonably expected to contribute and concentrate without a break and for it not to interfere with their course of study. One hour, as a maximum, should be sufficient to obtain in-depth responses for the purposes here.

3.3.3 Considering alternative methods

The participants in the study are University of Birmingham PGDipEd trainee teachers. Thus they are graduates with the desire to become teachers. The many differences between them

include their background, gender, personality, upbringings and ethnicity. In the first phase a brief survey was completed by the participants in order to gain information about their general profile (gender, age, degree subject). As a principal goal of this project is to find the kind of reasoning demonstrated by trainee teachers, the exact nature of the sample is less important than detailed analysis of the responses. In the second phase there was a preliminary interview (the interview schedule is given in Appendix VIII) in which I asked about the participants backgrounds and tried to glean other relevant information.

Large samples and wider ranging surveys are not an appropriate means to examine this field as the data would not be rich enough to analyse in depth. It could be considered that a case study approach would perhaps be preferable, with a bounded sample (Luker, 2008). However, this would have represented a sample of approximately 45 science trainee teachers, thus making the quantity of data unmanageable in the timeframe of this project. Therefore in this study all participants are volunteers who responded to a request for help. In the second phase of the study it was possible to build a detailed picture of participants; these are given in Chapter 5 in the form of pen portraits.

Some related studies have made use of experimental style approaches where they identified and measured variables. Korpan et al. (1997), for example, used counterbalancing in their approach and altered the order of presentation of material. Additionally Zimmerman et al. (1998) constructed fictitious media reports where the plausibility (knowledge consistent with personal knowledge) and typicality (how similar to school science) were strictly controlled. These sorts of approaches influenced this study in its early stages. Overall, I tried to keep the approach as naturalistic and as similar to real life as possible, perhaps like reading a newspaper on the train and talking to the person next to you about it.

As this study progressed I realised that the partly pseudo-experimental approach I adopted in the first phase was actually restricting the depth and breadth of data I was collecting. Furthermore, I realised it would not be possible to identify all of these factors and I acknowledged Thomas's (2009) reading of Kounin (1970) where social situations are identified as inherently dynamic and unstable processes and that any attempt at controlling is likely to lead to unintended outcomes. To put it another way "...if you squeeze an environment in one place it bulges somewhere else." (Thomas, 2009, p. 168). Therefore, in the second phase of data collection I opened up my approach and did not seek to control confounding variables, to use the vocabulary of science. Instead I tried to collect a wide range of evidence and then explain and account for this evidence.

3.3.4 Participants

The primary aim of this research is to explore *how* people respond to media reports of science. Potential participants included, for example, scientists, pupils, school leavers, and graduates. Trainee teachers' responses are of particular interest to me, however. They represent a small sub group of the wider population in society in that they hold at least a Bachelor's degree. It is possible to assume that most have also studied biology, chemistry and physics to at least GCSE level. Thus, they represent a "best case", as mentioned above, in terms of their educational background and potential to engage with and respond to media reports. To some extent, they show what is possible with regard to evaluation of media reports.

The second reason trainee teachers are especially interesting is that findings on the range and depth of their knowledge and understanding can be used to inform future curriculum planning, both in relation to the trainees' own knowledge and their teaching of pupils while on school placement. Finally, science trainee teachers have an awareness of school science

and the school science context. While this study is set in the context of teacher training in Higher Education, secondary school science is central to the PGDipEd course.

All participants were enrolled on a one-year postgraduate teacher preparation course (PGDipEd) and possess at least a Bachelor degree level qualification in a variety of science subjects. As I am a tutor on the PGDipEd, some participants were known to me. The University of Birmingham PGDipEd course is taught at Masters' level. Therefore participants will have some knowledge of educational research methodology from taught sessions and from essay feedback. It is not clear whether participants will draw upon this knowledge in their responses to media reports of science, even though it has the potential to be useful. Furthermore, participants may have received some input about the use of media reports of science in their own classroom practice and this may have an effect upon their thinking about the media reports of science. Both sets of data collection took place towards the end of the PGDipEd year.

As the research questions indicate, one of the purposes of this study is to examine relationships between formal science education and responses to news reports. Thus the selection of science and history trainee teachers was intended to provide contrasting groups which would allow exploration of differences in responses that may be caused by participants' education. In the English and Welsh education systems choices are made at age 16 to specialise in a small number of A-level subjects. Thus it is likely that science trainee teachers will have at least five years more formal science education than history trainee teachers, a substantial difference and therefore opening the possibility of producing noticeable differences in outcome.

Annually, the School of Education at the University of Birmingham has around 40-50 secondary science PGDipEd trainees which are split, although not evenly, between biology, chemistry and physics courses. There are generally smaller numbers in physics. The backgrounds of the students are varied although there is a requirement that at least 50% of first degree subjects match the subject of the PGCE. In practice this means that Science: Physics PGDipEd students, for example, enter the course with a range of first degrees from theoretical physics to engineering subjects. If the first degree has less than 50% physics or chemistry content then trainees may have completed a Subject Knowledge Enhancement course. The History trainee teachers forming part of the study are drawn from a group of around 20 trainees in each cohort.

All participants were volunteers and their selection was based on their willingness to be involved. For the reasons explained on the section on ethics below, there was a need to collect data towards the end of the PGDipEd course. Thus the window for data collection was short. While I recognise the desirability of approaches similar to "theoretical sampling" (Glaser and Strauss, 1967, p.45), where data collected is considered complete when there are enough participants to be able to confirm the identified categories rather than refine them (Denscombe, 2003, p.112), I was not able to work in this way due to the constraints described. Thus at the time of data collection I did not know if the data would be sufficient. It turned out that the first phase interviews did not yield the necessary data and a second round of interviews were required in a subsequent year.

3.4 Research access and ethical issues

I work in the institution where this research is based and so while research access to trainee teachers was relatively straightforward there are associated ethical issues to consider.

Regarding access, I sent an advertisement by email, asking trainee teachers if they would be willing to be involved in the project. Those who expressed a willingness to be involved were sent a further information sheet (Appendices I and II). As the research involves human participants there was a need to ensure informed consent. Participants signed a consent form (Appendix III). They were asked when it would be convenient for the interview to take place. Some interviews were completed while trainees were on school placement, others during a university phase of their PGCE course. Generally, if the opportunity for the interview was during a school placement I travelled to their school, but if it was during the university phase arrangements were made to meet in an office or a free teaching room. I took care to reduce the possibility that participants felt an obligation to take part by emphasising this in the information sheet. Furthermore, in both phases of the empirical work participants were almost at the end of the course and therefore there was no possibility that any course assessment issues might have influenced their decision to be involved.

All interviews were audio recorded. It was necessary, therefore, to ensure confidentiality for the participants and so participants' real names were not used. In the first phase of the study the transcripts were given a code and the in second the participants were given a pseudonym. In both phases the data was stored separately from the participants' real names given on the Consent Forms. Data has been and will continue to be stored according to the standard university regulations. An abridged version of the ethics form submitted to the appropriate ethics committee is given in Appendix IV and my responses to the conditions set by the committee are given in Appendix V.

Beyond these basic ethical issues there are further delicate considerations. Lincoln (1995, in Lincoln and Guba, 2000) identifies reciprocity in research relationships as an important

ethical and epistemological consideration. While there are power relations at play, in that I am asking questions as the researcher in the interview situation, there is some reciprocity in that in the interviews I give serious consideration to what participants say, and gave the option to receive further information following the data collection process.

On the topic of the epistemological/ethics nexus (Lincoln and Guba, 2000) there has been a relatively recent shift in research vocabulary - in psychology for example, from 'subject' to 'participant' (Phoenix and Thomas, 2002). This highlights the increasing awareness of the need to take seriously the participant in the research process and in ways other than in being mere providers of data. While I intend that participants' voices will be heard in my work, by including direct quotes for example, I do not envisage that they will devise their own means of communication as in more participatory approaches (Lincoln and Guba, 2000). I see any empirical data that comes from this research as a join construction between the researcher and participant, acknowledging that without the participant there would be no research, and thus placing an emphasis on the primary importance of their role.

The interview context can have a significant impact upon the behaviour of interviewer and interviewee (Lincoln and Guba, 1985, in Cohen et al., 2000) and so it is relevant to note that prior to starting the research I had working with some of the participants as their tutor and so the researcher-participant relationship was not newly established in these cases. Furthermore, it was my goal to keep the interview context as naturalistic as possible, and I tried to put the participant at ease and provide a quiet setting where they felt able to talk openly.

3.5 Selecting news reports about science for phase one of the study

In their work, Gray and Mill (1990), Korpan et al. (1997), Korpan et al. (1999) and Zimmerman et al. (1998) used fictitious media reports. Certain features of articles are

manipulated such that the impact of these features can be investigated and thus this approach is broadly experimental in nature. An example of one of these features is "typicality", that is, whether the subject is likely to have been taught in school (Zimmerman et al., 1998). In the present study, genuine media reports will be used, partly because of the difficulty in generating fictitious ones and partly because of the desire to make the interview situation as close to everyday life as possible. Consequently the articles used in the first phase have different lengths, different styles and include different features of research.

Furthermore, fictitious articles ameliorate, to some extent, the problems associated with taking into account individual differences in background knowledge as the fictional knowledge is new to everyone. However, presumably even with fictitious stories participants can draw upon some scientific knowledge. It cannot be assumed, though, that the use of background knowledge will result in an advantage as a greater familiarity with a subject area has been found to be associated with a less critical attitude (Kőller et al., 2000 in Trautwein and Ludtke, 2007; Trautwein and Ludtke, 2007).

In addition to being able to be read in a few minutes, something that allows a number of articles to be read in a limited time, I felt that the articles in the first phase should be in wide circulation and not aimed at a scientific audience. Further selection criteria stipulate that articles should contain some reference to investigatory methods and have some experimental results, even if they are generalised in written language, for example, using words like 'most' or 'fewer'. The media reports should be principally about a single report of scientific research which should be able to be identified. The advantage of this is that the reader can build something of a picture of the individual study. Some media articles report the findings of academic review papers that bring together a number of individual studies. A single research

study will simplify the process of identifying any references to scientific methods or scientific data for the participant and also allows me to access the original research article by the researcher. These selection criteria are similar to those used by Zimmerman et al. (2001). A summary of the criteria is shown in Box 3.1.

Selection criteria for media reports used in the first phase of this study

- Read for meaning in a few minutes
- In wide circulation
- In the popular press (not specialist publications such as New Scientist)
- Contains some reference to the research methods used
- Contains some data from the original research study
- Based on a single research study with identifiable author(s) and/or source.

Box 3.1: Summary of selection criteria for media reports used in the first phase

Over a period of 3 months or so in 2010 I searched news websites and looked in national newspapers for suitable stories. I also looked through archive newspaper materials. Suitable stories were kept on file and then in a subsequent short list, news reports were identified for the pilot study. The short list is shown in Table 3.2 below.

Headline	Source	Author	Published on
BBQ sauce can fight cancer	www.metro.co.uk	Attewill	25th March 2010
Brain scan 'lie detector' warning	www.bbc.co.uk	Parkinson	6th June 2010
Gender-bender chemicals 'putting everyone at risk'	www.dailymail.co.uk	Derbyshire	Last updated 25th March 2010
How cockroaches 'talk' about food	www.bbc.co.uk	Unknown	Last updated 4th June 2010
Brush teeth to prevent heart disease	www.bbc.co.uk	Wilkinson	25th May 2010
Ketamine drug use 'harms memory'	www.bbc.co.uk	Unknown	17th November 2009
Lasers could 'sense' vapours released by explosives	ww.bbc.co.uk	Moskvitch	Last updated 7th June 2010
Cancer danger of that night-time trip to the toilet	www.dailymail.co.uk	Unknown	Last updated 12th April 2010

Table 3.2: Short list of web articles selected for the pilot study

I had no intention of surveying a range of media reports and selecting representative articles from the survey findings. It is not possible to say that this shortlist of articles is representative of any wider set of articles. However, I will look briefly at the findings of some surveys which sought to examine the range of science news stories that appear in the press. Thus it is possible to compare the selected articles to these surveys.

Entwistle and Hancock-Beaulieu (1992) surveyed 8 national newspapers, for two weeks between 1981 and 1990, and found 778 articles related to health and medicine - a high number in the time frame. Pellechia's (1997) survey revealed that the percentage of science articles in three major US daily newspapers has increased to 2.04% of all articles in the period 1986-1990; 71% of those articles were on medicine/health, 4% related to technology and 25%

were categorized as natural/physical science. This implies that people are interested in medicine and health, possibly because they are relevant to their lives. Zimmerman et al. (2001) found that health studies accounted for about 40% of all reports, with natural science/engineering accounting for 24%, although this data came from a survey with particular selection criteria and so is not a sample of all reports of science in the media. Overall it is appropriate, therefore, that six of the eight pilot articles are related to health, one to ethology and one is technology/physics based. Furthermore, Zimmerman et al. (2001) found that 93% of reports of science were empirical in nature. Similarly, none of the articles selected for the pilot are theoretical in nature. Pellechia (1997) found that in 50% of the articles there were 30 or more words devoted to describing the methodology of the research in the news article. In all of the articles selected for the present study there was some mention of methodology.

3.6 Pilot study: Procedure and Refinements

In the pilot study I was hoping to:

1. establish the characteristics of suitable articles and eliminate articles which were unsuitable.
2. ascertain the amount of cueing that will be required in order to gain a suitable amount of information and that is required to keep the interview flowing (ultimately it was found that cueing was not a useful approach for this study).
3. find out how many articles can be evaluated by the trainee teachers in an hour long interview.
4. find out whether participants would be able to talk about the areas of interest at sufficient depth.

5. gain a sense of the sort of answers a trainee teacher might give.
6. determine whether interviewing non-scientists would give useful insights into evaluation and the role of specialist scientific knowledge.

A questionnaire was developed which asked for background information on the participant: age group, gender, A-level subjects studied, Bachelor degree and higher degree subjects. Participants were also asked to indicate if they had specialist knowledge in the broad topic area of each article. For example, for the article by Wilkinson (2010), participants were asked if they had studied heart disease beyond GCSE or had any specialist knowledge of it for some particular reason, e.g. a family member for whom this is a special concern.

Participants were then asked to make a judgement about how likely they thought the headline claim was to be true. In some cases this demanded that the headline was slightly rephrased so it was in the form of a declarative statement. For example for Wilkinson (2010) they were given the statement "Brushing teeth can prevent heart disease". Figure 3.1 gives the scale available to participants and they were asked to select one. At the end of the interview participants were asked how likely they thought it was to be true having read the article. The certainty scale used here is similar to those used by Norris and Phillips (1994) and Norris et al. (2003).

very unlikely to be true	unlikely	neither likely nor unlikely	likely	very likely to be true

Figure 3.1: Scale for rating certainty of the headline claim for each article.

Headline	Participant in Pilot Study			
	W	**X**	**Y**	**Z**
Participants' degree subject	Civil Engin-eering	Physics	Psych-ology	Modern History and Social Science
BBQ sauce can fight cancer	1			
Brain scan 'lie detector' warning			2	
Gender-bender chemicals 'putting everyone at risk'	5			
How cockroaches 'talk' about food		5	4	4
Brush teeth to prevent heart disease	3	2	3	3
Ketamine drug use 'harms memory'	4	3	5	1
Lasers could 'sense' vapours released by explosives		4	6	2
Cancer danger of that night-time trip to the toilet	2	1	1	

Table 3.2: Table showing which articles were presented to each participant and in which order (order chronological and indicated by the numbers in the table).

The Attewill (2010) article on BBQ sauce was found to be too short and contained insufficient material for participants to examine in depth. This resulted in brief and uninformative responses. Although Parkinson (2010) is about lie detectors, one participant correctly commented that it contained information relating to legal issues and little scientific information. Therefore, this article was also rejected. The article by Derbyshire (2010), about "gender-bender chemicals", is a summary of research study rather than reporting one individual study. This makes it difficult for the participant to discuss the scientific ideas as the points made in the arguments were complex and the source of ideas is difficult to identify. I had intended to use articles from a range of different media sources but it emerged that the articles on www.metro.co.uk and www.dailymail.co.uk were either too short or too implausible to sustain detailed analysis. The articles from the BBC news website were found to be an appropriate length with regard to time taken to read and depth of coverage of the story. Furthermore, as all articles came from the same source there would be fewer

differences in participant perception of source credibility, an advantage when comparing articles.

It was clear the first article was approached differently from the other articles. Participants were pre-empting the interview questions when they looked at the third and subsequent articles. This conclusion was both noticed in responses and expressed by participants. Four articles were settled on as the most appropriate number as five or more placed significant demands upon the interviewee and interviewer. I had been writing notes during the interview but it seemed that this was distracting to the participant and I concluded that it would be best to keep note taking to a minimum in future interviews. In the first interviews I realised participants could guess at certainty responses and my methodology had no way of recognising this. In the later interviews of the pilot I asked how sure participants were about their response.

Following the interview I asked participants about their experiences and it was indicated that they wanted to give helpful answers or said they hoped that the interview gave me what I wanted. While in interviews this is unlikely to be avoided, it should be taken into account during analysis. All three science trainees (W, X and Y) seemed to have had a desire to find some plausible mechanism for the event or phenomena etc. Unless they could find one, they were dissatisfied with the findings. In a number of cases reading the article shifted thinking about the certainty of the scientific statement. Participants did make reference to the authority and perceived credibility of institutions and publications, and this had an impact upon their thinking about the certainty of knowledge claims. On two occasions the idea that bigger is better in terms of sample size came up in the talk. Participants also showed signs of thinking about journalistic techniques including looking for a throw-away comment by the original

researchers that could be used as an attention-grabbing headline. Two participants showed signs of thinking on the spot as they reasoned one way and then another, using phrases like "then again" to indicate a weighing of viewpoints.

3.7 First phase interviews

3.7.1 Procedure

The refinements made as a consequence of the pilot study resulted in a procedure with four parts. First, all participants read the participant information sheet (in some cases re-read as it was sent to some by email), signed and dated the consent form. They were asked not to talk about the interview once it was complete as other people were still to be interviewed. Secondly, participants completed the questionnaire based on the one described above. Participants answered questions about their age group, gender, A-level subjects studied, Bachelor degree and higher degree subjects. The questionnaire also asked them about their opinion on the certainty of the headline claims in the form of a Likert scale. The Likert scale was based on the work of Norris and Phillips (1994) and Norris et al. (2003) who used a scale to indicate the "uncertainty of truth status" (2003, p.129). As a development from the pilot study I introduced a further scale to allow participants to give an indication about how sure they were about their decision about the certainty, or truth status, of the headline claims. This was intended to be an improvement on the approach used by Norris and colleagues. Table 3.4 gives these two Likert scales with associated interview questions and numerical values. During these stages of the interview I answered questions from participants about the questionnaire but made no other comments. A copy of the full questionnaire is included in Appendix VI.

How likely is it that the headline claim is true?	very unlikely	unlikely	neither likely or unlikely	likely	very likely
	1	2	3	4	5
How sure are you about your choice?	**very unsure/ guessed**	**not sure**	**neither sure or unsure**	**quite sure**	**very sure**
	1	2	3	4	5

Table 3.4: Codes for Likert scales about likelihood of claims being true and how sure about that choice

The third part of the procedure was the main interview. The interview was recorded using a digital voice recorder. Participants were asked to read the first media report in their own time. They were assured that they could take as much time as they needed and that I did not mind waiting. In this stage I made sure that I had something to read myself to reduce any pressure the participant might feel. When they indicated they had finished they were asked questions according to the schedule shown in Table 3.5 below.

The interviews were originally conceived to be cued in nature. In this cued approach, cues or prompts are given and there is an increasing amount of cueing as the interview proceeds. An example of a cued research approach can be seen in Gray and Mill (1990) where it was found that biology graduates needed fewer cues to spot missing control groups than English graduates. Similarly my goal was to explore the impact of questioning on participants' responses and to understand something of their spontaneous evaluation. The questions were deliberately open-ended so as not to give too much information about what I might expect as a researcher. In the second and subsequent articles more questions were asked in line with Table 3.5. Probes were used during the interview to encourage the participants' clarity and deepen their response.

I was hoping to identify the sorts of issues and ideas that they wanted to raise and not steer the interview content too much. It should be noted, however, that the questionnaire had Likert scales asking the participants about how likely they thought the headline claim was to be true,

before and after reading the articles. Thus these questions served to frame the interview. My role as science teacher trainer may also serve to prime the interviewees that the interview was about ‘science’.

Article number	Questions asked	Probes
1	What do you make of this article?	What do you mean? Would you like to add anything else? Go on?
2	What do you make of this article? Is there any data in the article that influenced your thinking?	
3	What do you make of this article? Are there references to scientific methods that influenced your thinking?	
4	What do you make of this article? Is there any data in the article that influenced your thinking? Are there references to scientific methods that influenced your thinking?	
At the end of all	Having read the article what will you take away from it? Having read the article what do you think now about your judgements of truth and how sure you are about that judgement?	

Table 3.5: Questions asked during first phase interviews
(including how questions were built up during the interview).

In the final phase participants were asked about their initial responses to all the headline claims and if they wished to change them to more or less certain. The opportunity to look again at responses to headline claims took place after each article was addressed, thus it was repeated four times.

3.7.2 Participant details

Within the first phase there were 26 participants, 14 with first degrees in science-related subjects and 12 with first degrees in history-related subjects. Tables 3.6 and 3.7 give details

of background qualifications with a focus on science qualifications. The participant codes used in the table are: F=female; M=male; H=history; B=biology; C=chemistry; and P=physics. It can be seen that around half of the history participants have at least one A-level in a science-related discipline, assuming a broad definition of science. For the remaining six history participants there is at least a five year difference in number of years studying science in formal contexts compared to the science PGCE trainees. The range of degree subjects within science, however, is wide.

Participant	PGCE subject	Age range	Gender	Science-related A-level subjects	Bachelor degree (Higher Degree)
01MP	Physics	26-35	Male	Physics	Mechanical Engineering
02FP	Physics	21-25	Female	Physics; Maths; Chemistry;	Physics (Masters)
03FP	Physics	21-25	Female	Physics; Chemistry; Maths; Geology	Physics/Astrophysics (MPhys Astrophysics)
04FP	Physics	21-25	Female	Chemistry; Physics; Maths;	Mechanical Engineering
05MP	Physics	26-35	Male	Physics; Chemistry; Maths	Physics Msci
06MC	Chemistry	21-25	Male	Chemistry; Human Biology; Psychology	Chemistry with Pharmacology
07MC	Chemistry	26-35	Male	Geology; Chemistry; Biology	Geology
08FB	Biology	21-25	Female	Physics; Chemistry; Biology;	Human Biology
09FB	Biology	21-25	Female	Biology; Chemistry; Maths;	Medical Science
10FB	Biology	26-35	Female	Biology; Chemistry; PE; Psychology	Biochemistry with Medical Biochemistry
11MP	Physics	21-15	Male	Physics; Maths; Electronics; Human Biology	Physics with Placement
12MP	Physics	21-25	Male	Maths; Further Maths; Physics; Chemistry	MSci Physics with Theoretical Physics
13FC	Chemistry	21-25	Female	Biology; Chemistry;	Biological Chemistry
14FC	Chemistry	21-25	Female	Sociology; Biology; Chemistry:	Chemistry

Table 3.6: Summary of background information on science participants

Participant	PGCE subject	Age range	Gender	Science-related A-level subjects	Bachelor degree (Higher Degree)
15FH	History	21-25	Female		History
16FH	History	21-25	Female	Chemistry; Biology;	Ancient History
17FH	History	21-25	Female	Geography; Biology	History
18MH	History	21-26	Male	Economics;	Politics and Modern History
19FH	History	26-35	Female		International Relations
20FH	History	21-25	Female		History and Politics
21FH	History	21-25	Female		History
22MH	History	21-25	Male	Physics	History
23FH	History	21-25	Female	Psychology	History
24FH	History	21-25	Female		History and Politics
25MH	History	21-15	Male		History (Medieval and Modern)
26FH	History	21-25	Female	International Baccalaureate (Biology, Chemistry)	History and Citizenship

Table 3.7: Summary of background information on history participants

3.7.3 News stories

Details for the four articles used in the interviews are given in Table 3.8. For each article it was possible to identify the original peer reviewed academic paper. These stories were selected following the pilot study and met the criteria described above.

Name of media report	**Brushing teeth**	**Ketamine**	**Cockroaches**	**Lasers**
Code used in analysis	A	B	C	D
Author (Date)	Wilkinson (2010)	Unknown (2009)	Unknown (2010)	Moskvitch (2010)
Media source	BBC News website	BBC News website	BBC News website	BBC News website
Original reports institution	University College London	University College London	Queen Mary's School of Biological and Chemical Sciences	University of St. Andrews, Fife.
Headline	Brush teeth to 'prevent' heart disease	Ketamine drug use 'harms memory'	How cockroaches 'talk' about food	Lasers could 'sense' vapours released by explosive.
Results	Those with the worst oral hygiene had a 70% increased chance of developing heart disease	Frequent ketamine users performed poorly on memory skills	Majority of hungry cockroaches fed solely on one piece of food until it was all gone	Molecules from explosive can switch off laser light emission
Methods	Epidemiol-ogical study	Memory tests; Questionnaire; Hair sampling; follow up year later	Food choice test; Mathematical model	Laboratory study and theoretical simulation

Table 3.8: Details of the four media reports selected for the first phase interviews

3.7.4 Likert Scales

Table 3.9 gives examples of how the scales were coded and summarised in a table. For example, the judgement of participant 06MC before reading the cockroach article was that they thought the headline claim was very unlikely to be true and that they were quite sure about their decision. After reading the article their judgement was that they thought the headline claim was neither likely nor unlikely to be true and they were neither sure nor unsure about their choice. Thus this data might suggest that after reading the article participant 06MC became more willing to accept the headline claim that cockroaches 'talk' about food but they were less sure about their decision than previously.

		Cockroaches				**Heart disease**			
		Before reading article		***After reading article***		***Before reading article***		***After reading article***	
Partic-ipant code	**Length of inter-view (mins)**	**How likely to be true?**	**How sure about choice?**	**How likely to be true?**	**How sure about choice?**	**How likely to be true?**	**How sure about choice?**	**How likely to be true?**	**How sure about choice?**
05MP	37	5	4	5	4	2	4	2	4
06MC	23	1	4	3	3	1	5	1	5

Table 3.9: Example questionnaire results for two participants

The Likert scales were found to be problematic. It became clear from the interviews that participants' understandings of the headline knowledge claims changed as they read the articles and had opportunities to reflect on the content. As participants' understandings of key aspects of the headline claim changed, so the usefulness of comparing decisions was reduced because there could be multiple reasons for a change in decision about certainty including the content of the article and their understanding of the questions. I had been hoping to isolate the content of the article as a cause of any changes, however, the instrument proved to be too insensitive to capture such changes, and my view now is that this goal was not useful. I have included details of this part of the interview in order to offer contextual information which

may help to interpret the rest of the interview data. The questions about the Likert scales frame the rest of the interview data, and thus serve some purpose.

3.7.5 Cued approach

I had hoped that following the scaling up of the cued approach following the pilot study it would be possible to tease out the impact of the questions on participants' responses. However, it was found that participants talked widely around the article and included a range of aspects to their answers, including going beyond the cues. Thus it was found that the cueing approach was too insensitive to yield results that could be interpreted. I used the cued approach in all of the 26 interviews in the first phase. I decided to neglect this part of the study and make use of the interview data without the cued element. The main implication for the data is a possible reduction in richness as the interview contained fewer questions or prompts than might otherwise have been the case.

3.7.6 Strengths and weaknesses of the approach

As this study is interpretivist it is not possible, or desirable, to generalise beyond this study to all news reports or to a wider population. While this group of trainee teachers may have similarities with other science trainee teachers it is not possible to say with confidence the extent of the differences. Furthermore, all participants were volunteers, thus the nature of the epistemic group is skewed, for this first phase, towards those who are willing to read an article in the presence of the researcher.

The extent to which an interview is able to 'tap' the beliefs, opinions, attitudes, skills, knowledge, reasoning or thinking of the participants is uncertain. I do not intend to infer any underlying cognitive structure or processing system. Instead I wish to examine the reasoning strategies used to make judgements 'in the moment'. The success of the interview depends

partly upon the extent to which the interviewer has appropriately understood and comprehended the meaning intended by the interviewee. Thus careful analysis of the interview data is required.

The participants will be making sense of the interview situation and responding to the situation but they will also be jointly constructing the interview. There is a three-way interplay between the interviewer, the interviewee and the texts under consideration. This adds a complexity to the interview situation.

Further, given my position as a teacher educator it is possible that participants would want to manage impressions given about themselves (Goffman, 1971). It is possible that both the researcher and the participants would wish to show themselves in the best light. An example of this could be found in responses to the ketamine article where participants may have wished, in their positions as trainee teachers, to emphasise their anti-drug stance. However, on balance it would have been very difficult for participants to know what it was that I was looking for in the interviews. It is possible participants may have wished to give the best response possible, in depth and scientifically correct, in order to present themselves as knowledgeable. This might have made participants read news stories more closely than they might normally have done.

The interview method has the strength of structuring the manner in which participants interact with the news reports and permitting clarifications of meaning. The participants were post-graduate teachers who were used to expressing views and opinion. When reading a news story on a website, a reader would normally have access to hyperlinks or search engines such as Google. Thus they may follow up on ideas presented in the news story. There was not the

facility to do this in this part of the study, thus it was more like reading a newspaper on a train.

3.8 Second phase interviews

3.8.1 Background

The second phase of data collection was intended to address some of the epistemic issues with the first set of interviews and the associated findings, discussion and analysis. Firstly, in the first interviews, four articles were researcher selected and everyone looked at the same articles. The participants, thus, may not have been motivated to read the articles. Secondly, the participants were expected to read the articles during the interview. This might have put pressure on them and they may not have been able to read in their normal way. Thirdly, the interviews included a cued structure. It emerged early in the analysis that this cueing would not yield useful data and thus there was no need to continue this strategy. The cued approach reduced the quantity of data produced and its removal made the interviews more focussed. Finally the overall approach in the second phase was more open, with the goal of collecting richer and deeper data.

3.8.2 Interview details

In the second round of data collection I interviewed science and history graduates from a different cohort to the first group of interviewees. In a preliminary interview I collected background information about participants' education, A-levels and their first degree subject. They were asked to describe any reading they had done in science and their reading habits and approaches. Science participants were asked about any use of science in the news in their teaching and history participants were asked more generally about any use of news stories in their teaching. All participants were then asked whether they had seen other teachers use

news stories in their teaching and to describe it. A full list of questions drawn upon in the interview are given in Appendix VIII.

At the end of the interview a further interview was arranged and instructions were given to select between four and six science-based articles on news websites and to read these before the next interview. Participants were asked to email web links prior to the follow-up interview to permit me to print off a copy of the news story, become familiar with it and have a copy for participants available during the interview. This did not always happen and sometimes the participant brought a printout of the article to the interview. There was an opportunity for participants to ask any questions about the task that had been set.

In the main interview, participants were asked questions based on the following:

- What led you to select this article?
- When you read it, what were you feeling or thinking?
- How does it fit with what you already knew?
- When you read it, how did you approach the text? How did you go about reading it?
- Have you taught anything in school about this?
- Was there anything in the article you were willing to accept as non-contentious?
- Was there anything in the article you were unwilling to accept as true?
- Did you follow up on anything you read in the article?

3.8.3 Participant details and pen portraits

There were five participants with science related first degrees and three with history related first degrees, making eight in total. Two participants completed preliminary interviews but it was found that it was not possible to arrange a follow-up interview due to the proximity to the

end of the course, so their data was not used. Table 3.10 gives an overview of the participants and their science qualifications.

Participant	PgDipEd subject	Formal education in science
Lee	Science	Double award GCSE; Maths, Further maths, Physics and Chemistry A-level; Physics Undergraduate Masters degree
Sheila	Science	Chemistry and Physics to GCSE; Chemistry and Physics A-level; Chemistry with French degree.
Joseph	Science	Triple award GCSE science; International Baccalaureate - 3 Higher subjects (Physics, Chemistry and Maths), 3 Standard (French, History, English plus Biology); Natural Science Degree (mostly Physics).
Simon	Science	Single award science GCSE; studied for A-levels in Biology, Chemistry and Physics but was not successful. Then took a Foundation degree, and degree in Forensic Science.
Becky	Science	Double award science GCSE; Chemistry, Geography and Biology to A2. Physics to AS. Degree in Chemistry.
Alex	History	Double award science GCSE; No science A-levels (History, Sociology, Geography and ICT); Degree in History and Social Science.
Nick	History	Double award science GCSE; No science A-levels (History, Sociology and Maths); Degree in History and Politics
Katie	History	Double award science GCSE; Biology A-level - Nuffield approach which was career based and included looking at science in a big organisation; Degree in History and International Relations.

Table 3.10: Summary of background information for second phase participants

In this section I will summarise the educational background of each reader and give details of their reading about science. The first part of the pen portrait is mostly taken from the preliminary interview and the details of the news stories they selected are taken from the main interview and my own reading of the news stories. Participants were given freedom of choice in selecting news stories, with guidance that it should be related to science. There was a wide range of topics represented.

Lee

Before starting university Lee completed a double award Science GCSE and gained A-levels in Mathematics, Further Mathematics, Physics and Chemistry A-level. While at university Lee obtained an undergraduate Master's degree. In his first year, he started on a Physics with Astronomy course but then moved to Physics only for his second year. In his final year at university he took a module on philosophy where he had to write three reports on how views about science had changed over time. His degree contained a lot of maths. Lee has no experience of working in scientific field and moved straight from his degree to teacher education.

During his degree he had subscriptions to Physics World and New Scientist. He had recently read a book called "Primitive Time Reckoning". He subscribes to BBC and New Scientist feeds. He also uses Reddit, an online site which includes links to news stories. He reads the BBC news website and also the Metro newspaper. He watched some science television programmes while in the Sixth Form but did so less during university.

In his teaching, he has used news stories to stimulate interest; he gave the example of concerns about Voyager 1 giving aliens information about where Earth is. He has also used them to show advances being made, including in the use of radiation in cancer treatment. He

has set his students research tasks on the Electromagnetic spectrum and intensive/organic farming. He has used recent news stories as introductions for lesson. He has also laid out stations around his teaching room and asked students to find information from each. Another example he saw in school was when a teacher made news announcements about a simulated volcanic eruption through the day.

Lee selected five articles to read. The first "MIT creates glucose fuel cell to power implanted brain-computer interface" (Anthony, 2012) was found on www.extremtech.com. It was about how a fuel cell could be powered by glucose in the body and could run implanted low power devises. The second article had the headline "Lithium-air battery advance could be jaw-dropping improvement over Li-ion" (Timmer, 2012) and was found on the website: http://arstechnica.com. In this article the author compared the two kinds of lithium battery. "A surprising find: Tropical lake on Saturn moon Titan" (Choi, 2012) seemed to have originated on www.msnbc.msn.com and examined how a lake of methane has been found at the equator of Titan. The fourth article had the headline "Trapping flying qubits in a crystal (and getting them back out)" (Lee, 2012) and was on the http://arstechnica.com website. The article reported developments in quantum computing where two research groups have produced memory for light based qubits (units of data). The fifth article was "Nasa's Nustar X-ray telescope rides to orbit" (Amos, 2012b) and was found on www.bbc.co.uk. The article reports that Nustar, a telescope, has been sent into space to study x-rays coming from sources such as black holes.

Sheila

Sheila attended an all-girls school and completed Chemistry and Physics GCSEs. At A-level she took Chemistry and Physics and went on to complete a Chemistry with French degree at

university. In her final two years she specialised in analytical chemistry and completed a project in physical chemistry. Before embarking on teacher training she worked in a scientific context in a management role and part of her role included staff and police training.

Since starting teacher training, she had not followed many news stories but read to follow up on issues that emerged in the classroom. In her previous role, she read a daily digest of news in the field. At the time of the initial interview, Sheila had read about Venus crossing the Sun and talked about this with her own children.

Her teaching in school had included showing the NPIA (National Policing Improvement Agency) website to her BTEC Forensic Science group to show recent cases solved by the DNA database. The goal of this was to prompt discussion about whether we should have a National DNA database. In another lesson Sheila asked her group to research 'Oakland Habitat' on the internet. Homework tasks set for her classes included researching animal classification and looking up earthquakes around the world.

Sheila read six articles which she brought to the interview. The first had the headline "DNA of thousands of innocent people still being collected by police" and was on www.telegraph.co.uk. Written by Beckford (2012) the article reports how DNA information is being stored despite legislation that suggests such databases should be scaled down. The second reading was not a news article but a report about the Fingerprint Enquiry (www.thefingerprintinquiryscotland.org.uk). The chair of the report committee was Sir Anthony Campbell and the report was published in 2011. The purpose of the inquiry was to verify fingerprints associated with a 1999 court case (H.M. Advocate v. McKie). The third article was titled "Nerve regrowth protein identified" (von Radowitz, 2012) and was about how, in a study on mice, a signalling protein was identified that turns on a "regenerative

programme". For the fourth article Sheila selected "Stargazers transfixed by transit of Venus" (2012). Next was an article where Professor Sir David King gives his view on the need to invest in nuclear power ("Nuclear energy: Kings urges billions in investment", www.bbc.co.uk, 2012). The final article had the headline "Solar-powered plane completes Moroccan desert flight" (2012) and was found on the website of the Telegraph newspaper.

Joseph

Joseph obtained triple award GCSE science and then completed an International Baccalaureate qualification with three subjects at higher level (Physics, Chemistry and Maths) and three at standard level (French, History, English). He attended Cambridge University and studied for a Natural Science Degree which was predominantly Physics. He did not take a module on history and philosophy of science, although such a module was available. While at school Joseph gained one week of work experience in a hospital and during one summer while at university he completed ten weeks experience as a computer programmer.

Joseph does not read journals but looks at the BBC website when he has time. He sometimes reads a magazine, for example Physics World, but this was particularly when he was at university. Now he is more likely to read material from the Association for Science Education (ASE). He enjoyed science books and TV when he was 18 years old but now finds the pace rather slow.

In his teaching Joseph has used a Sun newspaper article and a Wikipedia article about Alexander Lituenko. In the latter example he asked students to read and answer questions. He has also asked students to look at advice from the Environment Protection Agency about noise pollution. Students were asked to watch an episode of Myth Busters showing that man did go to the moon, despite conspiracy theories suggesting otherwise. Joseph stated that

students found this too difficult. Students undertook internet research to produce a table about different types of energy resources and also researched planets/moons in the Solar System where aliens could potentially live. Joseph had not seen other teachers make use of news stories in their teaching.

Joseph had read four articles prior to the interview. The first, found on www.bbc.co.uk was "Supervolcanoes 'can grow in just hundreds of years'" (2012). The article reports research which found that supervolcanoes could erupt hundreds of years after forming rather than hundreds of thousands of years as previously thought. The second media item was a short article plus a video called "Searching for dark matter in the Homestake Gold Mine". It was located on www.bbc.co.uk (the video producer was Matt Danzico but the journalist was not identified) and was dated 30th May 2012. The article described how a research facility is being built in a former gold mine. Joseph also selected the BBC news article "Space 'textures' nearly ruled out in WMap study" (Palmer, 2012) which explains that cosmic microwave background (CMB) radiation may not vary as much as previously thought. The final article reported a suggested link between diesel fumes and lung cancer ("Diesel exhausts do cause cancer, say WHO", www.bbc.co.uk, Gallagher, 2012a).

Simon

Simon took single award science at GCSE and said that he had enthusiastic teachers. He studied for A-levels in Biology, Chemistry and Physics but said he was not really successful in these. He then took a Foundation degree followed by a degree in Forensic Science. His degree was heavily weighted towards chemistry and biology, and was accredited by the Royal Society of Chemistry. The course included a little history of forensic science.

Simon has no science related work experience. In his work he did not make use of the scientific aspects of his degree but he did use the reading and information skills he gained in that time. Simon's father subscribed to New Scientist, which Simon read. He tends to read the BBC news website weekly mainly for recreation. For example, recently he read about using genomes to produce better vegetables. He also watches the evening news nightly. Simon explains he is not much of a reader and does not read popular science books.

In his teaching Simon made use of some material from his Foundation degree, including with his BTEC group. He also used a Daily Mail article about HIV, mainly as a comprehension exercise, where students produced a table with cause/effect/prevention. He used an episode of Top Gear about use of hydrogen as a fuel and asked the students to watch the clip, make notes and he followed this up with teacher questions. Simon used the BBC Bitesize website as an information source about viruses and bacteria. In a year 9 lesson he gave the group a list of metals in a table and asked them to use the internet to find information on the quantity used and recycled.

Prior to the interview Simon had read four articles. The first was about a competition asking people to explain the Mpemba effect, when hot water sometimes freezes faster than cold water (Emsley, 2012, www.guardian.co.uk). The second article was about the first human-made object to leave the Solar System. The headline for this www.guardian.co.uk article was: "Nasa's Voyager 1 on course to enter interstellar space" (Batty, 2011). The third article was from www.dailymail.co.uk: "TVs, fridges and fishing boats: How TWENTY MILLION tons of Japan tsunami debris is closing in on Hawaii" (Duell, 2011). It explains how debris from the Japanese Tsunami is travelling towards Hawaii faster than expected. The final article, also from the Daily Mail website, was about claims of an unidentified object at the bottom of

the Baltic Sea. It had the headline "'UFO' at the bottom of the Baltic Sea 'cuts off electrical equipment when divers get within 200m'" (Wrenn, 2012b).

Becky

Becky obtained a double award Science GCSE. She went on to gain full A-levels in Chemistry, Geography and Biology, and took Physics to AS-level. She completed a first degree in Chemistry. Her final year dissertation was on AKR NC3 proteins. Her degree did not contain any history or philosophy of science, although she did look at who came up with theories, e.g. Bohr.

Becky has no work experience other than going into schools. Becky's reading has included the Royal Society of Chemistry magazine. She watches news on the TV and takes special interest in science. She will not look specifically for science stories but if she see a link, e.g. on the Hotmail homepage, she will follow it. Recently she read about cancer treatments, the subject of her degree dissertation.

During her first school placement she was involved with GCSE Science in the News coursework about sunscreen and skin cancer. Students were given some articles and asked to look for more. They used the BBC and NHS websites to get data about skin cancer rates and then needed to draw and interpret graphs. They also needed to comment on things like bias and vested interests. Becky also gave some students an article about the mosquito device that emits a high frequency sound that can only be heard by young people, and explored the advantages and disadvantages with her students. Another example was when using an internet research activity, students researched the social and economic problems of IVF, and a lot of the information came from news stories. Becky had seen other teachers use news stories to stimulate interest and create enthusiasm.

Becky selected four articles. The first had the headline "New holey materials soak up CO_2" and is from the BBC news website (2012). The article was about 'carbon capture' and a new material which is able to absorb carbon dioxide from the atmosphere. There was a further article about carbon capture which Becky had printed off (Black, 2012a) but this was not discussed specifically. The second main article was also from www.bbc.co.uk : "China launches space mission with first woman astronaut" (Amos, 2012a). This describes how a woman will be part of the crew on the Shenzhou-9 capsule heading to the Tiangong space lab. Becky's third article was about how GM crops seem to increase the numbers of "natural pest-controlling predators" (GM crops 'aid plant neighbours', 2012, ww.bbc.co.uk). The final article which had the headline "Milk fats may alter gut bacteria causing bowel disease" (Gallagher, 2012b, www.bbc.co.uk) suggests reasons for the increasing incidence of inflammatory bowel diseases.

Alex

Alex studied for double award science GCSE but he did not do any science A-levels, selecting History, Sociology, Geography and ICT instead. While at school he did a General Studies examination which included a science module about climate change. He went on to complete a degree in History and Social Science. During his degree his lecturers would give some background information on scientific figures such as Isaac Newton but he did not study history of science explicitly.

In terms of work experience, Alex completed two weeks in a hotel during his year 10 at secondary school. Since then he has gained experience in a secondary school for four weeks where he watched some Key Stage 3 science lessons.

He watches TV news almost every night and reads newspapers at the weekend. He will look at the BBC news website and follow major news channels. He tends not to come across many science news stories unless they are in the news. He does read New Scientist occasionally, but this was mainly when he was at school. Alex sometimes watches television programmes such as Panorama, for example on the subject of clean hospitals.

He has taught a topic on "Medicine through time" and in teaching this topic he has used photographs of unemptied bins to show how some things can harm health and how local government may intervene. He has also used pictures of the Costa Concordia to spark interest in the Titanic and initiate analysis of who was to blame. He has showed pictures of Jamie Oliver's healthy eating campaign to stimulate interest in what causes people to be unhealthy and then compared this to the Greek view of four humours. Students have also examined an issue, such as swine flu and how the media educate people about that, and presented the finding to the class.

While in school Alex observed a science lesson about speed where four images of fast things were shown and then students looked at how different newspaper covered the HS2 high speed rail link. He also saw a geography lesson on the Japanese earthquake with Fukishima as a stimulus to explore what an earthquake is and impacts.

Alex selected five articles. The first had the headline "Healthy forests key for green growth, says UN report" (Kinver, 2012, www.bbc.co.uk) and was based on the United Nations "State of the World's forests 2012" report. The second article was from www.dailymail.co.uk and was about space tourism. The headline was "The final frontier in holiday destinations: British company prepares tourists trips to the moon (it's a 500,000-mile round-trip and will cost you £100 million)" (Wrenn, 2012a). Next was a technological article: "Microsoft unveils

Touchscreen Tablet" (2012, http://news.sky.com). Alex then chose the same story as Becky but used a different source (www.guardian.co.uk) : "China's first female astronaut shows how 'women hold up half the sky'" (Branigan, 2012). The final article was from www.newscientist.com and had the headline "Humanity weighs in at 287 million tonnes" (Marshall, 2012). The article suggested that total weight of humanity was a better measure of human impact on the Earth than population statistics.

Nick

Nick's experience of science in school included studying biology, chemistry and physics separately from year 7, and completing a double award Science GCSE. He took A-levels in History, Sociology and Maths. He went on to a degree in History and Politics. He did not study history and philosophy of science explicitly; his degree had a political focus.

Nick worked as a dispensing assistant in an opticians. In this role he needed to know about dispensing options, e.g. pupil centres, refractive indexes and options to thin down lenses. He keeps fish and needs to know some science in this part of everyday life. He does not follow or actively seek out science news stories, nor does he read popular science books or watch TV programmes about science, except the Gadget Show.

Nick has used news stories in his teaching to show the relevance of what is being taught. For example about the Arab/Israeli conflict as a starter activity. In another lesson he used pictures of a shoe thrown at George Bush as a starter activity. The purpose of using these examples was to stimulate interest and make a topic relevant to the students. In another starter activity he used pictures of Hitler and David Beckham to show how the Olympic Torch relay originated in Nazi Germany. He also used a news story of the death of his great grandfather to illustrate the need for the National Health Service (NHS).

The first of the five articles Nick selected was about a music website that suffered a password breach (2012, www.bbc.co.uk) and it included the suggestion that readers of the article should have different passwords for different websites. The second article (Gill, 2012a), also on the BBC news website, was about the Varroa virus that is found in bees. The headline was "Honeybee virus: Varroa mite spread lethal disease" and the article reported research findings from Hawaii that suggested the Varroa parasite helps spreads the deformed wing virus. The third article was the same as the one read by Sheila ("Nuclear energy: Kings urges billions in investment", www.bbc.co.uk, 2012) and was about a Professor who was advising the government not to rely on private companies to maintain a supply of electricity. The fourth article was "Scottish and US universities to work on medical research projects" and it was found on the BBC Scotland website (2012). The article reported new collaborative research projects into using stem cells to regenerate damaged tissue. Finally Nick selected "Slowest Greenland sharks huntssleeping prey [sic]" (Gill, 2012b, www.bbc.co.uk). The news story explains how researchers have measured the speed of the Greenland shark and realised that it is too slow to catch a swimming seal.

Katie

Katie studied double award Science at GCSE and then went onto complete A-levels, including biology. The biology course was Nuffield and part of it was to look at science in a big organisation. Katie then went on to complete a degree in History and International Relations. During her degree Katie did not study history or philosophy of science but she did look at how governments use things like science to influence their policies. Part of her course also looked at environmental issues and international relations.

When Katie was thinking of becoming a physiotherapist she gained some work experience in a prosthetic department of a hospital (during enrichment session of AS year), in a GP surgery and in a rehabilitation clinic.

Most days Katie spends 10 minutes on the BBC homepage but she rarely reads newspapers. Katie is interested in science but whether she reads about it depends on what it is and how accessible it is. For example, she is interested in medicine and planets. She has a couple of books by Richard Dawkins ready to read. She has watched the Great Human Journey on television.

In both of her placement schools Katie has taught the topic of "Medicine through time" as part of GCSE History. Katie explained that in school history, relevance and significance are two of the five core skills. In lessons Katie has given students a news story and asked them to annotate the text to highlight these things. Katie set a homework task to find an article about medical developments. In another lesson taught by Katie, pupils used the internet to find information about the development of transport. In a geography lesson Katie had seen another teacher use a PowerPoint presentation with news story to show sweat shops and global trade.

Katie brought four articles to the interview. The first was about a team of Japanese scientists who calculated that the oldest galaxy identified so far was 12.91 billion light years away. The headline was "'Oldest galaxy' discovered using Hawaii telescope" (2012, www.guardian.co.uk). Roberts's (2012) article had the headline "Children with older fathers and grandfathers live longer" and was about how the genetic make-up of sperm changes as a man ages such that it could be linked to longer life expectancy. The third article was about the Rio earth summit. In the article Black (2012b), writing under the headline "Nations at

odds over Rio + 20 Earth summit", suggests that nations are not in agreement on key issues and that progress in preparing the agreement is slow. The final article had the headline "Brain training helps beat depression" (2012, www.bbc.co.uk). The article explains how researchers have been using Magnetic Resonance Imaging (MRI) techniques to show people how their brain reacts to positive imagery, and how this might help people to control brain activity.

3.9 Strengths and limitations of the approach

In the pilot and first phase interviews, participants were asked to make a final decision about how certain they were about the headline knowledge claims in the news stories. It is significant that second phase participants were not expected to make such a decision. Identifying exactly what the decision is being based on is challenging as in news stories there are often multiple claims. Zimmerman et al. (1998) underlined claims in their text in order to help participants identify them. In the first phase of this study, participants were given the headline knowledge claim but in the second phase there was more flexibility and participants were not required to make such a decision.

One criticism directed at work in the field of personal epistemologies, and at Perry in particular, is that there is an "unwavering faith in the individual's ability to describe his or her own meaning making process" (Hofer, 2002, p. 9). In this study there is a dependence in the interviews upon individuals' understanding of the process of reading and sense making. However, as the participants have been asked to do a task there is also the outcome of that task, as well as the participants description of how they went about the task, so the issues with this criticism are reduced somewhat.

3.10 Exploring readers' understandings of news stories

As participants responded to news stories with a particular emphasis on likelihood of veracity, one approach to analysing the transcriptions would have been to make comparisons with published and peer reviewed research articles. While this would have been more possible in the first round of interviews where all participants were given news articles which originated in published journal articles, some articles selected by participants did not originate in research. Thus finding authoritative and generally accepted positions would have been unlikely to be possible. Furthermore, the goals of this study included identifying the sort of strategies used by postgraduates as they responded critically to what they read. The focus throughout this study is on readers' understandings of the news stories and not whether statements that readers make are scientifically correct or not.

A further strategy would have been to scrutinise the data with a view to placing each data item on a hierarchy of sophistication using, for example, Bloom's taxonomy (Bloom, 1956). This would have permitted the sophistication of different responses to be compared. However, it has been pointed out that the upper levels of the taxonomy (analyse, synthesise and evaluate) are to some extent interdependent rather than purely hierarchical (Ennis, 1993) and thus unreliable for this purpose.

King and Kitchener (2001) have developed the reflective judgement model (RJM) which highlights a developmental trajectory for individuals' engagement when reasoning about ill-structured problems. The three broad stages (pre-reflective, quasi reflective, reflective) are hierarchical and sequential with a trajectory starting in young adolescence, going through to young adulthood. This model has been used by Zeidler et al. (2009) to explore how teaching about socio-scientific issues might be associated with the progression through stages of the

RJM. However, with postgraduates, reasoning is likely to be associated with the higher stages of the model and incremental stages in the model are unlikely to be sensitive enough to differentiate between participants. Furthermore, while the Reflective Judgement Interview, the research strategy associated with the RJM (King and Kitchener, 2001), has been used in cross-sectional studies, it is more suitable for longitudinal studies. Thus, given the small scale and cross-sectional nature of the present study, its usefulness is limited. There are also some problems with the model in that acceptance of the views of those in authority is considered to be low in the hierarchy, when it has been argued elsewhere (Norris, 1995) that it may be rational to accept the position of experts.

A further possible strategy for examining transcriptions is through analysing argumentation. Erduran et al. (2004), amongst others, have used Toulmin's framework to analyse argumentation, for example by looking at the number of valid arguments. In one study Sadler and Fowler (2006) used the number and quality of justifications as a measure of argumentation. However, this analysis focuses only on arguments defined in this way and thus may miss out on other strategies that are used by participants.

Informal reasoning involves the generation and evaluation of arguments or positions (Means and Voss, 1996; Sadler, 2004; Sadler and Zeidler, 2005). Sadler and Zeidler (2005), in the context of genetic engineering, identified three categories of reasoning: rationalistic, emotive and intuitive reasoning. They also explored how these categories could combine into conflicting or coordinating patterns. They found that the patterning was context dependent. For the purposes of this study this approach does not offer a means for establishing a measure of quality for the participants' responses.

As stated at the start of this chapter, and in line with the research questions, in this study I will look at responses from three different perspectives. The perspectives are looking at heuristics, connections made between ideas in the news story and other ideas, and finally a thematic analysis with a focus on knowledge. However, what each perspective has in common is that the emphasis is on the understandings shown by readers.

3.11 Summary and conclusion for Chapter 3

In Figure 3.2 I have summarised the main stages of the research strategy showing how in this emergent design each of the two main stages was informed by the previous stage.

It is perhaps more common to include details of analysis in a methodology chapter. However, in this study the approach to analysis is very closely related to the interpretation of the analysis. Therefore, I made the decision to include the approach to analysis in Chapter 4, 5 and 6 along with the findings, analysis and discussion.

Data collection approach	Analysis	Outcome informing next stage
Pilot interview: 4 semi-structured interviews		
Four individual semi-structured interviews to try out questionnaire and to identify suitable news articles and an appropriate number of articles.	Scrutiny of responses, including looking at the potential to address the research questions and the potential to answer the questions in section 3.6.	Some news stories are too trivial for in-depth discussion. Four stories identified as an appropriate number for a single interview. Four news stories (all from BBC website) selected from the longer pilot list.
Phase 1: 26 semi-structured interviews		
14 science and 12 history trainee teachers. Semi-structured interviews framed by questionnaire with questions about participants' background and their views on the likelihood of veracity of headline claims before and after reading the articles. Researcher selected articles.	If…then… filter used to identify couplings between conclusions about likelihood of veracity and cues.	A range of heuristics (or lines of reasoning) identified. However, these are decontextualised. Readers may not have been interested in researcher selected articles. Participants gave responses richer than the single concept of likelihood of veracity. Likert scales for likelihood of veracity not found to be reliable enough to be useful.
Phase 2: 8 pairs of semi-structured interviews		
8 new participants (5 science and 3 history trainee teachers). Preliminary interviews to gain background information plus main interviews. Readers selected between 4 and 6 articles. Interview questions intended to be more open-ended to gain richer responses.	1. Concept maps drawn from interviews to identify extent of connectedness of ideas (36 in total). 2. Emergent themes associated with readers' understandings mapped for individual readers.	

Figure 3.2: Summary of main data collection phases and emergent design

CHAPTER 4: HEURISTIC REASONING ABOUT THE QUALITY OF SCIENCE IN THE NEWS

4.1 Introduction

Chapter 4 includes the findings, analysis and discussion associated with the research questions that were introduced in Chapter 2 about the heuristics that readers use when they reason about the quality of the science they encounter in the media. The aim of this chapter is to first identify heuristics used by readers and then to explore if there are differences in heuristic use based on readers' formal education in science. Included in this chapter are details of both the process and outcome of analysis. The reason for this is to signal, by the structure of the thesis, that the design of the study has been emergent and that there was not an analytical framework in place at the start of the study. In interpretivist studies it is not uncommon to integrate the analysis, findings and discussion (Thomas, 2009); I have taken this one step further and have put this alongside details of the analytical strategy.

The main approach taken to identify heuristics was to look for a coupling between a cue, which was found in the text or introduced by the reader, and a conclusion about the quality of the science. While most data here is drawn from the phase one interviews, the phase two interviews were analysed using the same approach and this chapter includes some of that evidence.

4.2 Approach to analysis

4.2.1 Identifying If…then… statements

The audio recordings of the interviews were all transcribed. As the researcher, I transcribed the first four and the rest were completed by a professional audio transcription service. In quotes from transcriptions, researcher utterances are shown emboldened. All transcriptions

were checked against the recordings and changes made to the text as appropriate. The accuracy of work of the audio typist was found to be extremely high. I recognise that in the process of audio recording and transcription, information is lost, for example, non-verbal signs. Thus the transcripts are a partial record of the interview and need to be interpreted in the light of this. The transcriptions were then read and re-read several times.

The transcriptions were scrutinised for quotes which matched the formulation shown in Box 4.1, which is based on the structure of heuristics described in section 2.5.3. There are two elements: cue and conclusion. The cue is an idea that is associated with a conclusion about certainty, it could come before or after the conclusion. The second element is the conclusion. There were two conclusions possible: increase epistemic distance and decrease epistemic distance. Epistemic distance was discussed in Section 2.5.5 and is an indication of the willingness of a reader to accept a knowledge claim. Briefly a large epistemic distance is associated with the rejection of a claim and a small epistemic distance associated with the acceptance of a knowledge claim.

General Formulation:	**If** (cue) **then** (conclusion about certainty of knowledge claim)
Example:	**If** (heard something similar before) **then** (decrease epistemic distance).

Box 4.1: If…then… lines of reasoning

The following illustrative quotes are taken from the analysis and give information about the conclusion about certainty. The conclusion about epistemic distance is included in brackets:

- *I am not surprised* (decrease epistemic distance)
- *it's a good indicator that's a good study* (decrease epistemic distance)
- *that's quite a large number of adults* (decrease epistemic distance)

- *I am not really convinced* (increase epistemic distance)
- *I think at the moment I'm just a bit cautious, that's probably the best word* (increase epistemic distance)

I annotated printouts of the transcripts where I had identified occurrences of cue/ conclusion couplings. This was completed for all 24 of the transcriptions from phase one and the 8 from phase two. Where possible I used the language of the participants to write the If…then… statements. The next stage of the analysis was to tabulate the If…then… statements and include a quote as supporting evidence. This information was entered into three Microsoft Excel spreadsheets: one spreadsheet for science trainee teachers from the first phase; one spreadsheet for history trainee teachers from the first phase; and one for the second phase of interviews.

As described in Chapter 3 each participant was given a number from 01 to 24, a gender code (M=male or F=female) and a code giving the subject of teacher training study (B=Science: Biology; C=Science: Chemistry; P=Science: Physics; H=History). Numbers 01-14 represent science trainees and numbers 15-24 represent history trainees. Further, each unit of data was given a unique code for identification. Examples of the analysed data for two participants are given below in Appendix VII. I selected these as examples because within the data there are If…then… statements for each article and a range of heuristics are represented. Details of the news stories have been described in Chapter 3 but for reference the codes I used are: Brushing teeth=A; Ketamine=B; Cockroaches=C; and Lasers=D. An example coding is 07MC/A, which indicates participant number 07 is a male chemist and the focus is on article is A, which is about Brushing teeth. A similar strategy was adopted for analysis of the second

phase but data is reported with a pseudonym instead of a code to highlight the differences in methodology from each phase.

Sometimes a cue was found in the text but did not have an associated conclusion and, therefore, it was omitted from the analysis. Furthermore, sometimes a conclusion was identified but had no associated cue and was also omitted. Generally If…then… lines of reasoning can be identified in the quote included in the summary table, however, on occasions some evidence for the If…then… statement can be found elsewhere in the text.

In early analysis I sought to distinguish between conclusions that were *absolute* statements, for example, "I don't believe it" and *relative* statements that give a more general sense of increasing or decreasing epistemic distance, such as "I would have like to have been a little bit more convinced by it". In some examples it was not possible to clearly determine if a unit of data was an absolute or relative conclusion. The categories, as a consequence, were collapsed into two broader conclusions: increase or decrease epistemic distance. In some cases the interviewee talks speculatively about something that may happen or might be true. An example is shown in Appendix VII, Data ID 107, where the interviewee talks about what they would find more convincing and thus the conclusion is 'decrease epistemic distance'.

Figure 4.1 shows a schematic representation of the interview process, which has previously been explained in Chapter 3. Initially participants made a judgement about how likely they thought it was that the headline knowledge claim was true. They then read the news article. The summary then shows how participants applied an If…then… lines of reasoning, in the form of a cue with an associated conclusion about certainty. Further If…then… lines of reasoning were then used, in series. The participants then made a final decision about the truth status of the headline knowledge claim. The focus here, however, is on the contents of

the dashed box. As previously argued, the decisions about the headline claim at the start and end proved not to be reliable but the articulation of the process of reasoning was found to be useful.

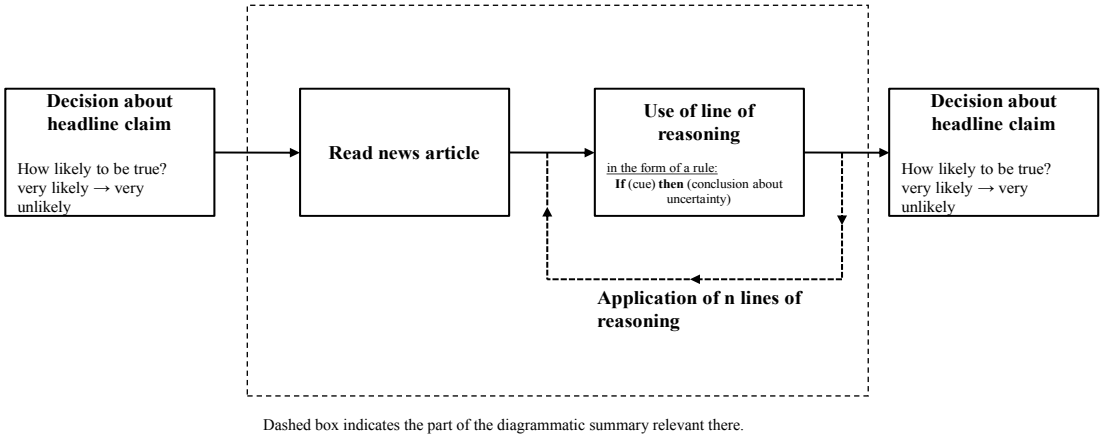


Figure 4.1: Summary of participant decision making and reasoning about the likelihood of veracity of claims in news reports of science.

4.2.2 Identifying heuristics

To identify heuristics I produced cards with one If…then… statement per card. I then sorted these into piles and began to think about the category title which could accommodate all the cards in that pile. The process of identifying categories was iterative and I moved from thinking about individual units of data to thinking about categories. Once I was satisfied that the category description could accommodate the individual units of data, I entered the categories for each unit of data into the spreadsheet described above. However, not all the

If…the… statements could be tagged in this way. In total about 25 categories were identified in this analysis. These heuristics are described in more detail later in this chapter.

This approach is consistent with the constant comparative method (Glaser and Strauss, 1967). I see any categories as 'constructed' and so a product of my interpretation rather than being discovered (Thomas and James, 2006). Furthermore, there is continuity between the data collection strategy and the analysis because the participants' accounts of their interaction with the media reports is predominant in the interview situation and is again emphasised in the analysis by using the words of the participants as much as possible (Pidgeon, 1996). The nature of the constant comparative method is such that the analysis and data collection are iterative and dynamic (Pidgeon, 1996). In the production of the categories, cards were sorted several times until I was satisfied the categories were robust. The identification of the If…then statements was a step towards producing categories at a higher level of abstraction than in the original transcriptions.

Recent studies on heuristics in chemistry (Maeyer and Talaquer, 2010; McClary and Talaquer, 2010) have emphasised the preconscious and automatic nature of heuristic reasoning and give short times for participants to undertake their tasks. The assumption that giving a short time for reasoning will mean that the preconscious and automatic heuristic reasoning will be accessed is somewhat difficult to support because of the difficultly of setting an appropriate time limit. In my research, I decided not to try to identify fast heuristic reasoning because setting a time limit to read the news report could mean participants could feel the interview process was a test in speed reading. This meant that any heuristics identified cannot be solely part of any fast or automatic processing but may include slower deliberate reasoning.

Figure 4.2 summarises how the data was reduced to these categories of If…then… statements which I have called heuristics. At each level data is lost, including contextualising evidence, however, this approach allows for the categories to be reconstructed offering new insights into the data including by increasing the level of abstraction.

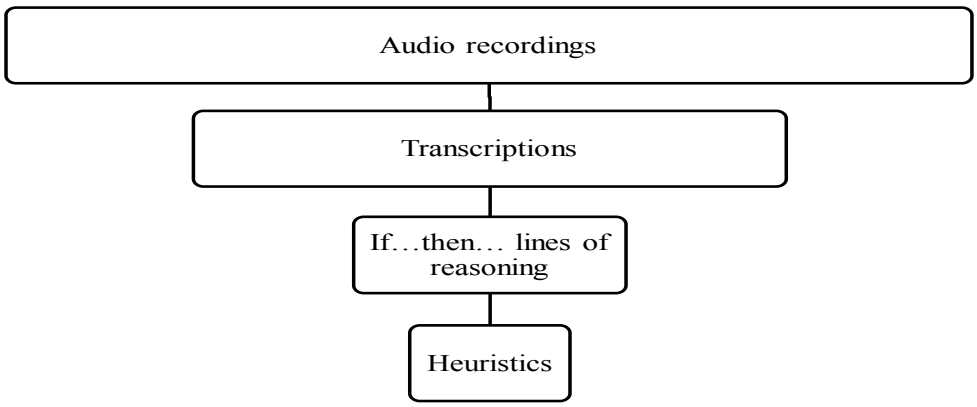


Figure 4.2: Representation of stages of the data reduction process with the box widths indicating that in the analysis some information is lost and the level of abstraction is increased.

4.2.3 Interpreting the evidence

The cues identified in this study are not external stimuli leading to a response in the form of a conclusion, as is found in behaviourist perspectives. The cue may be present in the text of the article, for example, in the article about heart disease (Wilkinson, 2010) Professor Richard Watt is reported to explicitly state that the nature of the link between oral health and cardiovascular disease is yet to be confirmed. However, the conditions may be explicit in the article and yet the participant may not use it in their reasoning. Thus I am not claiming the cues are located solely in the text, or in the mind of the individual, but that they are part of a constructive process (Norris and Phillips, 2003) where the participant interacts with the text, selecting which parts of the text to use in their reasoning. Furthermore, I consider it possible that participants will infer from what is present in the text and add to it from their own knowledge and understanding to form new insights.

The outcome of the analysis described above is a range of heuristics, some of which served to increase epistemic distance and some served to decrease epistemic distance. I will examine these heuristics in more detail in the rest of this chapter. I have divided the heuristics into five groups: explanations and factors; methods; subject knowledge; research and researchers; and communication. These five groups of heuristics are described in sections 4.3-4.7 respectively.

4.3 Heuristic Group 1: Scientific explanations and factors

4.3.1 Problems with scientific explanations

By identifying explanations as problematic, participants distance themselves from knowledge claims in news stories and create “epistemic distance” (Norris, 1997). These findings, or heuristics, are summarised in Box 4.2. In the first round of interviews, twelve of the fourteen participants with science degrees either identified explanations given in news stories as

problematic or suggested alternative explanations. There was, however, less evidence among those with history degrees, with five out of ten making these points. There are echoes here of what Keil describes as a "drive for explanation" (2006, p.17) when responding to the news stories. However, those with advanced education in science do not exclusively demonstrate this.

As Norris et al. (2003) indicate, the term *explanation* can mean a range of things, including "provide a causal account of", "justify or provide reasons for" or "to make intelligible" (p.144). In this section, explanation is taken to be broader than to "provide a causal account of" because in news stories describing science that is emerging, causal relations are often yet to be confirmed and thus correlations and other links are included within explanations.

<u>If (cue) then (conclusion about epistemic distance)</u>

If scientific explanation given in the news story are identified as problematic **then** increase epistemic distance

If can suggest an alternative explanation to that offered in the news story **then** increase epistemic distance

Box 4.2: Heuristics emerging from data analysis associated with explanations.

Although the two categories shown in Box 4.2 are distinct, the identification of scientific explanations as problematic is an overarching category which subsumes the alternative explanation category. This is because the implication of suggesting alternatives is that the stated scientific explanation is somehow inadequate on its own.

Examples of comments where participants identify explanations as problematic include:

> Um, and yeah, the stuff about chemicals seems to be, um, conjecture really (07MC/A)

In this quote the mention of chemicals refers to the means by which cockroaches communicate, the mechanism suggested by the research quoted in the news article (How cockroaches 'talk' about food, 2010). The quote implies that the participant is not willing to accept the explanation offered which includes chemicals.

To illustrate the subcategory where participants suggest alternative explanations, I will use an example from the Ketamine news story responses. The news story given to participants states:

> The study also raised concerns about the addictiveness of the drug – hair sampling from the recreational group showed drug use had doubled over the year. (Ketamine drug use 'harms memory', 2009)

Participants 03 raises two suggestions for alternative reasons for drug use doubling:

> hair sampling from the recreational group showed drug use had doubled over the year erm... that could not necessarily be to do with addictiveness that could be to do with other things like if the price has carried on coming down erm...or the strength of the drug on the market has like I don't know if the drug has got stronger what they were buying and that could show up in hair sampling like the increased amount of drug in the hair could be to do with other things than the addictiveness (03FP/C)

Therefore, by suggesting alternative explanations for the evidence that states drug use has doubled, the participant is also implying that the current scientific explanation is problematic.

A further example is from a history graduate who questions the explanation of why bacteria lead to heart disease:

> Um, don't know, 'cause it doesn't really explain how the bacteria causes problems in the heart, I don't think it did, so I suppose it makes sense but it doesn't help me to understand why it happens… **Right, okay.** And because it hasn't helped me to understand, I don't know how much I believe, right, 'cause in these type of articles, you get so many out all the time that contradict each other… **Mm-hmm.** And if it hasn't sort

> of explained it to me, then I'm not fully sure of whether it's true or not and then if there's, it just makes me less likely or less inclined to fully support the argument. (18MH/B)

In addition to challenging the relationship between bacteria and heart disease, the participant here also makes a link between belief in the article contents and his understanding. This quote is further evidence that participants expect or wish to have an explanation of phenomena.

An explanation, or plausible mechanism, was seen by another participant as an important means to convince people of the veracity of findings. In a response to an article by Gallagher (2012a) about the health effects of diesel fumes, one participant states:

> To just being because of diesel and the trouble with this kind of study is because you don't know why it's happening, it's much more difficult to kind of convince people that this is the truth, err, whereas if you came up with a mechanism for, you know, diesel fumes and ending with cancer… **Mm-hmm.** That would kind of give it more weight, but right now, it's just kind of, um, it's talking about diesel fumes and also it, there's nothing in there about, you know, what part of diesel fumes it is, it's just, you know, a very, very broad… **Mm-hmm.** Err, kind of sweep at what's going on. (Joseph: Physics)

The suggestion here is that the failure to determine the component of diesel fumes that is associated with cancer undermines the veracity of the findings. Therefore, this is a further subcategory within problematic scientific explanations where a key variable is teased apart into further variables. The absence of a plausible mechanism is seen by some as a means of distinguishing mainstream science from marginal science, for example, in homeopathy (Sokal, 2008).

4.3.2 Problems with causal factors

The two heuristics summarised in Box 4.3 are about factors, or variables. I am using the term 'factor' here as being broader than 'variables'. The reason is that 'variable' is often associated with experiments but the studies here use other methods than experimental ones.

The two heuristics are deliberately put together because of the relationship between them. By suggesting alternative factors, readers are implying dissatisfaction with the reported factors and thereby implying there is a problem with the reported factor. The data indicated that 9 out of 14 science participants and 9 of the 12 history participants used one or both of these two heuristics.

If (cue) then (conclusion about epistemic distance)

If indicate there is an issue with the reported factors **then** increase epistemic distance

If can suggest other possible factors **then** increase epistemic distance

Box 4.3: Heuristics emerging from data analysis associated with factors or variables.

Three out of the four news stories used in the first phase of this study postulate a relationship between factors. Box 4.4 shows the headline claims and relationships drawn from the articles. The heuristics in Box 4.3 accommodate relationships described by "using" and "linked". The important point here is that the readers have identified possible problems with the stated factors or relationships, not the exact nature of that relationship.

"How cockroaches 'talk' about food" (2010)
Cockroaches communicate using chemicals

"Brush teeth to 'prevent' heart disease" (Wilkinson, 2010)
Oral health is linked to heart disease

"Ketamine drug use 'harms memory'" (2009)
Frequent use of Ketamine is linked to memory problems

Box 4.4: Headlines and postulated relationships between factors from articles used in the first set of interviews.

I will now illustrate these heuristics. On reading one article (Ketamine drug use 'harms memory', 2009), a participant considered the possibility that there might be factors other than Ketamine use leading to the findings about memory:

> but there could be other factors that they haven't really mentioned or considered that could have had an effect on some of their memory maybe. I don't really know. (15FH)

Thus, this quote illustrates the heuristic where the issue of other possible factors are raised. To illustrate where participants suggested other possible factors I include another quote from a science graduate:

> I'm, I'm not convinced that there really would be a link between brushing your teeth and heart disease. Um, I think, I mean, maybe it, it contributes but I mean, they do say there's other factors, smoking and diet, exercise, um, (07MC/B)

Suggesting factors is a more sophisticated response than raising the possibility that there might be other possible factors as there is a need to identify the issue and also to generate alternatives.

News stories, by their nature, are at least one step away from any original research reported in peer reviewed journals. Ideas about relationships between variables are especially difficult to accurately report. For example, the article about heart disease starts with a sentence:

> People who fail to brush their teeth twice a day are putting themselves at risk of heart disease, research suggests. (Wilkinson, 2010)

However, the main conclusions in the de Oliveria et al. (2010) British Medical Journal article, from which the Wilkinson article stems, states:

> Poor oral hygiene is associated with higher levels of risk of cardiovascular disease and low grade inflammation, thought the causal nature of the association is yet to be determined. (p.1)

Thus the researchers' doubts about causality are not accurately represented in the headline. Readers face particular challenges as they try to make sense of such interpretations.

Kuhn et al. (2008) reported the difficulties sixth grade students had while coordinating the effect of multiple causal influences when predicting the risk of avalanche. The variables under consideration were wind speed, snow pollution, cloud covers, soil type and slope angle. An assumption about the type of multiple variable tasks used in the Kuhn study was that the effects of multiple variables could add or interact. Suggesting possible causal factors, as seen participants responses in this study, is in some ways less demanding than the task set by Kuhn et al. as participants were not asked to predict specific outcomes. On the other hand it is potentially more challenging because in reading stories they identified possible factors hidden in the text, or generate such factors, independently. Perhaps surprisingly, interaction between multiple factors or variables was something that was raised briefly only once in the present study:

> Related, so, but I mean, it, it could be a combination of all of the factors, they put there bad hygiene, bad, err, like smoking, drinking, things like that, so it could be… **Mm-hmm.** A combination of all three. (22MH/B)

Discussion in Chapter 2 highlighted the importance of reasoning about variables for scientific thinking and thus the absence of evidence of such reasoning suggests a need to address this in teacher education curricula.

4.3.3 Suggesting alternatives

In the previous two sections I have discussed two categories that emerged from the data where participants articulated alternatives: firstly suggesting alternative explanations and secondly suggesting alternative factors. These two categories are linked in that they both involve

respondents generating new ideas that potentially challenge the content of the news story. In this section, I will explore these two categories further.

Explanations

The next quote illustrates how a participant explored the plausibility of the explanatory mechanisms for the link between oral health and heart disease (Wilkinson, 2010):

> I still think it is unlikely. I think obviously they have got the link between the inflammation but I think, I mean, you can get the inflammation all the time like in your joints if you do exercise and stuff so no not only have you not got to brush your teeth you've also got to get some sort of infection which is then going to be inflamed… so I think as an actual factor to heart disease I still think it is unlikely. (05MP/B)

The mechanism offered in the news story is that proteins that suggest inflammation are present in those with poor oral health. Participant 05MP examines this explanation and making the point that inflammation can be caused by factors other than problems with oral health. A range of other explanations offered by participants are given in Box 4.5.

Cockroach article (How cockroaches 'talk' about food, 2010)

- Clustering not about communication about food but for defence (07MC)
- Just following, perhaps like sheep, (11MP; 20FH; 22MH, 23FH)
- Members of the same family and imitate for safety (14FC)
- Cockroaches can see each other (19FH)

Oral health and heart disease article (Wilkinson, 2010)

- Not lack of oral hygiene but that gums infected (01MP)
- Heart disease caused by smoking, bad diets and exercise (06MC)
- Proteins suggestive of inflammation could have been associated with smoking not other habits (06MC)
- Other reasons for lower heart risk than brushing teeth e.g. better diet (09FB; 13FC)
- Gum problems increase stress which leads to heart disease (18MH)
- Heart disease linked to other bad behaviour (21FH)

Ketamine article (Ketamine drug use 'harms memory', 2009)

- Drug use doubled not because of addictiveness but because price came down or strength increased (03FP)
- People don't just take Ketamine but other drugs too (19FH)
- People who do not use drugs have bad memories as well (23FH)

Milk fats article (Gallagher, 2012b)

- If do research more likely to find IBDS (Becky: Chemistry)

Honeybee virus article (Gill, 2012a)

- Perhaps not this virus that causes death but a cocktail of other viruses (Nick: History)

Box 4.5: Explanations offered by participants as alternatives to those included in the news story.

Korpan et al. (1997) found that requests for further information about *why* results occurred, in other words scientific explanations, were common among university psychology students responding to news stories. While this finding is confirmed to some extent in the analysis presented above, the information request methodology adopted by Korpan et al. yields a different kind of data to more direct approaches. It demonstrates what it is that participants

are interested in finding out and does not offer direct insight into how participants would use that information were it available.

Norris et al. (2003) approach of presenting university students with news stories and then asking them to decide upon the role of statements in the report allowed exploration of their capacity to distinguish explanations from phenomena. Norris et al. (2003) claim that participants found it difficult to interpret descriptive statements of phenomena and explanatory statements, however, the approach relied on students knowing what was meant by the words 'phenomena' and 'explanation'. As Norris et al. explain, within literature there is ambiguity about the use of the term 'explanation', thus it is likely to be even more of an issue among students. In the present study the data about explanations was collected indirectly by asking participants to undertake a task, thus they did not need to know a precise meaning of terms. As participants were not asked directly about explanations, and identification of explanation emerged at the analysis stage, any use of explanation stems from participants' own sense making.

Factors

The second category where respondents suggest alternatives is when they challenge the factors given in the article. In experimental approaches, variables other than those between which a relationship is postulated, and which have a disproportional effect on a dependent variable, are called confounding variables (Miell and Pike, 2002). The idea of confounding factors is useful for readers as they examine news stories. To illustrate from the data, one response to the article suggesting that readers should "Brush teeth to 'prevent' heart disease" (Wilkinson, 2010) one participant stated:

> Um, I think, I mean, maybe it, it contributes but I mean, they do say there's other factors, smoking and diet, exercise, um, (07MC)

Furthermore, after reading about how “Ketamine drug use 'harms memory'” (2009), the same participant suggested drug users in the study are unlikely to use only Ketamine:

> but it doesn’t, well, I don’t remember it mentioning other drugs that these people in the study will have used, because if they're regular Ketamine users, they probably use other drugs as well, so and maybe cannabis, so what effect that’s had on their memory. **Mm-hmm.** And whether it’s just the Ketamine. (07MC/B)

A further response draws on an example to make the point that there may be other factors influencing the outcome of a study (Gallagher, 2012a).

> I mean, there's going to be so much kind of trouble behind it, you know, rail worker A might, you know, also night shift in a nuclear factory, I don’t know, that kind of thing, um, whereas rail worker B might not, so it’s, you know, it’s really difficult to, to kind of say conclusively that this study points towards it, but it’s, it’s, it’s a jump in the right direction, I guess, so… (Joseph: Physics)

In addition to these illustrative quotes there was a range of other suggested factors, these are given in Box 4.6.

Cockroach article (How cockroaches 'talk' about food, 2010)

- Two food sources are not identical (11MP)

Oral health and heart disease article (Wilkinson, 2010)

- Smoking, diet and exercise (07MC)
- Smoking, obesity, social class and family medical history (15FH)
- Diabetes (16FH)
- Lifestyle (16FH)
- Medical history, family history, blood pressure, social class, obesity and smoking (21FH)
- Combination of factors like smoking and drinking (22MH)
- Balanced diet and smoking (23FH)
- Smoking, lifestyle and social class (24FH)
- Hereditary conditions (25MH)

Ketamine article (Ketamine drug use 'harms memory', 2009)

- Taking other drugs as well (05MP, 07MC)
- Different memory skills (08FB)

Diesel cancer link (Gallagher, 2012)

- Working in a nuclear context (Joseph: Physics)

Older fathers (Roberts, 2012)

- Some factors may have a greater influence (Katie: History)

Depression (Brain training helps beat depression, 2012)

- Different severities of depression (Katie: History)

Box 4.6: Confounding factors offered by participants as alternatives to those included in the news story.

Within the news story about oral health and heart disease (Wilkinson, 2010) a cardiac nurse is quoted and points out that things other than gum inflammation are associated with heart disease. She raises issues of smoking, diet and physical exercise. Elsewhere in the article, it is implied that medical history and family history of heart disease may be associated with occurrences of heart disease. Within the confounding factors category, some participants suggest these as possible factors. Therefore, it is possible that they are restating points made

in the news story. However, this still requires the respondent to identify the points made in the article and use it within their own reasoning. Thus while some of the suggested alternative factors may have emerged from the text some have been generated by respondents. Identifying possible alternative factors given in the text is a less sophisticated response than identifying a potential issue with the given factors. The most sophisticated response is when participants generate their own alternative factors

Responses suggesting alternative causes for outcomes, or possible confounding factors, were common with 15 such responses from science participants and 17 from history participants. In the context of marketing and by using experimental methods, Chandon and Janiszewski (2009) suggest a relationship between the acceptance of advertising claims and the capacity to generate "disabling conditions and alternative causes" (p.1008). They found that those who are able to generate these conditions and causes are less likely to accept claims. By disabling conditions they mean events which could stop a cause having an effect and by alternative causes they mean other events which could cause an outcome. In this study I have not been able to identify evidence for such a distinction but it could be useful to consider in the field of news stories about science.

4.3.4 Conclusion

Sadler (2004) draws upon work by Means and Voss (1996) and Zohar and Nemet (2002) in describing informal reasoning. He suggests that it:

> involves the generation and evaluation of positions in response to complex issues that lack clear-cut solutions. Thinkers are engaged in informal reasoning as they ponder causes and consequences, pros and cons, and positions and alternatives. (p.514)

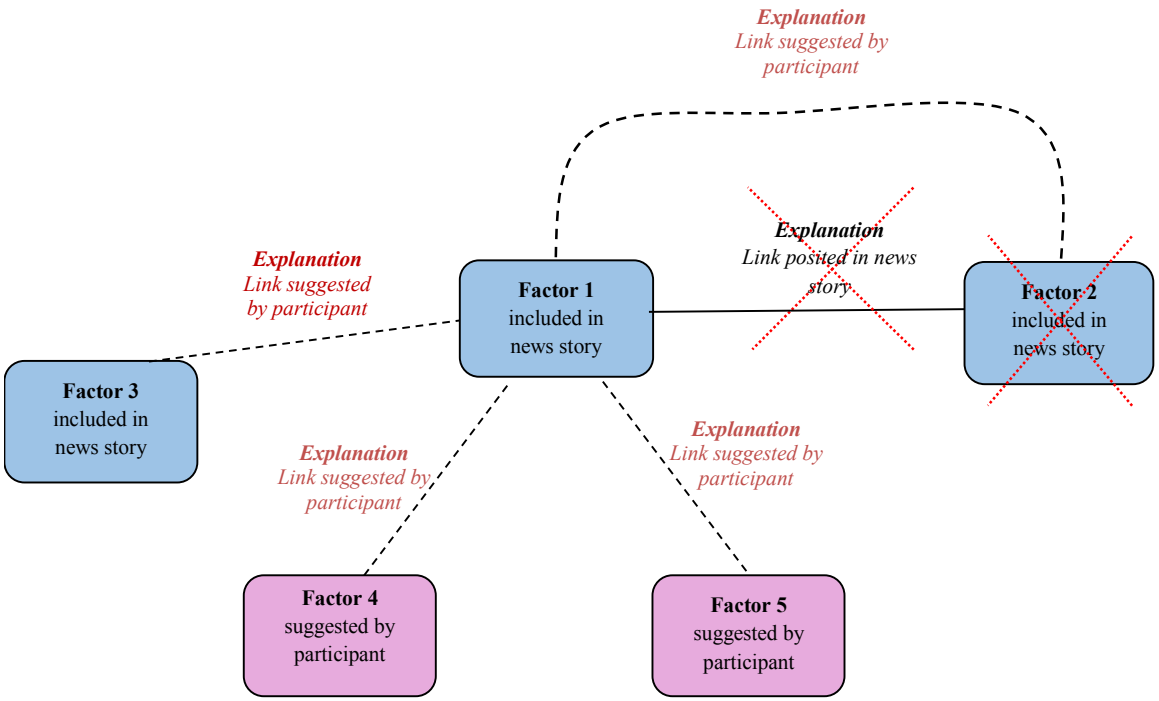
Sadler's definition is thus broader, and perhaps more productive, than the description of informal reasoning given in Chapter 2 (Johnson and Blaire, 1991, p.134) as it adds the

generation of positions and alternatives. The reasoning undertaken by the participants in the categories described above, where they generate alternative explanations and then reason through the consequences of that alternative, are consistent with this definition. Thus, the evidence in the previous section suggests that participants are engaged in informal reasoning in the present context.

Furthermore, based on information in a news story it is not possible to reach a definitive conclusion about the veracity of the claims made. In the example above (05MP/B), the alternative suggested is that the positive result from the testing for protein could be caused by another kind of inflammation. It is not that the alternative suggestions are necessarily correct that is important here. The important thing is that participants can conceive that the presented explanation or relationship between factors is potentially not the only one and there may be viable alternatives.

In the above sections, participants identified issues with factors or explanations, or generated alternative factors or explanations. While explanations are quite difficult to define precisely, they are understood here to account for links between factors, thus they suggest, or account for, a relationship. Figure 4.3 is an attempt to summarise the ideas presented above. It includes the following strategies:

- *Challenge a link posited in the news story*
- *Challenge a factor posited in the news story*
- *Suggest a new link between factors stated in the news story*
- *Suggest new factors not mentioned in the news story*
- *Suggest new links between factors generated by the reader*
- *Split a factor mentioned in the news story into further factors (not shown in Figure 4.3 for reasons of clarity)*



Key: The blue boxes indicate factors which were included in the news story. The pink boxes indicate factors that were generated by the participant. The solid line linking factors indicates a link posited in the news story and dotted lines indicated links posited by the reader. The explanation that is crossed out shows the reader challenged the link in the news story. The factor that is crossed out indicates the reader challenged the significance of the factor.

Figure 4.3: Summary of points made in sections 4.3

4.3.5 Role of scientific knowledge in suggesting alternatives

A challenge for researchers has been to identify the role of discipline specific content knowledge when reasoning about scientific information. Sadler (2004) demonstrates in a review of literature that conceptual understanding improves reasoning and its absence limits reasoning. However, Kolstø et al. (2006) found that when reading media sources, content knowledge is inadequate on its own and the mature readers in their study also drew upon knowledge of information sources and science methodology.

The generation of alternative explanations and factors offers a role for subject knowledge in critique. For example, while the reader may not have specific knowledge of honeybee viruses, they may have some ideas about honeybees and separate ideas about viruses. Thus these ideas are potential sources for alternative explanations. An example for this is found in a response to the article about oral health and heart disease (Wilkinson, 2010). Participant 01 makes the point that it was not necessarily oral hygiene that is the direct cause of heart disease but that gum infection is a potential risk factor. The participant then develops the point further:

> if you have, for example, areas where they fluorinate water where you have lower incidents of, of erm dental problems if you do areas that don't fluorinate water. Erm that's erm something that perhaps should be looked into that is perhaps not commented on in the article. (01MP)

Thus, the point the participant is making is that gum inflammation, which is associated with heart disease, may in turn be associated with factors other than brushing teeth twice a day. The example they give is whether fluorine is added to the water supply in the area. This point is not made in the news story, although fluoride toothpaste is mentioned briefly. The generation of alternative explanations or causal factors, then, is richer and more productive if the reader has specific content knowledge that is relevant to the area.

4.4 Heuristic Group 2: Methods

The four news stories used in the first phase of data collection contained some limited information about how the reported research was conducted; there was some reference, for example, to sample sizes, number of groups and time scales. Research findings about the use of methodological information were discussed in section 2.9. In this study I asked readers directly about methodology and thus I cannot claim they used this information spontaneously.

However, in the questioning there was no specific reference to research strategies reported in the news story so any specific points were raised by participants, though I raised the topic.

4.4.1 Methods – questioned and affirmed

Two quite general heuristics have been identified in the interview transcripts and are summarised in Box 4.7. During the first phase of data collection there was a similar number of points made about methods by science trainees and history trainees which increased epistemic distance. There were somewhat more points made by history trainees that decreased epistemic distance (7 points raised by science participants compared to 13 raised by history participants). Thus there is limited evidence that history trainees were more likely to identify positive points about methods. This may be accounted for by the possession of less knowledge about the drawbacks of various scientific research strategies and thus greater confidence in the reported strategies.

<u>If (cue) then (conclusion about epistemic distance)</u>

If methods queried **then** increase epistemic distance

If positive point made about methods **then** decrease epistemic distance

Box 4.7: Heuristics about methods

Overall there was more criticism directed at the heart disease article and more positive comments for the ketamine article. This might be explained by these both being health related articles which may have personal significance to the readers. Readers may also have more experience of reading such articles. A range of specific examples of points that serve to increase and decrease epistemic distance are given in Figures 4.11 and 4.12 respectively. It can be seen that a wide range of ideas was raised by participants.

Cockroach article (How cockroaches 'talk' about food, 2010)

- One test completed (21FH)
- Number of times experiment carried out (24FH)
- Experimental procedure questioned (01MP)

Oral health and heart disease article (Wilkinson, 2010)

- Sample selection issues (03FP)
- One geographical area (07MC)
- Surveys cannot establish causation (05MP; 16FH)
- Fill in questionnaire quickly (06MC)
- Truthfulness of responses in questionnaires/surveys (10FB; 10FB; 15FH; 16FH; 17FH; 19FH; 21FH)
- Questions potentially ambiguous in questionnaires (20FH)
- Problems with self-reporting (23FH)
- Blood samples only show so much (13FC)
- Other methodological factors e.g. Scottish cardiovascular rates (12MP)

Ketamine article (Ketamine drug use 'harms memory', 2009)

- Groups unequal size (03FP)
- Method of group selection (11MP)
- Self report used to identify groups (23FH)
- Groups not homogenous (03FP)
- Individual differences not taken into account (03FP)
- Not many tests (21FH)

Laser Article (Moskvitch, 2010)

- Method unclear (08FB)
- Methodological information missing (10FB)
- Not tested on other molecules (15FH)
- Research limited to laboratory (07MC; 12MP; 21FH; 23FH)
- Easier to get working in the laboratory (07MC)
- Not tested in the field (23FH)

Milk fats article (Gallagher, 2012b)

- Only done on mice (Becky: Chemistry)

Greenland shark (Gill, 2012b)

- Not videoed (Nick: History)

GM Crops (GM crops 'aid plant neighbours', 2012)

- Missing methodological information (Becky: Chemistry)

Weight of humanity (Marshall, 2012)

- Query about cross-section (Alex: History)
- Practical issue about how data collected (Alex: History)

UFO (Wrenn, 2012b)

- No sampling done (Simon: Chemistry)

Box 4.8: Points made about methods that increased epistemic distance (includes data from the second phase of interviews)

The nature of evidence is a theme which emerges from the data shown in Boxes 4.8 and 4.9. There appears to be a hierarchy in the eyes of readers of ways of collecting evidence. Questionnaires and surveys are challenged and it was suggested by a number of participants that those completing questionnaires or surveys may lie, or remember incorrectly. It is also mentioned that questionnaires cannot establish causation. One participant mentions that sometimes questionnaires are filled in quickly and perhaps not carefully considered. The idea of the hierarchy was reinforced by participants who received memory tests and blood or hair sampling more positively. This may be accounted for by participants having a greater confidence in findings from physical science. In the second phase of data collection one participant suggests there are different kinds of science, comparing astronomy with "table top" science and demonstrating greater confidence in the latter:

> it's very difficult to be, err, you know, anything that you, um… [pauses]... err, you know, could be wrong because it's, it's not as, as, um, it's not in the same league as, as, say, um, the kind of say, science you can do on the table top, where you can see it and you can do it. This is much more kind of abstract and you know, there's things pointing towards it… (Joseph: Physics)

Cockroach article (How cockroaches 'talk' about food, 2010)

- Controlled environment (05MP)

Oral health and heart disease article (Wilkinson, 2010)

- Tested for protein (10FB)
- Blood tests undertaken (12MP; 15FH; 17FH)
- Went back to same people (17FH)
- Factors taken into account (11MP)

Ketamine article (Ketamine drug use 'harms memory', 2009)

- Hair samples taken (04FP; 05MP; 22MH)
- Compared groups with themselves a year later (02FP)
- Range of people in study (06MC; 10FB)
- Memory tests completed (10FB; 15FH; 24FH)
- Good groupings (15FH)
- Repeated testing (17FH)
- Tested both ends of the spectrum (20FH)
- Compared different groups (22MH)
- Control group used (01MP; 04FP)

Laser Article (Moskvitch, 2010)

- Did lots of tests (22MH)

Box 4.9: Points made about methods that decreased epistemic distance

4.4.2 Sample size

Within the interview data there is evidence that larger sample sizes give the reader confidence in the veracity of the research, and thus decreases epistemic distance. There is also evidence of perceived smaller sample sizes leading to an increased epistemic distance (Box 4.8). The term 'sample' is potentially problematic since it is a general term and associated with random samples taken from a wider population, but often it refers to the number of people who participated in reported research.

<u>If (cue) then (conclusion about epistemic distance)</u>

If concerns about sample size **then** increase epistemic distance

If sample size judged reasonable **then** decrease epistemic distance

Box 4.10: Heuristics about sample size research

In general, participants considered that bigger is better in relation to sample size:

> I mean, that's 11 0000 people but with 11 000 people, when you're looking at something which can be caused by so many things, heart disease, brushing your teeth is a bit small to be picking that. (12MP/B)

But there was recognition that bigger sample sizes are not always possible:

> Um, the, the research methods, I think, it's, it's a 'wide-ish' bunch, I mean, you don't often have queues of people who take Ketamine willing to, to take part in research, I suppose, so 120 people with, is, is not a bad number of people. (12MP/C)

When responding to an article about older fathers (Roberts, 2012), one participant showed some uncertainty about whether a sample size was large or not:

> **What, what about the methods, the, you know, how they got their, how they did the study, how they got their data?** Um, yeah, I don't know particularly a lot about it, um, I mean, when, when it says here they're analysing DNA, I mean, they had quite a big sample size, well, I mean, don't know, is 1,779 a big sample, it seems like a lot of people to me… [Laughs]. (Katie: History)

I would suggest that there are good grounds to raise questions about whether a sample size is large or not. The evidence from the first round of interviews, where some participants stated that sample size was adequate and for the same article some stated it was problematic, suggests that individual participants, for a particular type of research, have threshold sample size (see Figure 4.4 for a representation of this idea). Below the threshold the sample size

leads the participants to question the findings but above this threshold participants are more willing to accept a claim to knowledge.

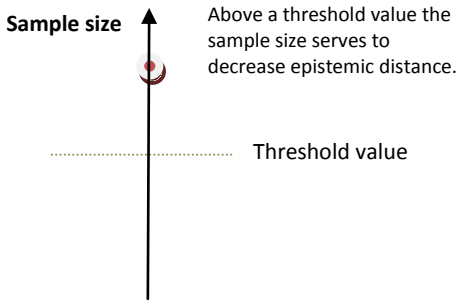


Figure 4.4: Diagram to represent the idea of a threshold value for sample size

Even if it were possible to identify such a threshold for a particular type of study the potential for any useful threshold to be established for any studies encountered in the future is threatened by the plurality of methods associated with science (see Longino, 2002, for example). Neither is any general value of sample size appropriate as a case of one may be sufficient in some fields where 100 000 participants in other fields may be too small in others. Linking to the issues of expertise raised by Norris (1995a and 1995b), detailed knowledge of the plurality of methods and how to interpret data for each of these methods is unlikely to be achievable. For a non-expert it may be that they can use methodological information, such as sample size, as a general check on plausibility. However, it is unlikely that anything more than a general sense is achievable.

There are also other issues raised by participants associated with samples that have not been addressed so far. The first, identified by Giere (1997) is about how the sample is selected. In an article about UFOs, one participant stated that "they've got no, um, sampling been done" (Simon: Chemistry). Furthermore, there are issues associated with how participants are grouped. For example, one participant pointed out in relation to the ketamine article that

“other users” are not all the same (03FP/C). A further participant (14FC/C) was interested in how the participants in the ketamine article were split into groups.

4.4.3 Number of times repeated

There were a few instances where participants raised the issue of the number of times the experiment with cockroaches was repeated (How cockroaches ‘talk’ about food, 2010). In one example the participant queried the number of cockroaches involved, the number of repeats of the procedure and the overall timesspan of the investigation:

> They’ve, they’ve given something a go and that’s probably how science is done, by just, um, having a pop and he's made the observations, it doesn’t tell me anything about how he did it. He didn’t say he did it with 3 million cockroaches or he did 7,000 repeats or he's been doing it, he doesn’t even say he's been doing it for the past 10 years. **Mm-hmm.** It just seems, you know, he could have done this in his kitchen, if that makes sense (12MP/B)

The implication of this reasoning is that the approach taken is problematic, although this is not stated explicitly. For reference, the original journal article (Lihoreau et al., 2010) states that groups of 50, 100 and 200 cockroaches were released on approximately 20 occasions.

4.4.4 Time scales

Time scales where seen to both increase and decrease epistemic distance (Fig 4.15). For example, for the article about heart disease one science participant stated that:

> but so they've also mediated it lot with erm actually this might not say what it looks like it says.....erm.....adults for 8 years - [inaudible] not a very long time in terms of heart disease really so although that 70% is a large number and it seems like it is quite erm conclusive really when you just think about the 70% (02FP/C)

Thus, they identified 8 years as not being very long in this type of study of health. The next quote is an example of a participant who was positive about time scales:

> but I guess it is good research, it's big in scope, you know, like, it's big, it's over a long time, it seems quite thorough (19FH/B)

There were relatively few comments about time scales overall with more history participants raising this issue and suggesting that timescales are appropriate. In common with the discussion above about sample size, timescales have been seen to both increase and decrease epistemic distance. Therefore, the same issue emerges about where a threshold for an appropriate timescale might lie.

If (cue) then (conclusion about epistemic distance)
If short time scales **then** increase epistemic distance
If time scales judged appropriate **then** decrease epistemic distance

Box 4.11: Heuristics for time scales of research

4.4.5 Experimental controls and control groups

Experimental controls and control groups are closely associated with the factors and the relationships between factors discussed earlier in this chapter because the presence of any confounding factors would challenge relationships between variables. Gray and Mill (1990) found that control group criticism did not come immediately to mind for both English and Biology students, similarly in this study relatively few comments were made by participants about control groups or experimental controls. There were instances, however, of querying whether the food sources were the same in the cockroach experiment (11MP and 12MP). Another participant, when reflecting on the article about heart disease, grapples with how it might be possible to eliminate other factors from a study:

> So did they do controls, did they eliminate the other factors, erm, they said they took them into account I don't know how they took that into account it doesn't say specifically erm it's a little bit more persuasive in the fact that they mention how long the study was

> done over a period of time and how many people were involved, erm, but I'm not sure whether the conclusion is valid. I would arg, wonder how they would wonder how they would eliminate these factors exactly. (14FC/A)

Furthermore, for 04FP, the presence of a control group in the Ketamine study leads then to be more accepting of claims:

> and I like the [inaudible] they had control groups for it so it's more believable because they have actually got something to compare it to. I like that I thought that was very good so I feel more convinced (04FP/C)

Another participant challenges whether the groups within the study are comparable and suggests other reasons for memory problems other than Ketamine:

> but it doesn't, well, I don't remember it mentioning other drugs that these people in the study will have used, because if they're regular Ketamine users, they probably use other drugs as well, so and maybe cannabis, so what effect that's had on their memory. **Mm-hmm.** And whether it's just the Ketamine (07MC/C)

Similarly, participant 05MP challenges the possibility that it would be possible to take into account the drug use of participants because there are too many factors involved:

> I don't think anyone that would do something like Ketamine, that would be the only drug that they used, especially the ones that used it every day and the recreational users would probably be doing other things like Ecstasy and stuff like that and maybe Cocaine, so in terms of control, I don't think the, anything they come up with would be that valid because you, they don't really have any control over what these people are doing and there's so many factors that would affect, you know, people's memory and things like that and so, and especially if they were doing different kinds of drugs and things. So, although it seems like the testing is probably quite valid, I would have said that the long term, the revisiting of them afterwards, it doesn't, because they can't control, err, their lives in that period. I don't think any results from that would be useful really at all, I don't know, I don't know why they've done it. (05MP/C)

The following quote indicates that the participant has identified a control group in the Ketamine study but questions the extent to which researchers were able to control for other factors:

> Err, they split them into five groups, so they've got a control group, which is the people that don't use it, but then they've got the other groups, um, who have varying amounts of use. Um, I mean, the fact that it says that the regular users were worse on memory, but the other groups didn't show much difference, does again make me wonder what, maybe, maybe what other drugs or what other factors are in those people's lifestyles, if they were heavy drug users, um, and, err, yeah, 'cause it doesn't say anything about that, err. (07MC/C)

4.4.6 Discussion about methods

The evidence in this section suggests that readers made use of methodological information to both increase and decrease epistemic distance. It also revealed that readers with history degrees where more positive about the methods used than those with a science degree. This demonstrates that news stories can include methodological information that offers the potential to create some distance between the reader and the claims being made, in line with Norris's (1997) ideas of epistemic distance. However, it is also possible for some readers that methodological information instils false confidence in the research.

Methodological information could potentially give clues as to the type of study that has been undertaken and help the reader to locate the research in a particular paradigm or discipline. However, this would rely on the ability of participants to identify these features of research as important. One approach which draws on more abstract thinking about research is given by Giere (1997) who distinguishes studies that are retrospective, prospective or experimental in design. The article by Wilkinson (2010), for example, about heart disease is a retrospective design and looks back to what has happened historically. The Ketamine article (Ketamine drug use 'harms memory', 2009) describes a study that is prospective in design where

individuals selected themselves dependent on their drug use into 5 groups, in this case using "snowball" sampling techniques (Morgan et al., 2010), although this is not explained in the news article. Being able to categorise a particular study allows the reader to identify general limitations of the design type, such as selection bias in the case of retrospective designs.

One participant, when asked about research methods stated that:

> And does it say anything in the article about any, um, research methods that they used to get this finding? I can't remember. [Pauses]... Just really about them testing on mice, rather than anything else. Were you able to take anything from that information? I didn't really think about it, [laughs], to tell you the truth. (Sheila: Chemistry/von Radowitz, 2012)

This participant has worked within a scientific context in a previous career and thus it might be expected that she would draw upon methodological information. However, it can be seen that it was not important for her in this instance. If it is the case that methodological information can only be appraised by experts, then it is possible that other readers may treat this information at a surface level. The quote from Sheila above does suggest that this might be the case with a cursory mention of mice studies. This is not always the case as Becky, from the second phase of this study, talks at length about the limitations of mice studies.

It might be expected that knowledge of scientific methodologies may be an advantage for the reader, however, Bromme et al. (2008) suggests that some knowledge of physics, for example, can threaten critical capacities. Some knowledge of physics could lead to the assumption that all collected data may have similar reliability and validity to simple physical measurements such as for temperature and mass, and therefore all physics knowledge is equally secure. The tremendous breadth of methods used in science (Cartwright, 1999; Longino, 2002) offers substantial challenges for a reader.

In this section I have argued that methodological information is not necessarily useful for the critical reader because of the impossibility of understanding the wide range of methods within science and, in some cases, the problem of deciding on the threshold values described above. However, I have also reported heuristics that have been used by experienced and educated readers of science as they reason about veracity.

4.5 Heuristic Group 3: Subject knowledge

In this section I will add to the brief discussion about the role of subject knowledge I presented in section 4.3.5. The heuristics in this section, despite carrying the heading of subject knowledge, cannot be assumed to be the only categories that draw upon readers' knowledge of science.

4.5.1 Consistent with existing knowledge

Four categories of heuristics associated with content knowledge emerged from the If…then… analysis and these are summarised in Box 4.12. Identifying places where participants make use of their knowledge of science is challenging because of the complex nature of their interpretation of the stories, their reasoning and reports of their reasoning.

<u>If (cue) then (conclusion about epistemic distance)</u>

If compare to a similar phenomena **then** decrease epistemic distance

If consistent with existing knowledge **then** decrease epistemic distance

If surprising or self-evidence **then** decrease epistemic distance

If draw upon own observations or experience **then** decrease epistemic distance

Box 4.12: Heuristics emerging from data analysis associated with existing knowledge.

Participants draw upon their existing knowledge when they compare the phenomena under consideration to something they are familiar with. The following quotation is part of a response to the article about cockroaches:

> Yeah, I still think it's very likely, I mean, 'cause other insects communicate, like ants and stuff like that and bees communicate and that's already been proven, so the theory that another insect will communicate, I don't think it's, it's completely out there, so I don't see why, any reason why not. (05MP/A)

In this quote the participant likens cockroaches to bees and ants, and concludes it is possible that cockroaches communicate. In total I identified 13 instances where participants made comparisons with something they considered to be similar (01MP/A; 05MP/A; 05MP/C; 07MC/C; 08FB/C; 11MP/C; 12MP/A; 16FH/A; 16FH/C; 17FH/A; 20FH/C; 21FH/C; and 21FH/C). It can be seen from the list that there is a similar number of such responses from both science and history trainee teachers. This strategy, however, can only be successful if there are sufficient similarities between the entities being compared. Keil (2006), in an exploration of the evaluation of explanations, identifies judging relevance as challenging:

> Relevance would also seem to be straightforward. Yet, levels of abstraction, analogies, and surprising connections to other domains can complicate the assessment of relevance. (p.10)

Similarly the comparability of different entities is also subject to abstractions, analogies and surprising connections.

The second heuristic in Box 4.12 is more general than the first heuristic in this section. In order for existing knowledge to be useful to the reader it needs to be sufficiently closely related to the area under consideration. Participants sometimes mentioned their own studies but, as in the quote below, specific ideas were generally not used:

> ‘Cause I did a bit on polymers and that kind of stuff when I, when I was in my degree, so I think it’s a lot more reliable than the last one was because of the fact that it was published and it’s got scientific theories thrown in, which the other one didn’t really have any in, um,” (13FC/D)

The sort of explicit mention of existing knowledge echoes with Kolstø (2001), who identified what he called ‘reliability indicators’ (p.886) which 16 year old students used to judge knowledge statements. Similarly here, the evidence suggests that there are some instances of use of existing knowledge as such an indicator.

The third heuristic given in Box 4.12 is where participants state that they find a claim unsurprising or self-evident. For example:

> Um, when, when I answered it over there as well, I thought it was quite likely, ‘cause I don’t know, you just think that that’s kind of thing that animals or cockroach, um, cockroaches do, like they kind of communicate… **Mm-hmm.** In ways that we can't really understand, um, yeah, it, it made a lot of sense really, just, um, it didn’t really surprise me or anything, um… (26FH/A)

This category was quite common (02FP/C; 05MP/A; 05MP/C; 09FB/A; 11MP/C; 14FC/C; 19FH/C; 26FH/A; Nick: History/ Bee Virus; Katie: History/ Rio Summit). This heuristics could potentially be an epiphenomenon of the interview process with participants seeking to show that they are knowledgeable in matters of science, the kind of impression management suggested by Goffman (1971). Stating that something is not surprising brings a closure to the reasoning process. However, I did not sense this during the interviews.

The final category of heuristics shown in Box 4.12 is where participants drew upon their own observations or personal experience (07MC/C; 19FH/A; 22MH/A; and 26FH/C) and therefore are more confident in the published claims. An example is when one participant discusses the ketamine article and draws upon their own experiences of seeing someone having taken the drug:

> Um, I, I have seen somebody take Ketamine actually at a party… **Mm-hmm.** And they just kind of vegged out in a corner and it didn't seem very appealing. [Laughs]. They were literally just sat there, eyes glazed, um, in a world of their own, um, but yeah, I mean, it, it, I think a drug that's sort of that strong, um, I could, I could believe that it could have an effect on, on the brain in some way, definitely, yeah. (07MC/C)

While personal experience of phenomena are unlikely to be a reliable source of evidence, Tytler et al. (2001) point out that this sort informal evidence has the potential to act as a bridge between a personal understanding and a scientific point of view, and therefore may have some use. One participant with a science degree made reference to their own observations compared to four historians. One explanation of this is that formal education in science is associated with an understanding of the limitations of direct personal experience as evidence, and that those trained in history are more likely to draw upon such evidence. Though, the evidence for that conclusion is limited.

The four heuristics shown in Box 4.11 all serve to decrease epistemic distance and result in greater confidence in claims. It should also be noted that the category of "If inconsistent with existing knowledge then increase epistemic distance" is poorly populated with limited evidence of existing knowledge, in the form discussed in this section, being used to challenge claims and increase epistemic distance. A single example was identified from the first round of data collection:

> Yeah, but having said that, I've never really seen, um, like a group of them together, but maybe around food, they are like that, but if you, um, put, like if you're like throwing, um, fish, like food into a, um, pond for fish, they will come. (16FH/A)

A possible explanation here is that participants' existing knowledge is more likely to lead them to decrease epistemic distance than increase epistemic distance and therefore has the potential to lead readers into false confidence in claims. There is evidence from previous

research that supports such reservations with Dodds et al. (2008) finding that people tend to accept scientific arguments that are consistent with their existing knowledge.

Elsewhere there is evidence to suggest that scientific knowledge is underutilised by participants. Korpan et al. (1997) asked individuals to ask questions whose answers would help them to decide if a conclusion was true. They found that only 33% of students (n=60) made requests for information about previous research. This can be compared, for example, to 93% who made requests for information about methods and 60% to social context. This suggests that comparing the claims under consideration to existing public scientific knowledge is not a priority for readers. There were instances in the second round of data collection where participants raised points about what could be described as 'canonical knowledge':

> So, um, well, like the initial couple of, the background was all just quantum theory and is just stuff that you, they teach in universities… **Mm-hmm.** Um, and obviously they're trying to put it in plain language as possible and it all seemed fairly straight, well, not straightforward but, you know… **Yeah, yeah, yeah, yeah.** Set in stone almost, um (Lee: Quantum computing)

While this quote does not contain a clear conclusion about epistemic distance, there is an implication that a certain type of knowledge is secure. A different science trainee selected an article about dark matter and indicates that they think there is a difference between knowledge in different parts of the news story. In the quote they suggest that knowledge of dark matter is quite secure but also considers that the detector that is being described in the article is not necessarily going to be successful:

> Pretty much it basically, um, and you know, whether or not this, this detector is going to get any results, that's another story, but, um, for the purpose of, of kind of thinking of, well, what is dark matter, how do we find it, it was pretty much, pretty much there (Joseph: Dark Matter)

The evidence here, where the participants draw more upon canonical knowledge, may be accounted for by the research strategy adopted in the second part of the present study where the reader had more time to explore the topic than in the first round of data collection, or perhaps because readers selected articles in a field in which they already had some familiarity.

There were two specific cases (11MP/B and 16FH/B) of participants saying that they have read similar articles about oral health and heart disease before the interview:

> **Originally when you looked at the er the the that brushing teeth can prevent heart disease you put very likely to be true. Have you changed your perspective?** No. I mean as I say that perspective was based on having read a very similar article in the not too distant future (sic). So I was aware of the research beforehand. ... so you are saying very likely? Yeah. (11MP/B)

It is conceivable, though, that participants had previously read the article quickly, or just the headline, and that this small amount of knowledge was sufficient to limit further close reading of the story. Thus, having read a similar article before does not necessarily offer an advantage.

4.5.2 Discussion and exploration of use of scientific knowledge

On balance the evidence suggests that existing knowledge leads a reader to be more confident in the research claims in the news story, but this confidence is not necessarily well placed. Successful use of existing knowledge depends upon making comparisons between similar phenomena. It depends on appropriate understanding of previous encounters with the same or similar research. Further, considering something to be unsurprising could limit further reasoning about the story. Readers also need to be aware of the limitations of their personal experience. Taken together, these heuristics about scientific knowledge reveal some potential pitfalls for readers with and without science degrees.

4.6 Heuristic Group 4: Research and Researchers

Some participants used heuristics with a focus on the research being reported in the news story or the researchers who conducted the research. Norris (1997) makes the point that deferring to expertise is rational for a reader and done more easily than autonomously evaluating knowledge claims. Further, Collins and Evans (2002), in their work on their third wave of sociology, suspend questions of truth in favour of questions of expertise. If the primacy of expertise is accepted then it would be expected that readers would pay careful attention to *who* is making scientific claims. The findings in this section offer some insight into whether experienced readers share this concern for expertise.

<u>If (cue) then (conclusion about epistemic distance)</u>

If accept the superior knowledge of the researcher **then** decrease epistemic distance

If research is conducted by scientists or is published **then** decrease epistemic distance

If research incomplete or more needed **then** increase epistemic distance

If researchers not certain about reported claims **then** increase epistemic distance

Box 4.13: Heuristics about research and researchers

4.6.1 Researchers and publishers

In the first phase of data collection only science graduates used the heuristic: "If accept the superior knowledge of the researcher then decrease epistemic distance". One was identified in the following quote:

> and you get the impression reading it that these people are clearly clever and know what they are doing therefore I will agree with them and I think a lot of science articles are written like that (03FP/D)

Here the focus is on accepting what researchers say because they know more. Given the points made above, it is somewhat surprising that there is not more evidence of readers deferring to expertise. One possible explanation for this is the nature of news stories, where the reporting means that access to knowledge about the researchers is filtered by the journalist. A further explanation is that readers would not wish to be seen to defer to a researcher.

Readers made much more use of information about where the original research was published and identity of the researchers. For example, the status of the journal in the following quote seems to have increased the confidence of the reader in what they read, for example:

> Yeah, I'd say I'm quite sure… **You'd be quite sure…?** Because of the journal that's, um, cited in here, so… **Mm-hmm.** It's come from the, a respectable journal… **Mm-hmm.** So you would have thought that it would be quite accurate. (08FB/C)

A further example of this reasoning is where the scientist is the focus:

> I am reading about people who seem like they are ...knowledgeable. Scientists from universities are likely to be believable (02FP/D)

The heuristic "If research is conducted by scientists or is published then decrease epistemic distance" deliberately includes two aspects because both relate to using status or authority to judge veracity. This heuristic was used 14 times by science trainees and 16 times by history trainees in the first round of interviews, thus it can be concluded that an advanced training in science is not uniquely associated with accepting claims for reasons associated with authority or source.

Issues of authority present the reader with some difficulty. As Bergstrom et al. (2006) point out, learning relies on testimony and culturally transmitted information, thus the capacity to

appraise information is important, and according to Bergstrom et al. not clearly understood. People need to trust sources to some extent. Kolstø (2001) found that 16 year old pupils evaluated sources of knowledge claims more than they evaluated the contents. He also found evidence for a dual attitude toward research and researchers, with the same pupils both finding it difficult to rely on researchers but at the same time expressing trust. He consequently claims that both trust and appraisal sit alongside one another in the same reader. There is ample evidence in the present study of this duality with frequent evidence of epistemic distance being increased, while at the same time using the status of the researcher or research publisher as a "reliability indicator" using Kolstø's term (2001).

In later work Kolstø et al. (2006) suggested that contextual information is significant for examining the trustworthiness of researchers. One example of useful contextual information is the workplace of those who undertook the research, perhaps a university. Bowker (1991, in Jarman and McClune, 2002) makes the point that discussion about science in the news tends to focus too much on rather narrow issues of bias. In the current study it was rare for participants to raise matters of researcher bias or vested interests. It is possible this could be explained by the first round of interviews all exploring research published in science journals. However, one participant (11MP) asked where funding came from for the laser research, and another (19FH) suggested researchers were trying to sell the laser technology. Responding to an article about GM crops one participant raised profit as a motivation (Becky: GM crops). Simon, from the second set of interviews selected an article about UFOs, a quote from which states:

> The company have created a submarine that they hope will appeal to tourists and wannabe shipwreck hunters who will pay to take a trip down to the bottom of the Baltic Sea to see for themselves. (Wrenn, 2012a)

However, vested interests or motivations were not raised, perhaps surprising given the self-declared motivations of the company. Similarly in the article about space tourism (Wrenn, 2012a) the participants did not raise that those involved in the project were from a for-profit company.

Irwin (1996) makes the point that "sources of information are inseparable from the information itself" (p.97) and further suggests that "…credibility judgements about science become inseparable from judgments about the institutions which actually offer scientific accounts." (p.107). If this claim to the inseparability of knowledge from source is accepted, then the source/information "package" in an article would need to be identified, with perhaps the source having greater potential for scrutiny than the scientific content.

4.6.2 Incomplete research and researchers' uncertainty

Further heuristics were found that were about incomplete or uncertain research (Box 4.12). One is when participants make a decision that the research being reported is incomplete and conclude that epistemic distance should increase, for example:

> but I think there's such a long way to go on it. I think at the moment I'm just a bit cautious, that's probably the best word. (23FH/D)

A further example is:

> although it says at one point that, um, there's a few things that could give you a false positive, but I don't think it seems to give you much proof that it would actually work. Yeah, they don't seem, it doesn't seem to be very well tested I think would be the general… **Right.** Or if it has, they haven't really mentioned it very much in this article. (15FH/D)

An associated heuristic is "If researchers are not certain about the reported claims then increase epistemic distance". Here the focus is on the view of the researcher:

> but then when you've actually, when they're actually quoting any of the people in the profession, they're all saying that more research would need to be done (05MP/B)

Another example is a science participant (12MP/B) who suggests that when a scientist in the article about heart disease says "whatever the true position" (Wilkinson, 2010) this can be interpreted as very sceptical indeed. On one level it could be argued that this is a quite straightforward type of response and that participants are effectively restating what has been said by the researchers, however, the reader has identified this information as useful.

4.7 Heuristic Group 5: Communication

In this section the news story itself is the focus of attention rather than any primary source, such as a research journal. Communication here is concerned with how readers draw upon their knowledge of media and media production; how they understand and view the genre of web based news text; and how they interpret the language of news stories. From the data I identified four heuristics in this area (Box 4.14).

<u>If (cue) then (conclusion about epistemic distance)</u>

If positive reference to news publisher **then** decrease epistemic distance

If issues with the reporting or writing within the article **then** increase epistemic distance

If metaphor use a concern **then** increase epistemic distance

If do not have enough information **then** increase epistemic distance

Box 4.14: Heuristics about communication in article

4.7.1 News articles: publishers and reporting

Participants made a small number of positive references to the news publisher. Sheila from the second round of interviews expressed a general scepticism towards newspapers. Using

information about the news publisher to increase epistemic distance was very uncommon. One science participant stated:

> it's the BBC, but I'm not sure if I'm convinced. (07MC/B)

The statement suggests a positive view of the BBC as a publisher but this is insufficient to tip the balance toward accepting the claims.

Bråten et al. (2011) exposed undergraduates to seven different information sources and asked them to rate trustworthiness and identify the criteria that the trustworthiness rating was based on. They found that newspaper reports were trusted least of all the sources by those with "low knowledge" of the topic while for those with "high knowledge" of the topic rated newspapers above a commercial publication. This suggests that those with limited knowledge of a field are less able to decide upon what sort of source is dependable. In the present study there is insufficient evidence to identify whether those with science and history degrees have different perspective on news publishers.

The heuristic "If issues with the reporting or writing within the article then increase epistemic distance" was used by very slightly more science participants (7) than history participants (5). In one example the participant suggests that the article is written for a popular audience and does not sound very "scientific":

> [Pauses]... Err, I find the language quite, I don't know, it doesn't sound that scientific to me, which is why I'm sceptical, 'cause it's pumping in explanation marks and, um, TNT like molecules. Now, I don't know whether that's just so people who are reading the BBC News can understand it more, but it doesn't, as a scientist, it doesn't make me confident that it's, it's going to be, um, useful to us because TNT like molecules, I'm not entirely sure how that, how that fits into it and how that, how, how comfortable it makes me that it's actually going to be a benefit and is actually something that is based on a lot of science. Um… [pauses]... yeah, like sniff around, it's, um, the only real scientific thing I can see there is like Polyfluorene and that's it. [Pauses]... (09FB/D)

In the above quote there is reference to the habit of some journalists of putting contentious words in inverted commas, perhaps with a goal of moderating the claims being made. There is also recognition in the quote of a need to make the content of news stories accessible to a range of readers.

Metaphors were only identified as a concern by science graduates on four occasions, although they were present in the cockroach and the laser article. The identification led to increased epistemic distance. The mention of 'pumping' in the above quote is an example of a metaphor being used, presumably, to aid understanding of how photons are moved. A 'talk' metaphor is identified by another reader:

> but again I think the choice of words has really confirmed I am not really convinced again it is this use in the title of having the inverted commas and saying talk how cockroaches talk about food (04FP/A)

Pramling (2009) suggests that while metaphors are very important in learning they also present significant challenges for the learner and, by extension, for the reader. For a reader to appreciate the meaning of the metaphor, logically they will need to distinguish the representation (how something is explained) and the referent (the explained things) (Pramling, 2009). Readers need to be knowledgeable about the referent in particular. With the use of metaphors there is a requirement for comparability between the representation and the referent.

Linked to ideas about communication via the medium of news articles is the notion raised by Milne (1998) that texts are not neutral but have meaning and values implicit within them. An example given by Milne, found in a science textbook, is of the hero Galileo who defends scientific knowledge against pressure from the church. The message, according to Milne, is that scientific knowledge is privileged above other forms of knowledge. Likewise in news

articles, the way a story is written carries implicit messages about values and meaning. The headline for the article about heart disease is “Brush teeth to 'prevent' heart disease”, thus claiming that cleaning teeth can prevent heart disease. In response to this article one participant comments that the “press love scaremongering” (05MP/B). This gives some insight into readers’ sense of how news is produced and how the news text is received. It might be expected that readers would make more reference to this area given the multiple constraints on journalists including tight deadlines for news production, the need to capture reader interest and the necessity to maintain sales but there are few references to this area.

Online news stories have headlines and some participants identified discrepancies between headlines and the main body of the articles. The idea of a catchy headline is raised by a number of participants who used quite strong language to describe this (examples are given in Box 4.15).

- Headline as a “hook” (19FH/B)
- Headline as “devious” (20FH/B)
- Headline “taking the mick” (21FH/B)
- “got massively misled” (Lee/Saturn’s moon Titan)

Box 4.15: Descriptions of discrepancies between headline and main body of articles

4.8 Conclusions for Chapter 4

In this chapter I have demonstrated how I identified a range of heuristics that are used by readers as they reason about the likelihood of veracity of knowledge claims. The heuristics were divided into five categories: scientific explanations and factors; methods; subject knowledge; research and researchers; and communication. I explained how some of these heuristics served to increase epistemic distance and others served to decrease epistemic

distance. In concluding this chapter I will signal to what extent I was able to answer the first two research questions and indicate how the findings from this chapter served as a platform for the next phase of this study.

The way of identifying heuristics used by readers as they reason depends to a significant extent upon the meaning and value of the cue/conclusion coupling described above. An important question is whether finding multiple occurrences of a particular coupling of cue/conclusion (or an abstraction of that coupling) is an effective means to identifying rules used in reasoning. The If…then… statements identified here are not associated with formal conditional logic but a more flexible type of reasoning, informal reasoning (Johnson and Blair, 1991) which involves the reasoning about causes and consequences, for example. In this section I have identified patterns in the use of these rules.

The two groups of readers in this part of the study used similar strategies and methods as they scrutinised news stories with likelihood of veracity in mind. Both science and history graduates challenged reported factors and scientific explanations to account for relationships between factors. Both groups suggested new factors and explanations, although science participants were more interested in explanations than history participants. Both groups examined reported research methods but there was some evidence indicating that history participants were more positive about this information. When drawing on existing knowledge science participants did less comparison to similar phenomena and drew less on their existing knowledge. Perhaps the biggest difference was found in the category about communication where science participants were significantly more negative about the reporting and writing. Taken together these differences suggest that science graduates are somewhat less willing to accept the veracity of the claims they have read, although this difference is not substantial.

The heuristics identified in the chapter can be divided into two broad categories: those whose successful use depends upon generic knowledge, and those that depend on specific scientific knowledge. In the category of generic knowledge would come ideas about journalism and news production, including how journalists are motivated by interesting the readership. Further knowledge of peer review and academic journals production and status is generic knowledge. Ideas about causality and correlation and other relationships between factors is also generic knowledge.

In contrast heuristics which draw on methodology, for example, are quite specific. The list of ideas raised by participants in Figures 4.11 and 4.12 are evidence of the wide variety of responses. As explained above information about methods can indicate to the reader the sort of field which the research is located in, palaeontology or epidemiology, for example. Thus mention of methods potentially gives the reader some leverage into understanding the study using generic rather than specific knowledge of the field. An example is epidemiology, a quick look on Wikipedia indicated that a general rule for epidemiology “Correlation does not imply causation" (Wikipedia) is readily available in public knowledge. However, beyond these general ideas about science a high level of expertise is needed, unlikely to be attainable by those with a general education at secondary science or from those with education to degree level in another discipline.

A further example of specific knowledge in use is given in scientific explanations and the desire for plausible mechanisms to explain the evidence. Identifying who is expert in a field requires a very specific knowledge, however, appreciating which are prestigious universities and the status of different news publishers is more generic knowledge. For the non-expert reader understanding of the general ideas described above would be relatively easily gained.

However, even within a first degree it may not be possible to gain an appreciation of specific research projects or scientific facts.

In summary, this discussion points to the limitations of heuristics as a way of describing and thinking about how well educated readers respond to news stories. The discussion points to limitations of an approach based on epistemic distance. The use of veracity as an indicator of the quality of science has been found to be rather too restrictive and readers at times were surprised they were being asked about this. Furthermore, the heuristics offered above are decontextualized and so it would not be possible to apply these finding to other news stories or other readers. Thus this finding points an opportunity to explore beyond measures of quality of science towards how readers *understand* what they read.

CHAPTER 5: INTERCONNECTEDNESS

5.1 Introduction

In pursuit of the wider goal of understanding trainee teachers' responses to news stories I explored, in Chapter 4, readers' reasoning about the likelihood of veracity of knowledge claims. The heuristics that were identified made use of information about scientific explanations, methods, researchers and communication to increase or decrease epistemic distance. The perspective on heuristic reasoning I adopted, however, restricts analysis to exploring the likelihood of veracity and is thus somewhat limited in breadth; during the interviews it was as if readers had more to say outside of this perspective. Participants were also reading articles which I, as the researcher, had selected and thus did not take into account participants' interests and motivation to read the stories. This may also have limited the readers' responses.

In the analysis and identification of the If…then… statements contextual information about the identified heuristics was removed. A second round of interviews, where participants selected articles themselves and where interview questions were not framed with ideas about certainty of knowledge claims, was undertaken in order to gain a broader view of reader responses. The data from this second phase has been analysed in two ways: firstly, in Chapter 5 the focus is on exploring the connections participants made between concepts; secondly, in Chapter 6 I will examine themes that emerged. In this chapter I examine the research questions:

- To what extent do readers integrate what they read about science in the media with other knowledge?

- Is there any relationship between the extent of integration and readers' formal education?

As I explored in Chapter 2, a number of authors have suggested that making links is an important part of reading about science. This led to the ideas I articulated about interconnectedness and the crossword metaphor. In this chapter I will explain how I went about analysing the transcription data and present findings from the second phase of interviews in the form of concept maps. I will then explore three areas raised in Chapter 2. Firstly I will present data showing how readers' ideas are interconnected and, in particular, explore any relationship between formal education and the extent of interconnectedness of scientific ideas. Secondly I will discuss the gross structure of concept maps in relation to the crossword metaphor. Finally I will return to the Kitchener (1983) three-level model of cognitive processing and examine evidence for readers' higher level cognition.

5.2 Concept map analysis

In Chapter 2 I began discussion about concept maps, what they are like and how they are useful in this study. I produced concept maps for each participant's responses to the news stories they selected, with a view to reducing and summarising the interview data (Daley, 2004). In total there are 36 concept maps. I wanted to draw out patterns from the data by eliminating the chronological order in which participants talked about the concepts and to identify the extent to which ideas were integrated into a wider framework of ideas. When producing the maps I read through the corrected interview transcripts and wrote concepts chronologically, as they appear in the text onto Post-It notes, with one concept per Post-It note. In this context, concepts are defined as words or phrases that represent something, such as thoughts, feelings or ideas. This is a deliberately broad definition as the goal was to produce a rich and varied map and not to miss out anything that would be meaningful for the

participant. The next step was to re-read the transcription and produce a map which comprised of pairs of concepts and a linking phrase between concepts, known as a proposition. I tried to produce propositions which made use of participants' language. In some instances a proposition did not make sense if it started and ended with a concept, in which case the proposition might be rephrased and the concept repeated in the linking phrase, trying to retain the readers' original language.

Once identified, the concepts on Post-It notes were moved around on a large sheet of paper and linking arrows and phrases were drawn onto the paper. The arrows show the direction in which the proposition should be read. The paper based maps were then transferred to CMap software (IHMC). The software allows the entry of propositions and then automatically formats the map. Sometimes the automatic format was not appropriate because lines crossed and the map was difficult to follow. The software permits further attempts at different automatic formatting but on a few occasions I manually adjusted the map. An example concept map for a science trainee responding to a news report about nuclear energy is shown in Figure 5.1.

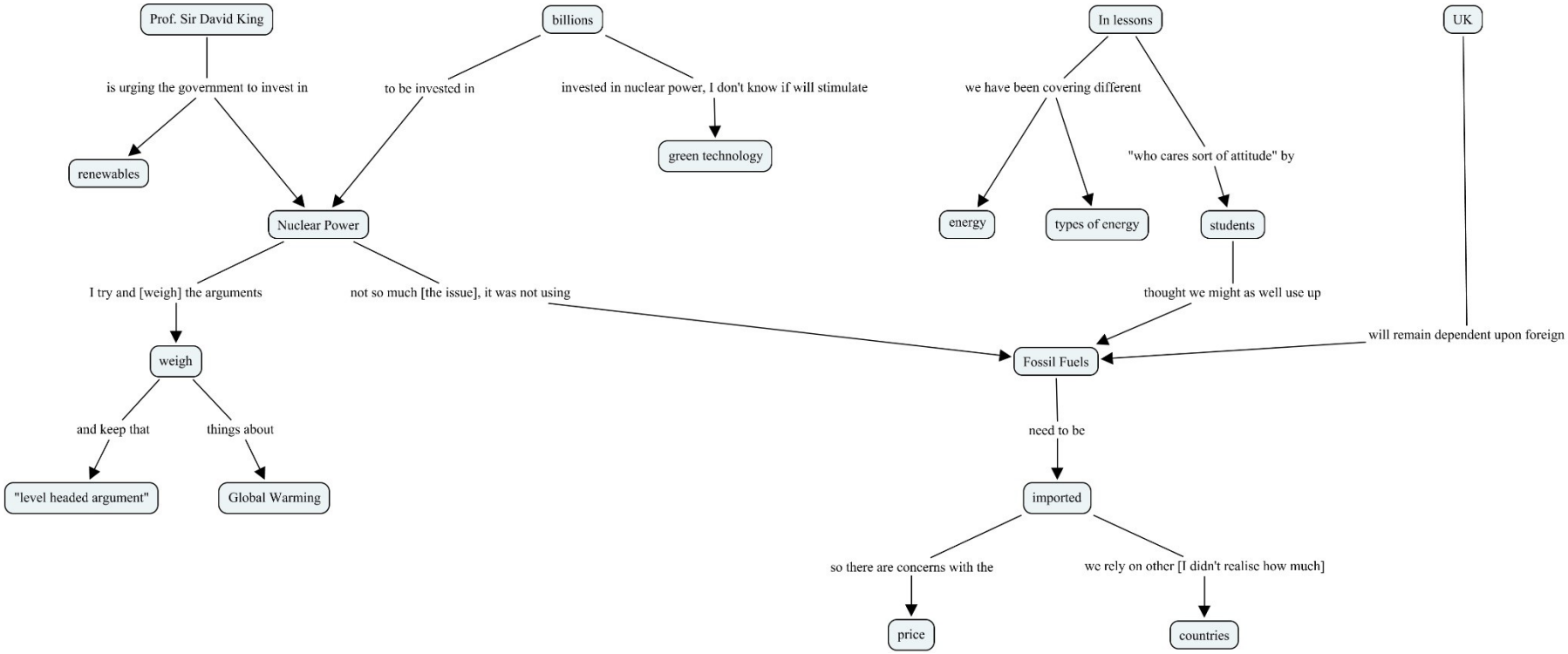


Figure 5.1: Sheila: ‘Nuclear energy’ - example of a completed concept map

Concept maps are interpretations of the interviews and thus it is possible that someone else could draw a map in a different way. This is consistent with the interpretivist positioning of this study. An illustration of this is from the quote below:

> I remembered some of the like sciency words, which I was quite proud of myself for, [laughs], remembering them from, err, from, err, school, but… (Katie: Older Fathers)

It was necessary to make decisions about how to represent this part of the interview. "I" was taken to be a concept. However, there are other possible concepts: "sciency", "words", "proud", "remember", and "school". There is some need to reduce the data so decisions need to be made about what to include and what to omit, while at the same time trying to retain the voice of the participant. The proposition selected for the concept map was "I remembered some of the sciency words" (concepts shown underlined), as it was true to the text and captured the sense of the interview extract. The alternative I considered was "I remembered words that were sciency" but his was rejected because the main object of the sentence seems to be "words" rather than "sciency" which is being used more as an adjective in this context.

Once concept maps were produced, the next stage was to identify clusters, or networks of concepts that share a common theme. These clusters were represented by drawing a lasso around the concepts and links between concepts. The lassos, shown in different colours, define clusters of concepts about a particular theme. The colours have no specific significance but help the lines to stand out. A label was given for each cluster of ideas in the same colour as the lasso. An example map for Becky, a science participant, can be seen in Figure 5.2. At this stage of analysis, propositions that had a concept that had only one link was identified as spokes and marked with a green dot. It should be noted that such a spoke is different from a concept map that has a purely hub and spoke gross structure (Kinchin and Alias, 2005). Spokes and clusters here are not mutually exclusive and a spoke can be

contained within a cluster. These propositions had one concept that is shared but are otherwise isolated. In Figure 5.2 an example spoke can be seen in the bottom right of the map (concepts are underlined):

Carbon dioxide can be stored in rocks

An example of a cluster can be seen on the left hand side of the map:

One opinion which may be biased

Within the clusters of concepts I looked for a subcategory of clusters which I have called "clusters of ideas *about* interconnectedness". The content of these clusters is not specific scientific ideas, but instead ideas *about* science more generally. Within these clusters of ideas *about* science are examples of how ideas in science are connected to one another and *about* how these connections are made. The example given above about a biased opinion is an instance of such a cluster *about* interconnectedness because it is a reference to the status of an opinion. It is not how the scientific idea itself is connected within a wider network of ideas. Other examples of ideas *about* interconnectedness include the peer review process because this is the means by which new scientific knowledge is integrated into existing network of ideas. Knowledge of expertise and the processes of news production are also examples of "ideas *about* interconnectedness". Further examples are explored later in this chapter.

In Figure 5.2 it can be seen that there are a number of spokes and three clusters. The cluster about "NOTT/202 and carbon capture" includes scientific concepts that are integrated, with "carbon dioxide" a concept which forms part of four propositions; in total there are nine concepts and nine links within this cluster. The findings about spokes and clusters for all 36 concept maps were put into tables with three columns, there is one table for each article for each participant. Table 5.1 illustrates this tabulation. In some cases participants made

reference to how ideas in science are interconnected but made a single comment, rather than ideas that are interconnected with other ideas. In such cases the proposition *about* interconnectedness is shown in the first column in italics.

In the next section I will make use of the outcomes of the analysis described above. In particular I will explore the extent to which the concept map analysis shows interconnectedness of ideas and possible relationships between readers' formal science education.

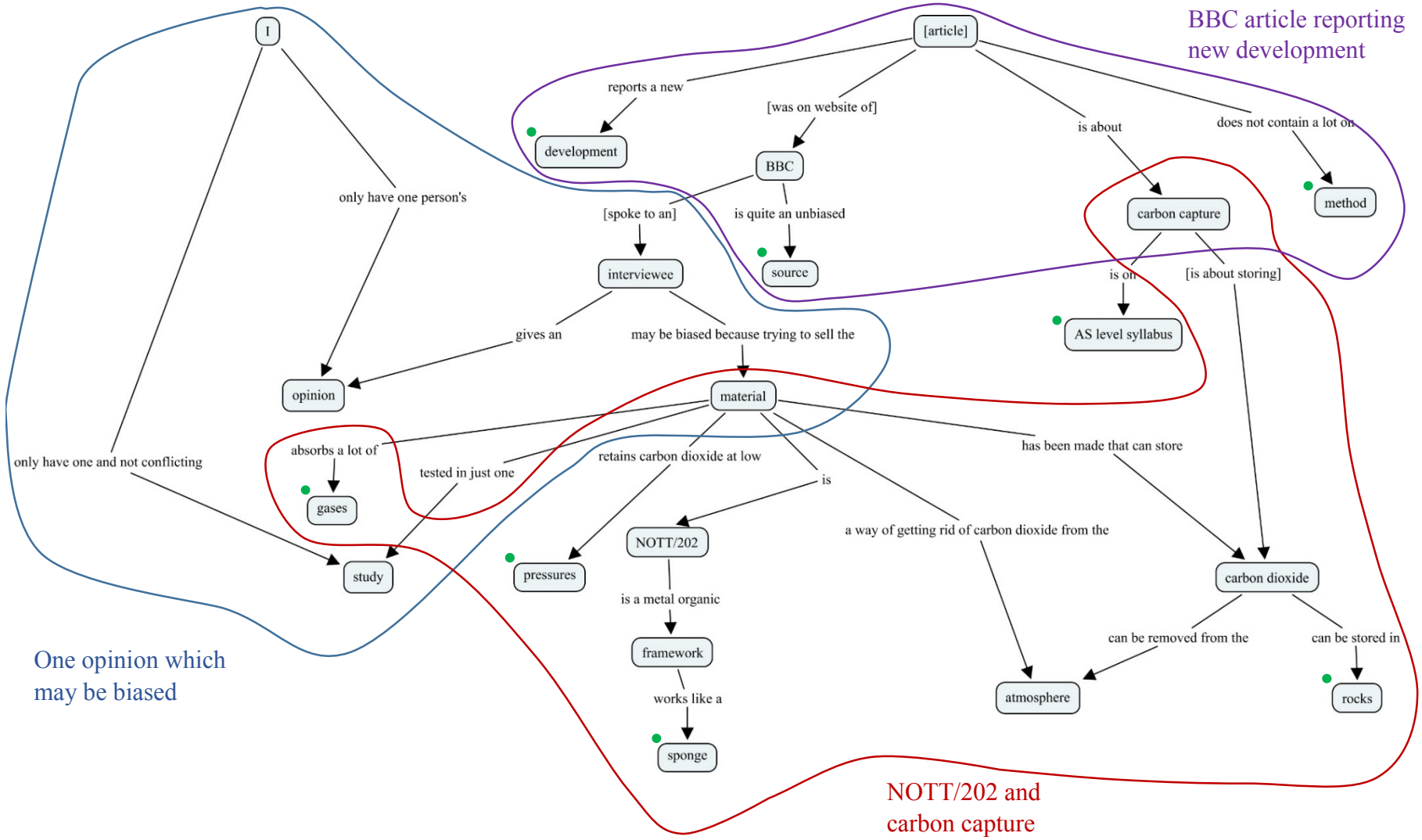

BBC article reporting new development
[article]
reports a new
development
[was on website of]
BBC
is about
carbon capture
does not contain a lot on
method
[spoke to an]
is quite an unbiased
source
interviewee
is on
AS level syllabus
[is about storing]
gives an
may be biased because trying to sell the
opinion
material
I
only have one person's
only have one and not conflicting
absorbs a lot of
gases
tested in just one
study
retains carbon dioxide at low
pressures
is
NOTT/202
is a metal organic
framework
works like a
sponge
a way of getting rid of carbon dioxide from the
has been made that can store
carbon dioxide
can be removed from the
atmosphere
can be stored in
rocks
One opinion which may be biased
NOTT/202 and carbon capture

Figure 5.2: Example of annotated concept map (Becky: Carbon capture)

Article title: Carbon Capture		
Spokes	**Clusters**	**Clusters about interconnectedness**
• Article reports new development • Material retains carbon dioxide at low pressure • Carbon dioxide can be stored in rocks • Article does not contain a lot on method • *BBC is quite an unbiased source*	• NOTT/202 and carbon capture	• BBC article reporting new development • One opinion which may be biased

Table 5.1: Example of summary table showing three categories from the concept map analysis (Becky: Carbon Capture)

5.3 Interconnectedness and relevance of formal science education

In this section I will give an overview of the findings from the concept maps analysis and explore links to the readers' formal educational background. As part of this discussion I will make use of the pen portrait for each participant that is given in Chapter 3. A further goal of this section is to explore the response of each participant in turn, with a view to identifying particular parts of the interview to look at in more detail in section 5.4. A starting point for this section is the hypothesis that if the contents of a readers' formal education is closely related to the contents of a news story, the more links they will be able to make between ideas and the more references they will make to ideas *about* interconnectedness.

5.3.1 Science Participants

Lee

Of the four articles analysed here, the least networked response was about the Lithium-Air battery article. This was quite 'spoke' like and included a range of propositions which had only one concept that was linked to other concepts. For this response there was only one cluster about how the article was claiming nothing 'outlandish'. Lee had taught the topic of

electrical cells to one of his classes and was likely to have explored the ideas to some extent during his A-level and degree level Physics. For example, the unit of watt-hours per kilogram would be comprehendible by A-level Physics students. This response included a cluster of ideas *about* interconnectedness concerning the original research journal.

The other three concept maps were more integrated. The article about Saturn's moon Titan was probably the most highly networked with three clusters of interconnected scientific ideas and included scientific vocabulary such as absorption values and anomaly. This particular response included a range of specific scientific vocabulary, but did not include any clusters of ideas *about* interconnectedness. Lee undertook a Physics degree with the first year containing a substantial amount of astronomy so he has substantial formal education in this area. The article about glucose fuel cells included the idea of a human/computer interface, associated with bio-physics, an area Lee studied in his second year at university.

Overall, Lee's responses included a range of propositions and clusters of networked propositions, but had only two clusters and a small number of propositions *about* interconnectedness. All four articles were about physics, the subject of his first degree, and he used a wide range of scientific ideas in his responses.

Sheila

The analysis of Sheila's responses reveals a range of propositions and clusters of concepts. There are three clusters and a small number of propositions *about* interconnectedness in total. The responses about DNA and the Fingerprint Inquiry include specific reference to a range of scientific ideas including statistical models and DNA, and these two response are the most integrated and contain the most scientific vocabulary. These two articles are associated with

Sheila's work prior to embarking on teacher training but it is not possible to identify any specific association with her formal education.

Responses to the other four articles are more general and include less scientific type vocabulary. For the article about Nerve Regrowth, Sheila mentions DLK, mice and the nervous system. In this response there are three clusters of integrated ideas and two propositions *about* interconnectedness. The participant states that her knowledge of biology is limited and there is no obvious link to work experience or degree content. Similarly for the article about the Transit of Venus, the participant has an A-level in Physics and this may have included some astronomy. Furthermore, the participant states that she has taught about the Solar System recently. This, however, does not relate to Sheila's formal advanced education. For this article there is some use of scientific vocabulary such as Sun, planets, etc. ,but this is at a basic level. There is a relatively small number of concepts overall in this concept map and there is only one cluster.

The response to the article about Solar Powered Aeroplanes includes personal experience and mostly everyday ideas, although there is reference to hydrogen power, solar panels and flight speed. It is not possible to identify any specific aspect of Sheila's formal education that is associated with this topic.

Joseph

The first three articles Joseph selected have links to Physics. Further, he possesses a Natural Science degree which was mainly in Physics and he states that the reasons for selecting at least one of the articles was due to his interest in Physics. The responses contain a range of clusters of ideas. Compared to other participants there is a particularly large number of points *about* interconnectedness, both clusters and propositions.

The topic of Supervolcanoes seems to have some limited association with Joseph's degree content. In his response, however, there is only limited interconnectedness with two networked clusters. One is about personal experience of teaching and the others is more about how the research is presented. The use of scientific vocabulary is limited in the overall response to this article. Similarly, for the article about Dark Matter the participant stated that they did this sort of thing at university. Although the interview does not contain scientific concepts that are specific to that field, it does include more general terms, namely model, detector and technology.

For the article about Space Textures the participant stated that they did cosmological theories at university and in the concept map there were four clusters of interconnected ideas. Furthermore, there was evidence of the integration of scientific vocabulary including: anomalies; universe; microwave background; and temperature. Finally for the Diesel Cancer Link article there were three clusters and one proposition about interconnectedness. Joseph's formal education in science was unlikely to have included such specific reference to cancer.

Simon

Simon selected four articles about science in a broad sense but none of these were directly related to his degree in Forensic Science. Simon stated that he took A-levels in Biology, Chemistry and Physics, although he said he was unsuccessful. The responses contain a mixture of spokes and clusters of interconnected ideas. However, in the response there is only one cluster of ideas *about* interconnectedness that is identified.

For the Freezing problem article it seems reasonable to assume that Simon's formal education included aspects of changes of state. For this response there are three clusters of interconnected ideas. However, the scientific content within these is limited. The clusters are

mainly restating the problem and expressing a personal response such as "I was amazed…". Similarly, the response to the article about Voyager 1 may have some relevance to the content of physics A-level. For this article there was three clusters of interconnected ideas. Within this response there was mention of NASA and accuracy/rounding, but two of the clusters are mainly about personal responses.

The participant's degree is not directly associated with Earthquakes or Biodiversity, the topic of the third article. The participant states that their degree included "fine detail biology and human biology", but the participant did study A-level biology and thus was likely to have some understanding of biodiversity. Within the concept map there is a range of scientific vocabulary, including: competition, organisms, diversity, sampling and balance. There are also links between these concepts. The response to the final article about UFOs included two clusters of interconnected ideas but other than that the number of scientific ideas is limited.

Becky

Within the four responses there was a balance between 'spokes' and networked ideas. For example in the carbon capture article there was evidence of networked ideas about NOTT/202. The Chinese space mission response was dominated by a personal perspective and there was almost no integration with any existing knowledge. Links to clusters *about* interconnectedness was evident in two articles with the emphasis on bias and opinion.

The response about Carbon Capture included the following concepts: carbon dioxide, capture, atmosphere, materials, carbon capture, metal organic frameworks and pressure. Thus it is relevant to both chemistry and geography, disciplines studied to degree and A-level respectively. The participants did not mention that they had specifically studied these concepts; however, it is hard to imagine that they are not included in a chemistry degree.

Overall, there was one cluster of ideas and two clusters *about* interconnectedness. There was also one proposition *about* interconnectedness.

The China space mission article was about astronauts and as such is not related to the degree content of the participant. The participant states they do not know anything about space stations. In the response there are two clusters of interconnected ideas about the article content and the participants own interest and knowledge. Thus while there is some integration of ideas, this does not include many specific scientific concepts.

For the article about GM crops Becky was likely to have studied genetics within an A-level specification for Biology. There are four clusters and they include the scientific vocabulary: insecticide, vitamin, beta-keratin and genetically modified. While there is a range of scientific ideas there is quite a strong hub and spoke concept map structure and only limited interconnectedness between concepts. The article on Milk fats is about bowel disease and there is likely to have been some reference to genetics within an A-level specification for Biology. Becky stated that the topic of her degree dissertation was cancer and computer modelling, which suggests some advanced knowledge of the topic. For this concept map there is a range of scientific ideas used, although they are in everyday vocabulary (diet; fat; bacteria). Taken together the concepts and links indicate that there is a range of integrated scientific ideas in this response.

5.3.2 History Participants

Alex

Alex has no formal education in science beyond the age of 16 years. There are some clusters of interconnected ideas, but for the articles about the Microsoft touch screen and Female

Astronaut there is only on cluster each. Overall there is little mention of ideas *about* interconnectedness with one cluster and two propositions.

The first article is about healthy forests and this has two clusters; one is about politicians keeping their promises and the other is rainforests trapping carbon. The latter includes a limited number of scientific concepts, for example, 'carbon dioxide'. The inclusion of the Amazon, however, links to the geography curriculum at A-level. The article about Space tourism has three clusters which draw mainly on everyday language including a discussion about safety, cost and astronauts. The ideas are integrated but do not draw principally upon a scientific perspective, instead drawing upon historical ideas.

Similarly the article about the Microsoft touchscreen shows limited integration of scientific ideas; there is a range of 'spokes' and a proposition *about* interconnectedness. The one cluster includes ideas about risk and competition from a personal perspective. The reader had studied ICT and history at A-level standard. However, nearly all propositions in the concept map are in everyday language rather than the specialist language. There is use of some more specialist terms such as risk, quantitative, society, competition and profit.

The response to the Female astronaut article included one cluster but no specific scientific vocabulary (if 'space station' is excluded). The reader's advanced qualifications might be considered to be associated with the discussion of gender stereotypes. A similar pattern is seen in the final article on the Weight of humanity. There is some integration of scientific ideas with two clusters and other 'spokes' which include what might be considered scientific concepts (overweight, obesity, population, data, etc.). The number of links is limited. In a broad sense the use of population data may have been part of Alex's geography A-level qualification.

Nick

Nick's responses all contained clusters of integrated ideas. Two responses included reference to ideas *about* interconnectedness. Nick did not study science beyond aged 16, but he did work in a dispensing opticians.

The Password breach article content was some distance from Nick's A-level and degree subjects. However, it is clear that Nick had an interest in technology. In his response there were two clusters that included almost no scientific vocabulary, even in a broad sense; one cluster draws upon the reader's personal experience and the other makes some general points about hacking.

The response to the Honey Bee article was quite different to that described above. There are no clear links between the reader's advanced education in science and the topic of the article. There are three clusters which include a range of scientific vocabulary and which are integrated. The reader raises the issue of Varroa and suggests reasons for bee populations declining. Nick included two propositions *about* interconnectedness.

Nuclear Energy is a controversial topic which has links to politics, part of Nick's degree. The concept map contains three clusters of integrated ideas with some broadly scientific language included such as low carbon, fossil fuels and wind energy. The topic of Stem cells is unlikely to have been part of Nick's advanced formal education. For this article, one of the three clusters is about personal experience. A further cluster is about how universities are working together. One cluster includes ideas about strokes and spinal cords. Overall there are some scientific concepts and limited integration of ideas.

The topic of the article on Greenland sharks is again unlikely to have been included in the reader's formal education. However, two clusters were identified. The ideas in the cluster

about possible explanations for the shark feeding paradox are very highly integrated and after some thought I was not able to identify separate clusters. Instead I have seen it as a single, large and well integrated, cluster.

Katie

Katie's degree is in History and International Relations. She completed an A-level in Biology. Her concept maps contain a range of propositions and clusters. In particular each response has one cluster *about* interconnectedness. The response to the article about Older Fathers includes concepts that Katie remembered from her A-level biology course (telomeres and DNA). There is some evidence of scientific concepts being integrated into a network of concepts.

The article about the Rio Summit was relevant to a module Katie completed on government and the environment while at university. The article did not mention any particular ideas that Katie studied and the ideas in the concept map are general and political. There is some interconnection between the ideas, although the concepts are general, rather than explicitly scientific in nature.

The reader has an A-level in Biology and experience in a medical context but there is no evidence of depression being included in this formal education. The concept map for the Depression article had two clusters, one is about the research being in its early stages and the second about the reader's interest in how the brain responds. These are quite large clusters which are well integrated. The final article about the Oldest Galaxy does not seem to be relevant to Katie's formal education. In the response there is one cluster of ideas, and one cluster and four propositions *about* interconnectedness.

5.3.3 Conclusion

The account above demonstrates that any relationship between the interconnectedness of scientific ideas shown in the concept maps and readers' formal science education is not straightforward. There is some evidence to suggest that readers without science qualifications approach what they read in a different way to those with science qualifications. For example, responses by Alex (Microsoft Touch Screen; Female Astronaut) and Katie (Oldest Galaxy) show very little integration of scientific ideas. However, there are responses by history trainees that include a range of well integrated scientific ideas even though the article content does not seem directly related to their formal education (Nick: Honey Bees; Nuclear Energy; Greenland Sharks) and Katie (Depression). Furthermore, there are some responses by science trainees that show limited interconnectedness of scientific ideas, such as Sheila's response to the article about the transit of Venus and Becky's response to the Chinese Space Mission article. However, taken together there is somewhat more evidence of integrated scientific ideas in the responses by science trainees.

Thus the hypothesis suggested at the start of this section is not supported in a simple way. There are science trainees who have responses that demonstrate a good amount of 'interconnectedness', but there are also history trainees who demonstrate this. It follows from this discussion that a deeper exploration of responses is required to further examine any relationship between formal science education and the interconnectedness of ideas in concept maps. Furthermore, I felt it would be useful to give some examples of the concept map analysis to further exemplify the discussion above. To this end, in the next section I will continue to examine particular examples of concept maps and their analysis. A goal here is to achieve a balance between depth and breadth of analysis, and to increase transparency of analysis.

5.4 Interconnectedness and formal science education: Further explorations

In this section I will draw upon four examples of responses to news stories. I will show examples for science and history participants that show relatively low and relatively high levels of interconnectedness.

5.4.1 Science participants

Sheila's response to the Transit of Venus webpage (Figure 5.3 and Table 5.2) shows one cluster and a small number of spoke-like propositions. These spoke-like propositions are marked in Figure 5.3, and the other concept maps, with a green dot. An example of a spoke-like proposition in Figure 5.3 is "Teacher encouraged them to look into Transit of Venus". The concept "Teacher" has a green dot by it because it is only connected to the network via one link. These spoke-like propositions, which are marked with a green dot are also listed in the first column of Table 5.2, and the other similar tables.

It can be seen in Figure 5.3 that there are no examples of "ideas *about* interconnectedness". Furthermore, there is both reference to the context of the secondary school classroom and the personal experience. It can also be seen that the interconnected cluster is about the size of Venus. Given that elsewhere Sheila gave a response that was very detailed and included a range of clusters, it can be concluded that she has the potential to give such responses. This raises the question of why this response does not exhibit the same degree of interconnectedness. Certainly, the topic is one which Sheila is not as knowledgeable about compared to the DNA or Fingerprint Inquiry article as the field of astronomy is not part of her advanced formal education or her work experience. It can be seen that this response is also located in the secondary school context, which perhaps sheds some light on how Sheila interpreted the task of reading and responding to the news stories.

Joseph selected an article about links between diesel fumes and cancer (Figure 5.4 and Table 5.3). His response includes a lot of interconnected concepts. However, there is only one reference I identified *about* interconnectedness, that is about the media's perspective on cancer. In response to the reported research, Joseph identifies an absence of an explanatory mechanism and also comments on the significance of this research ("not the world's biggest problem"). As mentioned above, it is unlikely that Joseph's degree included a substantial amount of work on this area.

There are significant differences between these two concept maps in terms of the number of concepts, the number of links, the amount of interconnectedness and also what the propositions are referring to. Further, Sheila draws upon her personal experience and ideas about her teaching, but for Joseph there are not such points. From the evidence available, advanced formal education is not able to account for such differences. A notable similarity, however, is the absence of comments *about* interconnectedness.

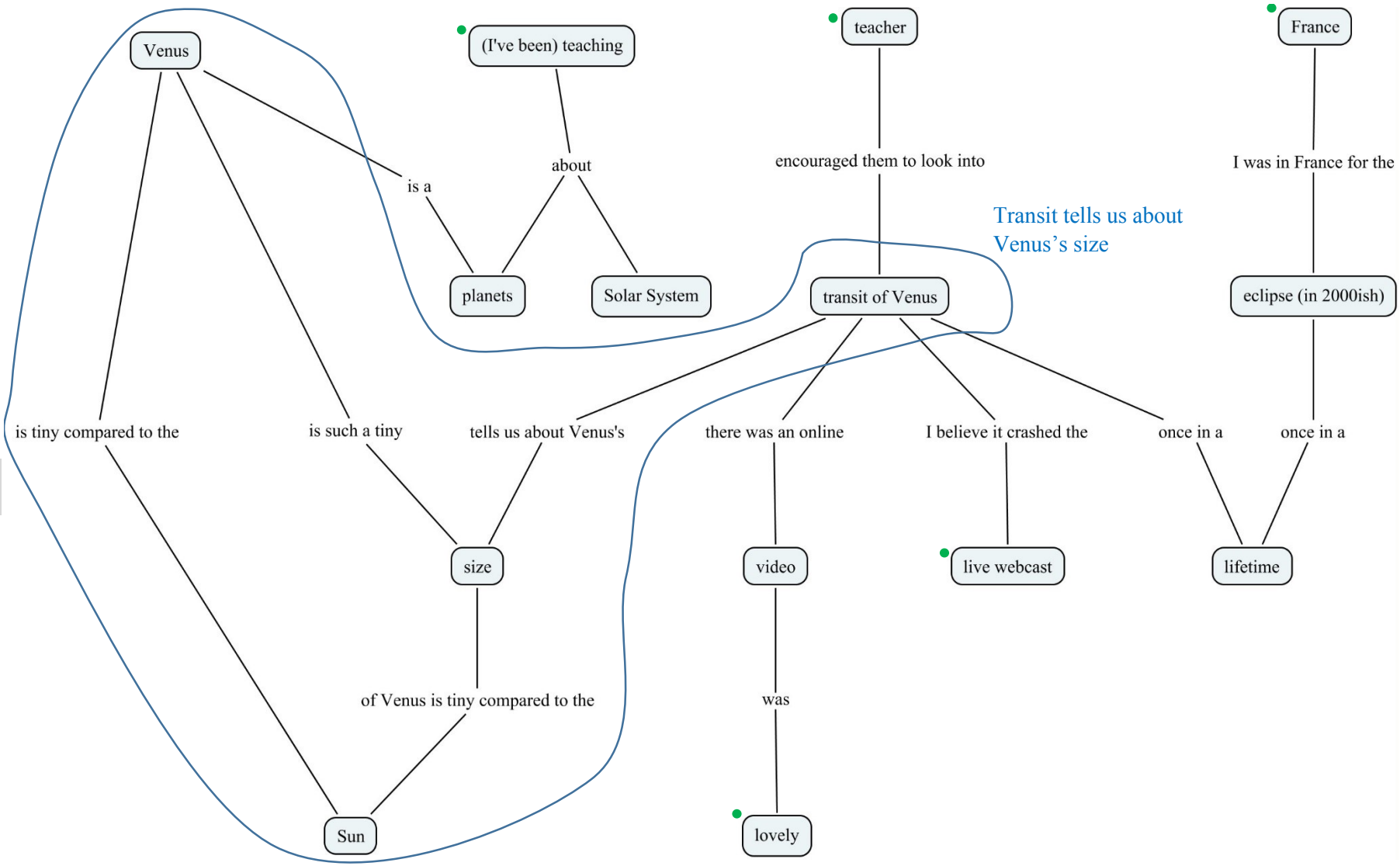


Figure 5.3: Annotated concept map for Sheila: Transit of Venus article

Article title: Transit of Venus		
Spokes	**Clusters**	**Clusters about interconnectedness**
• Teacher encouraged them to look into transit of Venus • I was in France for the eclipse (in 2000ish) • Video was lovely • Transit of Venus I believed it crashed the live webcast	• Transit of Venus tells us about Venus's size	

Table 5.2**:** Spokes and clusters for Sheila: Transit of Venus (based on Figure 5.3)

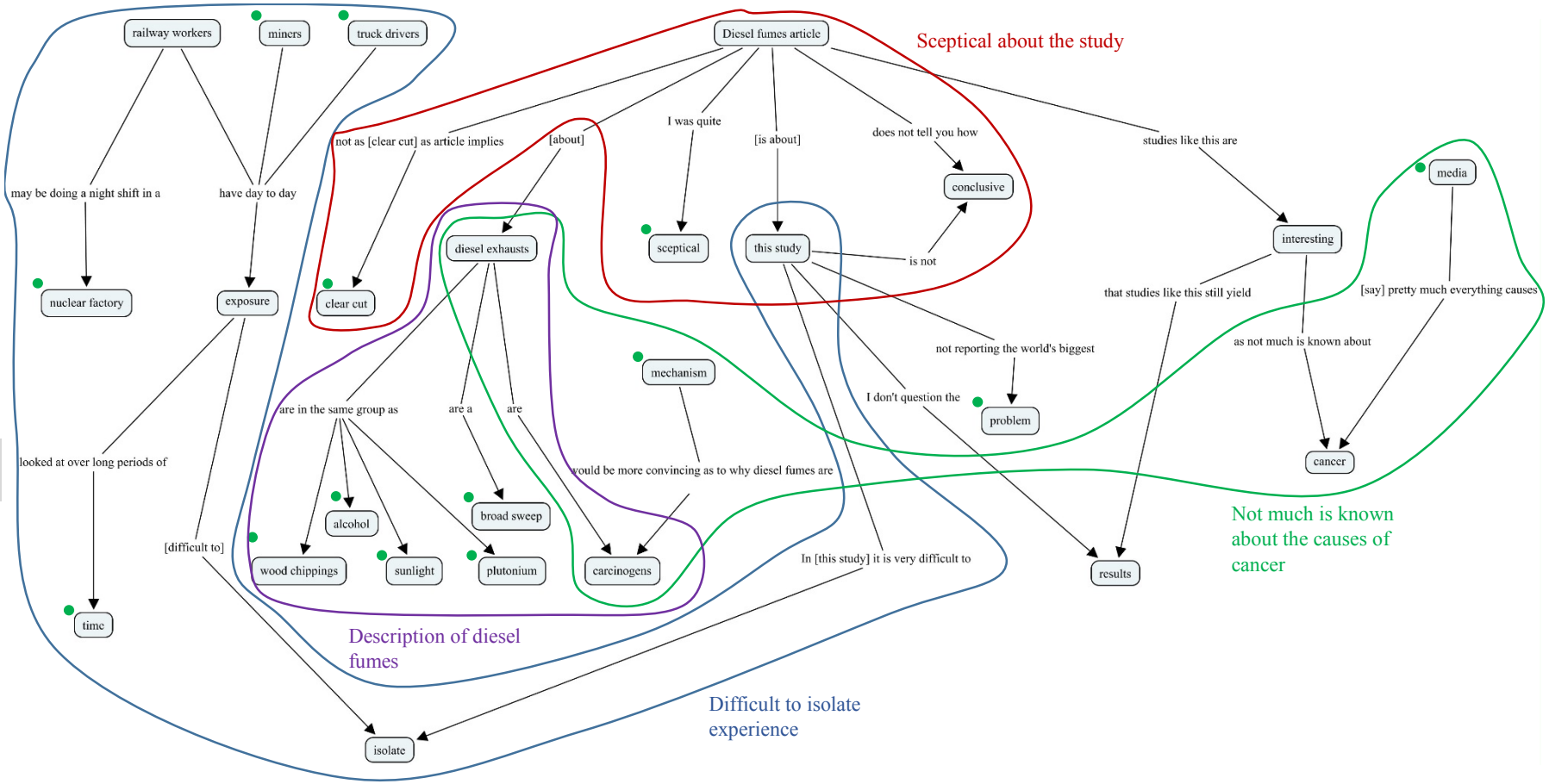


Figure 5.4: Annotated concept map for Joseph: Diesel Cancer Link

Article title: Diesel cancer link		
Spokes	**Clusters**	**Clusters about connectedness**
• Railway workers might be doing a night shift in a nuclear factory • Exposure looked at over long periods of time • Miners have day to day exposure • Truck drivers have day to day exposure • Diesel exhausts are broad sweep • Diesel exhausts are in the same group as wood chippings (and three other things) • This study not reporting the world's biggest problem • *Media [say] pretty much everything causes cancer*	• Difficult to isolate exposure • Sceptical about this study • Not much is known about the causes of cancer	

Table 5.3: Spokes and clusters for Joseph: Diesel Cancer Link (based on Figure 5.4)

5.4.2 History participants

The most spoke-like map I identified in the study was from Katie's response to the article she read about the oldest galaxy; the map contains very few concepts with more than one link (Figure 5.5). The two concepts with the most links in the map are "I" and "people" which suggests that Katie found it difficult to link the concepts in this article to other ideas. The concepts identified in the map indicate that the response is very personal, with the two main 'hubs' "I" and "people". Katie mentions that she found the article interesting but inaccessible and hard to understand. Thus in this case Katie's own comments, and the gross structure of this spoke-like concept map, point to a limited understanding of this topic. However, elsewhere in the interview, Katie has more integrated responses.

In more than one place, Katie expresses confidence in the expertise of those conducting the research. As such she is referring to ideas *about* interconnectedness, but these ideas are not

interconnected. These propositions about expertise represent a fairly superficial treatment and are consistent with the rest of this part of the interview in that they are do not exhibit a confidence in the subject matter. Katie's qualifications do not include physics beyond the age of 16 years.

Similarly Nick completed his formal education in science at GCSE level, but the map shown in Figure 5.6 contrasts to Katie's response to the Oldest Galaxy article. It has a large number of concepts, some of which are associated with science. Examples are: environment, parasite, virus and disease. Furthermore, there is a range of links between the concepts and is highly networked.

In Figure 5.6 it can be seen that three clusters of ideas were identified. The first was about Varroa, the second about the reasons for numbers of bees declining and the final about how some islands are not affected. It is interesting to note that Nick challenges the gravity of the situation implied by the headline "Honeybee virus: Varroa mite spread lethal disease" (Gill, 2012a). He reflects on whether the virus is that bad given that some Hawaiian islands do not have Varroa. He also suggested that it might be that a 'cocktail' of viruses have caused the decline in numbers. This seems to be a further example how readers suggest alternative explanations, initially raised in section 4.3.

The additional evidence presented here confirms the discussion in the previous section that there is not a simple relationship between advanced formal education in science and the extent to which ideas are integrated. Further, from this discussion it is not possible to say that highly networked maps are necessarily associated with superior responses. However, in some cases there are highly integrated responses which include a range of scientific vocabulary and interconnections. There are examples from science and history trainees of concept maps

which are very personal in nature, including relatively few scientific concepts, which are well integrated.

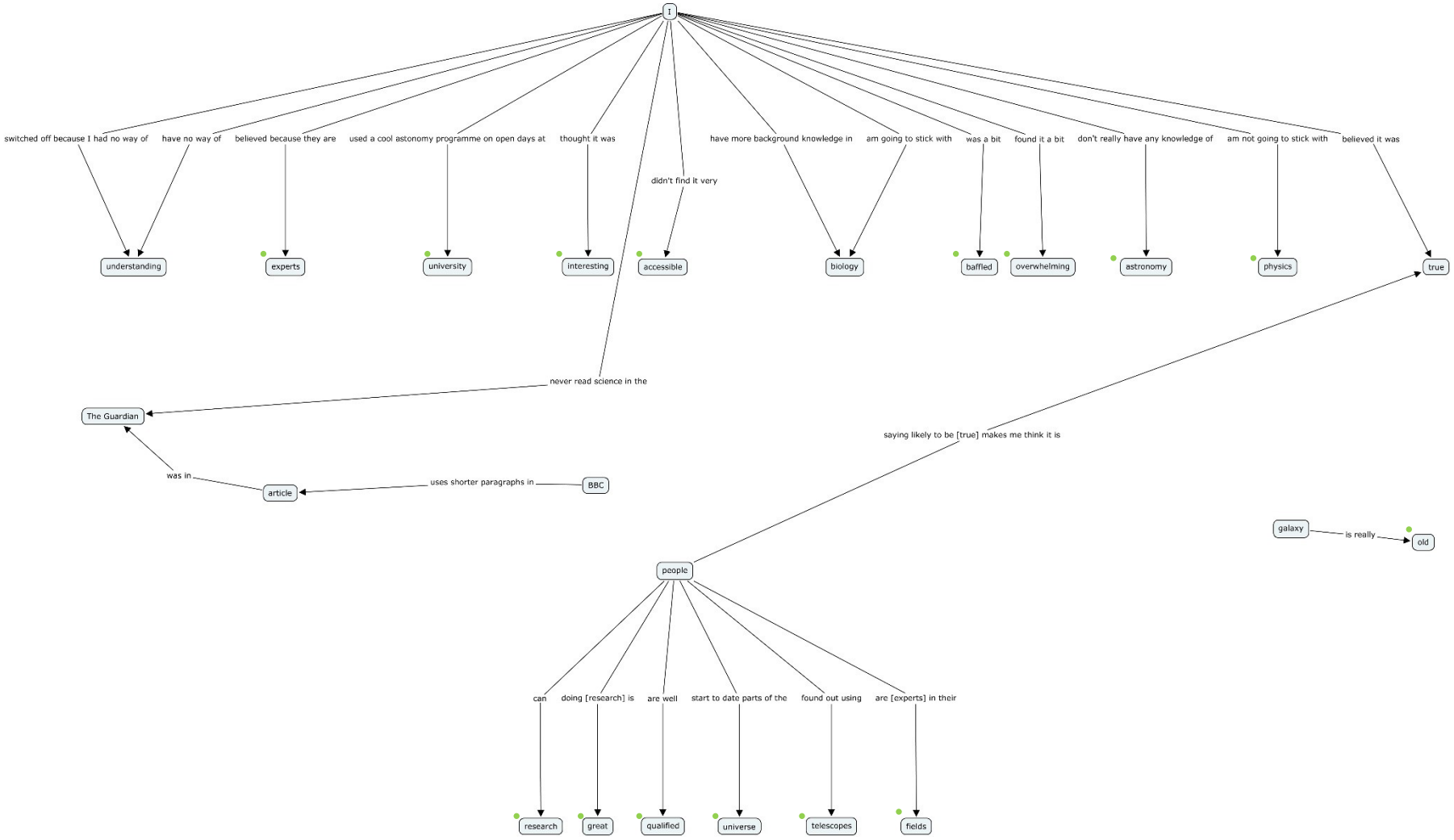


Figure 5.5: Annotated concept map for Katie: Oldest Galaxy

Article title: Oldest Galaxy		
Spokes	**Clusters**	**Clusters about interconnectedness**
• I didn't find it very accessible • *BBC uses shorter paragraphs in article* • *I believed because they are experts* • I used a cool astronomy programme on open days at university • I thought it was interesting • I don't find it very accessible • I was a bit baffled • I found it a bit overwhelming • I don't really have any knowledge of astronomy • I am not going to stick with physics • I believed it was true • *People saying likely to be [true] makes me think it is true* • People can research • People doing [research] is great • People are well qualified • People are experts in their fields • People start to date parts of the universe • People found out using telescopes • *People are [experts] in their fields* • Galaxy is really old		

Table 5.4: Spokes and clusters for Katie: Oldest galaxy (based on Figure 5.5)

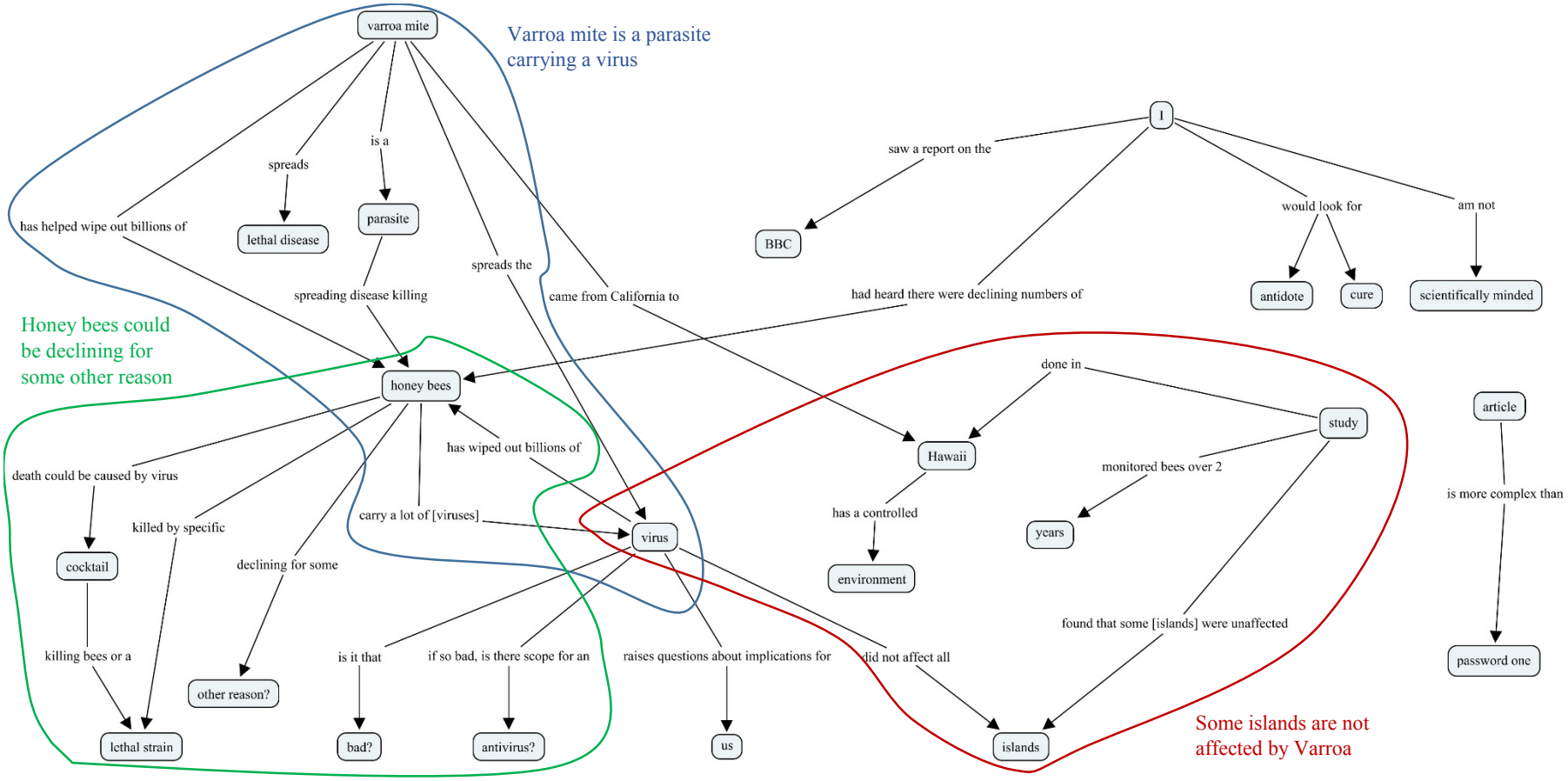


Figure 5.6: Annotated concept map for Nick: Honey Bees

Article title: Honey Bees		
Spokes	**Clusters**	**Clusters about interconnectedness**
• Varroa – Varroa mite • Varroa mite spreads lethal disease • Hawaii has controlled environment • Study monitored bees over 2 years • Virus, is it that bad? • Virus, if so bad, is there scope for an antivirus? • Virus raised questions about implications for us • Honey bees declining for some other reason? • *I saw the report on the BBC* • *Article is more complex than password one*	• Varroa is a parasite carrying a virus • Honey bees could be declining for other reasons than Varroa • Some Hawaiian islands not affected by Varroa	

Table 5.5: Spokes and clusters for Nick: Honey Bees (based on Figure 5.6)

5.5 Discussion of interconnectedness

5.5.1 Concept map gross structure and crossword metaphor

As discussed in Chapter 2, concept maps can be used to identify interconnections between concepts. The discussion in this chapter shows that the concept maps from this study do not easily fall into these three categories of spoke, chain and networked (Kinchin et al., 2000; Hay and Kinchin, 2006), as all of the maps are networked to some extent. However, there are maps that are more spoke-like and are thus networked to different extents. Within the concept maps there are a different number of concepts identified, different numbers of clusters and different numbers of clusters *about* interconnectedness. However, the primary goal here was not to undertake quantitative analysis, but to explore the links readers made between ideas found in the article and other ideas they had.

The crossword metaphor emphasises that in responses to news stories readers might use ideas as cross-checks on the plausibility of what they read. In other words, part of the plausibility check is that ideas fit into an existing framework. What has emerged in the data is that checks on plausibility are less emphasised than the reader trying to understand the news story and fit it in with their current thinking. Thus while the interconnected aspect of the crossword is relevant here, the checking seems to be less of a priority for readers.

5.5.2 Higher level cognition: Metacognition and epistemic cognition

I argued in Chapter 2 that statements of fact or unconnected ideas are suggestive of cognition, for example, reading and remembering. If links are made between ideas, then I claimed that the reader had processed declarative knowledge in some way, either consciously or unconsciously. Furthermore, I suggested that if the reader had integrated ideas *about* interconnectedness then this is associated with epistemic cognition. Thus concept maps potentially offer a means of identifying metacognition and epistemic cognition.

Sheila starts her response to the Nerve Regrowth article by saying "I know nothing about biology and I don't know how to make biology interesting [for pupils]". While this was followed by a laugh and not entirely serious, Sheila was expressing here an awareness of the limitations of her knowledge and thus demonstrated metacognition. Presumably it is preferable to be aware of limitations in personal knowledge. The concept map for the Nerve Regrowth article showed three clusters, which to some extent support Sheila's stated position. There is some evidence of integration with a reference to mice studies but this is at a simple level. The other two clusters are about making biology teaching interesting and about Sheila's brother-in-law. This shows that Sheila is not especially confident in her knowledge of the topic but has made links to her personal experience.

Ratcliffe (1999) found that only younger secondary aged readers drew upon personal experience in her study, although this might be accounted for by the fact the questions asked were more focussed and less general than in this study. However, making such links to personal experience has the potential to be useful for the reader as it gives a foothold in the topic and is, therefore, not necessarily evidence of undesirable thinking. So while in science more generally, evidence in the form of personal experience generally has a lower status compared to other evidence, in the interpretation of secondary sources such personal experience may have a place.

This example of linking encountered ideas to things that are known by a reader is consistent with a metacognitive strategy. A further example was given by Nick who spoke about stem cells and their potential to be used to regenerate tissue:

> I want to know exactly what this thing about stem cells mean, means, so how are these stem cells going to be produced… Um, yeah, I don't really know much about that.

He talks here about his uncertainty about the topic and in a different way demonstrates metacognition, an example of awareness of ignorance.

As mentioned previously, in his response to the article about the Varroa virus in honeybees, Nick challenges some of the contents of the article. The response has three clusters of well interconnected ideas which show that Nick has been able to integrate the ideas in the story with ideas he has generated himself:

> But how can we be sure that that virus specifically on its own, um, has caused the deaths of the bees or is it a cocktail maybe of, you know, the other viruses… Latching onto that? I mean, I don't know whether that sounds ridiculous or not and I'm not really scientifically minded…

This quote is a further evidence of metacognition and Nick's awareness of his knowledge of the topic. He also raises the idea that it might be a "cocktail" of viruses rather than just one that is threatening bees. Thus being able to generate and integrate a new idea is evidence of a metacognitive strategy.

Another example of a participant linking ideas is where Sheila integrated existing knowledge in her response about a Solar Powered Aeroplane. The article includes a mention of "greening" (Solar-powered plane completes Moroccan desert flight, 2012) and Sheila makes a connection to hydrogen powered cars, evidenced in a cluster about green travel.

Nick adopted a similar approach when he talked about the article about Greenland sharks. He spoke at some length about how the sharks might be able to catch a seal, despite their low speed, suggesting alternatives to the one suggested in the article. Nick's "knowledge of knowledge" about this article is interesting:

> **And does it fit with what you know or did you, you have any knowledge of this sort of thing?** Um, yeah, I mean, err, the, the, it fits in with, err, with what I regard about animals is that they're, they're far more clever than we realise, um, and we're only beginning to scratch the surface as, as to what goes on in their minds, um, and, and resourceful ways of living…

Here he shows a perspective on scientific knowledge, touching on how difficult it is to understand animal behaviour. This is an example of more abstract ideas being taken and applied to a particular situation.

A final example in this section is where ideas are integrated but they are outside of everyday definitions of science. Nick in his response to the Password Breach article talks about his experiences of password problems, his own experiences and technology more generally. Nick

makes links and make comparisons, but they are outside of the sphere of science, even in a broad sense.

In Table 5.6 I have included a list of all the *clusters* of ideas about interconnectedness. It can be seen that there are relatively few occurrences of clusters within this category. For a reader who did not have specific knowledge of the contents of a news story, the use of ideas *about* interconnectedness offer a potential way of understanding what is being read. It would seem reasonable to draw upon some more generalised knowledge about science such as about peer review, who is likely to be an expert and how news stories are produced. However, there are few references to these. It can be seen that there is not a discernable difference between the science and history trainee teachers in this analysis.

Parti-cipant	**Article**	**Cluster of ideas about interconnectedness**
Lee	Glucose fuel cells	Article links to research journal
	Saturn's moon Titan	
	Lithium air battery	
	Quantum computing	Comparing research from different places
Sheila	DNA	
	Fingerprints	
	Nerve regrowth	
	Transit of Venus	
	Nuclear Power	
	Solar-powered aeroplane	
Joseph	Supervolcanoes	Article presented as if truth and does on reflect what is going on
	Dark matter	
	Space textures	Humans don't know much about cosmology; Cosmology not in the same league as table top science (limited interconnections)
	Diesel cancer link	
Simon	Freezing problem	Much has been explained but not the freezing problem
	Voyager 1	
	Earthquake	
	UFO	
Becky	Carbon capture	One opinion which may be biased
	China space mission	
	GM crops	Opinion and bias
	Milk fats	
Alex	Healthy forests	
	Space tourism	

	Microsoft touchscreen	
	Female astronaut	
	Weight of humanity	[mention of research but this was not expanded upon]
Nick	Password breach	
	Honey bees	
	Nuclear energy	
	Stem cells	Universities working together to research diseases
	Greenland sharks	
Katie	Older fathers	Article from BBC and is balanced
	Rio Summit	
	Depression	
	Oldest galaxy	

Table 5.6: Summary of clusters of ideas *about* connectedness for each participant

Within the data there more propositions *about* interconnectedness than clusters *about* interconnectedness. For example, Sheila's responses contain no clusters of ideas *about* interconnectedness. However, she does mention individual points *about* interconnectedness. The first point is about the Fingerprint Inquiry being published; the implication here is that the claims within the report are thus subject to scrutiny. In Sheila's response to the Nerve regrowth article I identified two propositions about interconnected. These are that she is cautious about accepting what newspapers say and that the Neuron Journal is not one she knows.

From Table 5.6 it can be seen that Nick has one instance of a cluster of ideas about interconnectedness. This is in the response to the article about stem cells where he talks about how universities are working together. He also raises two points about bees that are not part of a cluster of ideas *about* interconnectedness but are propositions: "I saw the report on the BBC" and "Article is more complex than password one".

Among the 36 concept maps produced in this analysis there are a lot of spokes and some integration of ideas, but there is very little evidence of epistemic cognition, or 'knowledge of knowledge' in use. The main question that emerges from this is why is there little use of such

ideas? The first possible alternative is that the interview questions and context do not facilitate such thinking. The general and open nature of the questions asked were intended to provide the reader with a broad framework within which to respond. There were some such responses and so the interview context cannot be prohibitive of such responses. A second alternative explanation is that readers do not possess, in an accessible form, such epistemic knowledge that they can articulate. It seem unlikely that graduates, and particularly those who have undertaken study at Master's level, should not have at least a basic understanding of these things.

Thirdly, the requirement for the third column, that there should be a *cluster* of ideas about connectedness, is quite a demanding one to satisfy. The examples of Sheila and Nick show that there are some spokes that are *about* interconnectedness, but the overall number is small. A final possible explanation is that readers do not think to draw upon such knowledge when reading news stories. Perhaps they do not consider them relevant. The fact that in many cases such knowledge was not used suggests that this is not part of a natural or spontaneous response. Perhaps readers have not considered the usefulness of such generalised thinking in areas outside their personal expertise.

Given the importance of peer review within science (Levinson, 2006) is it perhaps surprising that this area is mentioned so infrequently, by science graduates in particular. One participant responding to an article about Supervolcanoes (Joseph) challenged the way the article was presented and the associated implications for how scientific knowledge emerges:

> And the, the, the authors managed to present it in such a way that it, it kind of supersedes all the previous work and… **Right, okay.** You know, this clearly shows that, um, that it's this way and not, not how it was thought of before… **Mm-hmm, mm-hmm.** And there was no kind of, um, you know, it doesn't happen like that in science, in the kind of

> scientific community… **Mm-hmm.** And there was no, um, none of that process in the article at all, if that makes sense.

Thus this participant demonstrates their understanding of how new knowledge is approached by scientists. Points related to this area are also found in the If…then… analysis described in Chapter 4. Some evidence (18MH/A; 18MH/B; 19FH/A; 19FH/B; 20FH/A; 21FH/B), albeit limited, was found for two different but related heuristics:

> **If** consensus reached or peer reviewed **then** reduce epistemic distance
>
> **If** lack of consensus **then** increase epistemic distance.

It is interesting to note that history trainees' comments are represented more strongly in this area, with peer review being largely neglected as a means of exploring the veracity of knowledge claims by science trainees. There are some instances where verification by other researchers is mentioned (Katie and Lee) but on balance there are few references. There were found to be two instances of participants raising the lack of consensus as an issue (Becky and Nick).

In some of the articles selected by participants for the second round of interview, the reported research articles originated in the PLOS One open access journal. According to the journal website the contributions are peer reviewed but a fee is payable by the author or research sponsor. This is a different model to many peer reviewed journals. One of the stated goals of the journal is to have fast publications times. The speed of publication and the open access nature of the journal may be one reason why the journal is cited as the source for some of the articles selected by participants in round two of the interviews.

Associated with conceptions of peer review and of consensus is the idea that there are different voices present within news stories. A number of the news stories used in phase one of this study, and selected by participants, have references to different voices. For example, the story about heart disease (Wilkinson, 2010) reports findings of a research study but included quotes by a nurse from the British Heart Foundation and also from a representative from the British Dental Association. Zeidler et al. (2002) found that college students conflated scientific knowledge and opinion. While there were few references made by participants to opinion, one participant (Becky) suggested that quotations marks signalled an opinion. One participant pointed out that the BBC is balanced and how this is helpful to the reader:

> it's always the BBC, they kind of, 'cause everything's so balanced, they're like, well, this is really exciting good research, but then there's actually all these flaws, so when you were saying to think about whether it was like fact or, you know, whether how much… **Mm-hmm, yeah.** Fiction I thought there was, it was kind of, well actually, it already tells you, doesn't it? (Katie: Older Fathers)

Further, Nick implies that one story includes an opinion:

> …is an ex chief governmental scientist, [tuts], and he's basically pushing through or, or urging the Government rather, um, to stop, um, [tuts], stop dithering basically… (Nuclear Power)

One final point associated with social perspectives is a point raised by one participant about the purpose of an article (17FH/B). This point did not emerge from any of the conversations with science trainees. Exploring article purposes is a strategy suggested by Jarman and McClune (2007) as part of critical reading of news stories. An example of this is the point made by a history trainee that the researcher was trying to "big up" (19FH/A) their research. It is in the interests of researchers to have a publishable story and for this research to be available.

Also associated with this area are reader perceptions of a lack of consensus in a particular area of science:

> I don't know how much I believe, right, 'cause in these types of articles, you get so many out all the time that contradict each other… (18MH/D)

Thus this quote points towards the challenges of deciding upon the value of articles and the scientific ideas within those articles.

The spokes I identified in the concept maps and in the tables are concerned with declarative knowledge. They are usually statements of fact, of opinion, or a restatements of what is in the article, or other statements. One example is "wings on solar powered aeroplane the size of a jumbo" (Sheila: Solar Powered Aeroplane) which is an isolated statement. Where ideas are linked together into a network there is evidence to suggest that the reader has, either consciously or unconsciously, made links between ideas or checked ideas against what they know in the way suggested in the crossword metaphor described above. This linking acts on declarative knowledge and I would tentatively suggest that it is evidence of metacognition (Kuhn, 2000).

For Kitchener (1983) epistemic cognition is about "the limits of knowing, the certainty of knowing and the criteria of knowing" (p.222). As discussed above there are relatively few instances where participants made reference to ideas *about* interconnectedness and thus, according to my analysis, there is relatively little evidence of epistemic cognition from this analysis.

5.6 Limitations of this approach

While the concept maps are beneficial because they permit the removal of chronological time from the analysis and they emphasise connections between ideas, they are also subject to

interpretation as the researcher decides what to include and what to omit during the data reduction process. However, I have taken care to make values and assumptions explicit and I have described the context and the participants in detail; further, I have included specific examples to support my reasoning (Elliott et al., 1999, in Willig, 2008). Thus I have taken reasonable measures to maximise the quality of the research reported here. Furthermore, concept maps, although quite common in research, have not been used retrospectively very often in interview studies. However, researchers in qualitative studies necessarily select and reduce data, so producing concept maps retrospectively is not substantially removed from other types of interpretative analysis.

A substantial challenge within my doctoral research has been to identify a means of exploring the 'quality' of readers' responses. In this chapter I have used the extent of interconnectedness of scientific ideas and made use of ideas about higher level cognition to differentiate between participants' responses. I also have discussed the propositions identified in interview transcriptions and whether they contain 'scientific' vocabulary. However, I have generally not examined whether what readers have said would be compatible with the views of scientists. Thus the principal concern here has been exploring the process of reasoning, rather than the outcome of the reasoning. Given the limited information contained within a news story, an authoritative statement about the 'correctness' of the content may not be possible. In Chapter 7 I will take this point further by exploring issues about indeterminacy and whether it is possible to identify the 'correctness' of claims. Thus the focus here on the process is perhaps a strength of this study as well as a limitation.

This study relies on participants accurately reporting their formal advanced education, work experience and reading habits. For example, if a participant said they knew something

already, their perspective provided the only evidence available for this. However, in the concept map analysis the evidence for knowledge of a topic is also indirect and is seen in the propositions and interconnectedness in the map, thus to some extent ameliorating the problem. A further limitation of the approach adopted here is that participants were not shown the concept map produced from their interview for practical reasons. In any future study using researcher constructed concepts maps such confirmatory discussion would be helpful.

5.7 Comparing to If…then… analysis to the concept map analysis

The If…then… analysis described in Chapter 4 uses units of data that are small, typically a phrase or a sentence, or a paragraph at most. These units of data are decontextualised and consequently the approach is subject to criticism that it is reductionist. The formation of abstract categories is useful as it allows findings from different news stories to be gathered together. As well as this being a strength it is also a weakness as the analysis does not allow the relationship of the heuristic to specific scientific fields to be identified. The findings are thus summative. If this is compared to the approach in Chapter 5 it can be seen that in the concept map the analysis stems from consideration of the whole of a response to a news story. A concept map allows the interview response for each article to be seen on a single page. This is quite different from the small units of data in the If…then… analysis. Neither the concept maps nor the If…then… analysis have a time element included.

5.8 Conclusions

In this chapter I set out to answer the research question: To what extent do readers integrate what they read about science in the media with other knowledge? The evidence and discussion above points to a range of extents of integration, with nearly all responses showing

some interconnectedness of ideas and some spoke-like characteristics. The process of making links between ideas, and checking ideas against each another, are arguably metacognitive processes, so I have suggested that the integrated concept maps include evidence of metacognition.

Moore (2011) quoted a literary studies academic who suggested that:

> … the most exciting thing is when in a sense students move sideways – where they make a connection between the text that you've given them and something else – either another text from elsewhere, or some literary concept, or their own personal experience. (p.266)

This quote offers a promising perspective on the reading and interpreting of second order sources, and emphasises making connections between the text being explored and other ideas. Further, Tytler et al. (2001) identified three dimensions of evidence: formal scientific evidence; informal evidence; and wider issues impinging on evidence. They assert that "Informal evidence, then can be seen as acting as a bridge between technical assertions and personal or practical or political understandings." (p.825). There is evidence in these concept maps of readers drawing upon informal ideas, opinion and personal experience and that these may offer the reader a foothold on the contents of the story and perhaps should not necessarily be taken as evidence of 'unscientific' thinking or reasoning.

The second research question was: Is there any relationship between the extent of integration and readers' formal education? The use of two groups, with very different background in science, offers an opportunity to identify what contribution an education in science might make to responses. Both history and science trainees, and thus those with and without formal advanced science education, have well integrated concept maps. Thus the starting hypothesis that those with more advanced education in science should show greater integration of ideas is not supported and there is not a clear picture here. The evidence, though, suggests that,

overall, science trainees' responses tended to show more integrated scientific vocabulary. The findings here demonstrate that an advanced education in science does not necessarily result in making a wide range of links, neither does the absence of such an advanced education prohibit such linking. There is also a significant variation within the groups of science and history trainees.

Separating interconnections in the concept map from use of ideas *about* interconnection allowed the exploration of evidence for epistemic cognition, or the use of 'knowledge about knowing'. There are relatively few examples of how readers make links to clusters of ideas *about* interconnectedness, such as those associated with peer review. There are, however, more examples of isolated statements *about* interconnectedness. These offer a more generalist approach to thinking about news stories. In Figure 5.7 I have summarised the main points relating to Kitchener's (1983) hierarchical model of cognition. At present 'ideas about interconnectedness', as a concept, is an underspecified area and future research could usefully be undertaken to clarify its meaning.

	Spokes	**Clusters**	**Clusters about interconnectedness**
Concept map evidence	Propositions form spoke-like gross structures such that ideas are not interconnected but isolated. Propositions are thus anchored to a concept map by only one concept.	There are multiple links between concepts which form a networked concept map. It is usually possible to identify clusters of multiply connected ideas which share a theme.	There are multiple links between concepts about interconnectedness in a networked concept map. The clusters may include peer review; knowledge of experts' ideas about the status of knowledge; functioning of wider scientific community; and process of news production.
Conclusion	Spokes may be evidence of cognition, of reading and thinking, in particular. Cognition is concerned with declarative knowledge. There is some evidence to suggest that if a topic has not been studied as part of a formal science education there is more spoke like character in the concept map.	Networked concept maps can be evidence that checking and linking has taken place. Checking and making links are tentatively identified as metacognitive strategies.	In concept maps where there are links made to clusters of ideas *about* interconnectedness, and propositions *about* interconnectedness, there may be evidence of epistemic cognition: 'knowledge about knowledge'.

Table 5.7: Summary of relationships between concept maps and Kitchener's (1983) model of cognitive processing

For Moore (2011) a tentative answer to questions about the extent to which critical thinking is domain specific is given in the idea that successful critical thinkers are able to move between disciplinary languages. The analysis presented here offers some support to this idea. Those educated in specific domains seem to be able to draw upon appropriate scientific vocabulary and integrate what they have read with other ideas. The findings here also suggest that readers without advanced education may possess language appropriate for conversing within a particular domain.

The extent to which scientific ideas can be integrated with other ideas is also a useful check for the reader on news stories' plausibility. The discussion about higher level cognition showed that there was relatively little evidence of specific metacognition or epistemic cognition and thus readers are possibly missing out on using valuable information for the purposes of quickly checking plausibility.

The value of the 'interconnectedness' idea and the crossword metaphor is that it focusses attention on the whole response rather than a small part of it, locating individual points into a wider framework of points. However, in this chapter I have not looked closely at the propositions themselves or their content. In Chapter 6, I seek to address this limitation by undertaking a thematic analysis of the second phase interviews.

CHAPTER 6: READERS' UNDERSTANDINGS OF NEWS STORIES

6.1 Introduction

The unit of analysis for Chapter 4 was the If…then… heuristic, which was summative in nature, and potentially subject to the criticism that it is reductionist. In Chapter 5 the main unit of analysis was 'whole' concept maps. This had the advantage of allowing the data to be presented on a single page. However, during this study it became apparent that both heuristics, and the extent to which concepts were integrated, offered rather too narrow a perspective, which was not able to capture the depth of readers' engagement with the text. Thus, in this chapter the focus is broader, and on readers' *understandings.* The title of this chapter and the thesis as a whole deliberately emphasises understandings, in the plural, because it will be seen that there are range of ways of understanding the news texts. These understandings include references to truth, certainty and veracity, but this is not the only way readers look at these texts. In this chapter I will explore the themes that emerged and the relationships between these themes, and also any relationships between the content of the themes and the subject of readers' formal advanced education.

6.2 Approach to analysis and examples

In Chapter 6 I explore themes that come from the second round of interviews. I used constant comparative approaches to analyse interview transcripts; ideas within the interview transcripts were compared with ideas within the same transcript and within other transcripts. The eight interview transcripts were read through several times and a number of temporary constructs were established and explored with a range of data. The transcript data was tagged with codes for these temporary constructs, with tags serving as an indexing system which could be searched, using computer software (Adobe Acrobat Pro 9), to facilitate comparison. The

identification of themes within the interview was an evolutionary, iterative process involving the adjustment of theme descriptions and then retesting them with new material from the transcripts. They were gradually refined until two main themes were identified: *loci of knowing* and *knowledge focus*.

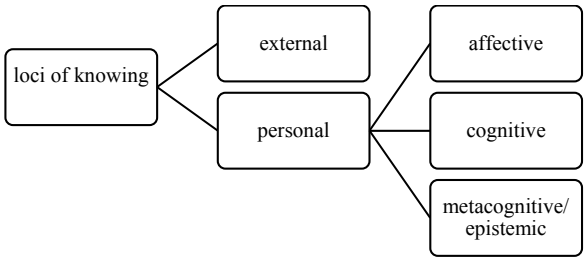


Figure 6.1**:** Network map showing the emergent themes for *loci of knowing,* and the relationships between them.

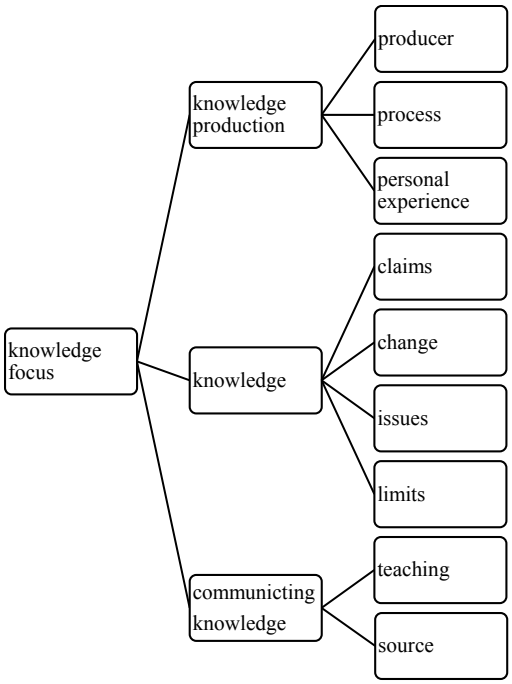


Figure 6.2**:** Network map showing the emergent themes for *knowledge focus*, and relationships between them.

Various methods for mapping the themes were attempted but two network maps best accounted for the themes and sub-themes (Figure 6.1 and 6.2). For each participant network

maps, using the themes identified in Figures 6.1 and 6.2, were produced with quotations to illustrate each theme. An example pair of networked maps for Sheila is reproduced below (Figures 6.3 and 6.4). I also wrote a commentary for each participant in which I have tried to give an overview of the interview in the light of the themes. A full set of commentaries is offered below. A full set of network maps, with associated example quotes, is given in the Appendix IX. The content of each theme is exemplified later in this chapter.

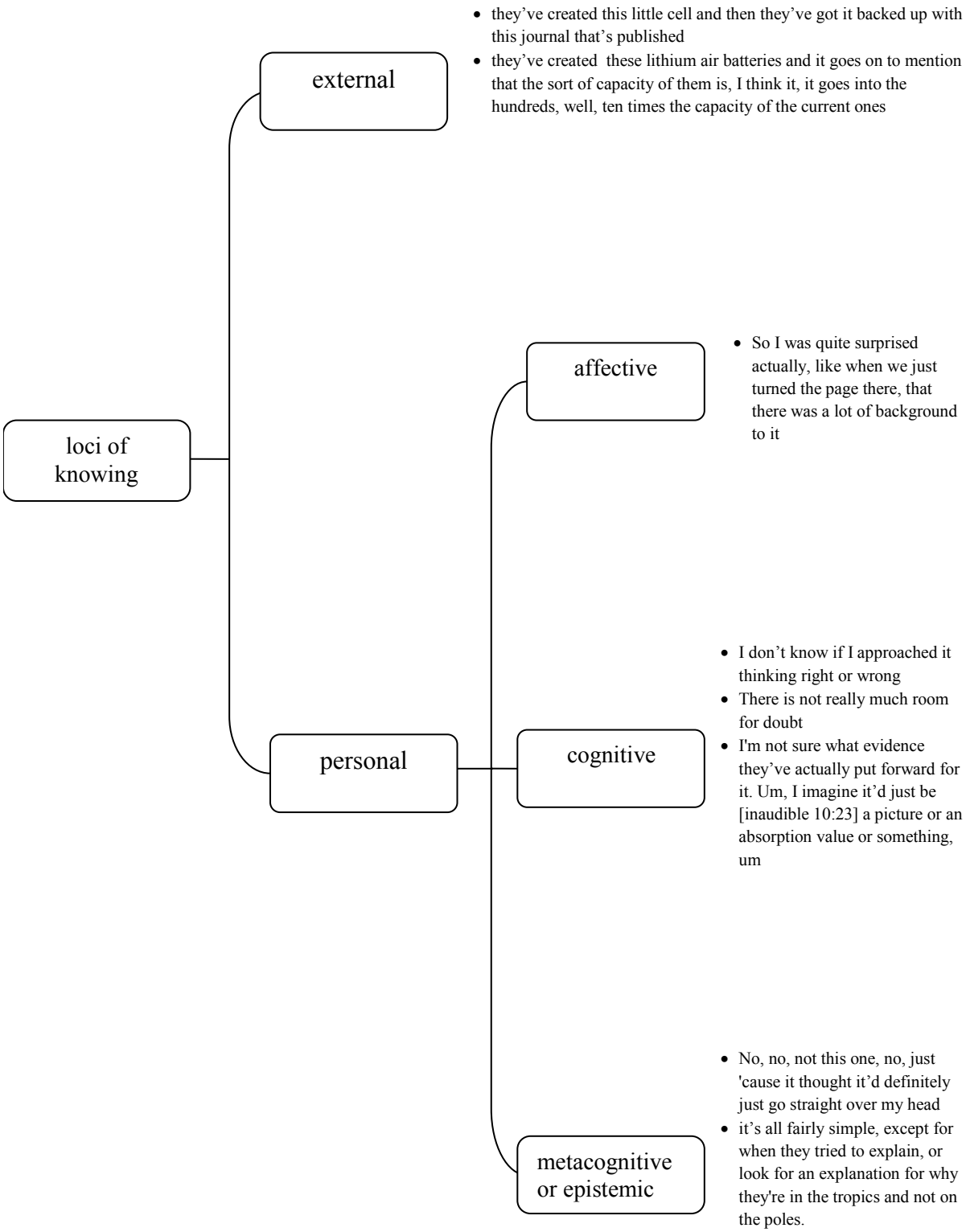


Figure 6.3: Network diagram for Sheila: *Loci of knowing*

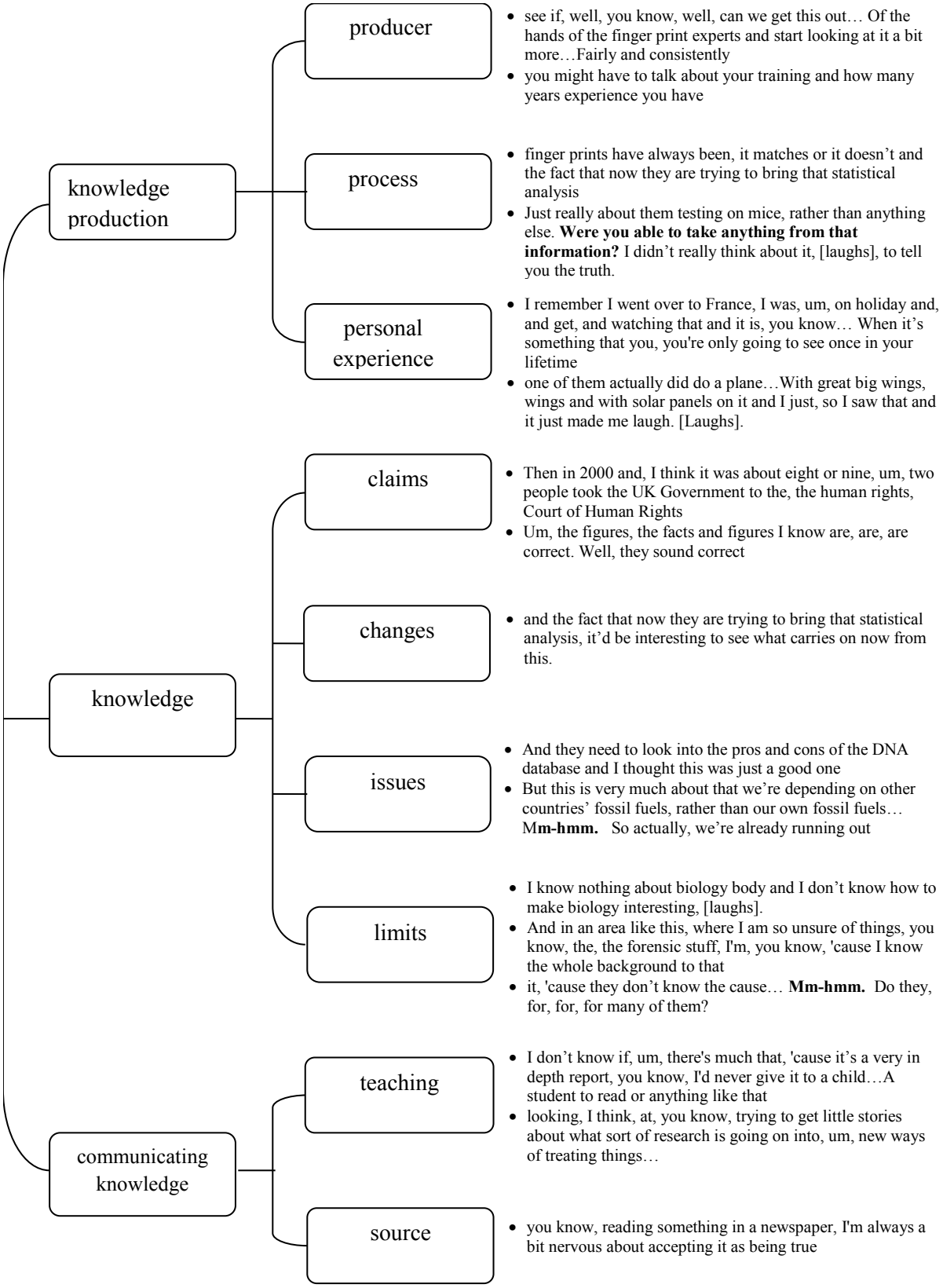


Figure 6.4: Network diagram for Sheila: *Knowledge focus*

6.2.1 Commentaries for each participant

Sheila (Chemistry)

In the early part of the interview there was a rich discussion of the limitations of evidence in fingerprint and DNA analysis. There was very little evidence associated with the *external* theme; neither was there very much associated with *change* or *metacognition/ epistemic* thinking. Sheila identified issues and showed an awareness of both sides of arguments. She raised matters associated with the processes of *knowledge production* and *producers* of knowledge. The context of teaching played an important part in the conversation and Sheila drew upon her personal experience. There was one reference to newspapers as a source of communicated knowledge.

Lee (Physics)

In Lee's responses he draws upon a view of science as evolving and changing over time. He seems to enjoy talking about developments and new ideas. He had a reluctance to reject claims too quickly and a willingness to accept the content of the articles. This is not to say that he simply accepted what he had read. Instead he compared what he read to other knowledge and was sceptical of motives. Lee had an awareness of possible interests and raised the possibility of the motivations of an article author. At times Lee drew upon the external perspective in his conversation.

Joseph (Physics)

Joseph demonstrated *metacognition/epistemic* thinking as he talked about the process of science and how the process has been misrepresented within news stories. He made very limited use of the *external loci of knowing*, the one occurrence I identified resulted from specific prompting during the interview. There is also very little, if any, data that has been

tagged with *producer, personal experience* or *issues.* In Joseph's responses there was a balance between *affective*, *cognitive* and *metacognitive/epistemic* thinking. He spoke on at least two occasions about how the description in the articles did not match with how science occurred in genuine contexts. There was some mention of scientific claims. Overall much of the interview focussed on the *limits* and *process* themes.

Simon (Chemistry)

In his responses Simon drew upon the external perspective. He did not seem to demonstrate metacognitive or epistemic thinking, with much of the evidence in loci of knowing being theme being *affective* or *cognitive*. Simon made some reference to the *process* of scientific knowledge production but made no identifiable reference to knowledge producers. His concern was not with changes to scientific knowledge but he made reference to the *limits* of both personal and public knowledge. The sources of information are examined. Simon did not really draw upon personal experience.

Becky (Chemistry)

In her responses Becky included comments in both *external* and *personal loci of knowing*. Becky spoke at length about the limitations of scientific methods, thus demonstrating evidence in both *metacognitive/epistemi*c and *process* themes. These comments were quite closely linked to the contents of her undergraduate final year project. There are a range of responses in all of the *knowledge* themes with the exception of the *changes* theme. Reference to teaching received only moderate attention during the interview and *personal experience* did not feature in the themes.

Alex (History)

Alex, in his interview, was interested in things that effect his life and the lives of others. His responses fell within the *external*, *affective* and *cognitive loci of knowing*. His responses did not fall into the *metacognitive/epistemic* theme. Within the *knowledge* network map there is a wide range of quotes that have been included. The perspective taken on the articles is more political and social than scientific with references to gender stereotypes and political will. Personal experience did not feature in the identified themes.

Nick (History)

Nick demonstrated cognitive involvement in reading the story by asking questions about what had been read and challenging conclusions that are raised in the article. There is limited focus on the process of public knowledge production and this was limited to the article about bees. There was also limited attention paid to knowledge producers. Personal experience was drawn upon during the conversation. Facts were identified from the news story and used in the discussion, furthermore on several occasions the participant stated their opinion. Issues were raised and there was evidence of discussion of the limits of knowledge (personal and public). Nick did not make use of the *metacognitive/epistemic* theme, neither did he make reference to how knowledge was communicated.

Katie (History)

Katie made use of the full range of sub-themes in the *loci of knowing* theme, although the *affective* and *cognitive* were more frequent. She did not mention teaching during the interview but did talk about the source of knowledge and the article or article publisher. Limitations of public and private knowledge played a large part in the interview data. In places she adopted a political perspective and framed the articles in this way.

6.3 First main theme: Loci of knowing

Kahneman and Tversky (1982) distinguish between external uncertainty and internal uncertainty, where the former is the absence of public knowledge and the latter refers to personal ignorance. Here, I draw upon an external/internal distinction but use it in a wider sense and not only about uncertain knowledge. In the *external* sub-theme, the focus is on what other people or groups know, or claim to know, and can be identified by expressions such as "they know" and "it is known". In this category the loci of knowing is located outside of the reader and could be based on something stated in the article, by the researcher or in the original journal article on which the news article was based. In Table 6.1 below I have given the statements and questions which helped to inform the coding in this section.

	Cognition	**Metacognition**	**Epistemic cognition**
External perspective	• It is know that	• What is known? • How is it known?	• What is known about knowing? • How does one come to know?
Internal / Personal perspective	• I know that	• What do I know? • How do I know it?	• What I know about knowing • What do I know of what I know? • What do I know of my ignorance? • What do I know about interconnectedness?

Table 6.1: Internal and external perspectives on knowledge

External

Lee uses an external perspective to describe a key point found in the article and to put a response in context:

> they've created this little cell and then they've got it backed up with this journal that's published on that site PLOS One, so yeah, just the fact that it's backed up by… **Mm-hmm.** Something that's been published… (Lee, p.3)

In a further example Lee builds on an external loci of knowledge and reads between the lines, adding his own ideas to the points restated from the article:

> So, well, it says they've used the Cassini space craft that's orbiting Saturn, near infra-red pictures that actually show the lakes and then they've gradually narrowed it down to where they actually are on the surface, um, so in terms of the methods, they've used fairly… **Mm-hmm.** Sort of seems fairly anyway, um, [inaudible 12:32] just like here's a weird picture, look a bit closer at it… **Mm-hmm.** As with any, like almost any experiment, you find an anomaly or something, you go closer and… (Lee, p.8)

In common with the first quote above, the use of the voice of another person or source with associated arguments or opinion are present in both science and history trainees responses:

> I can't remember if there's a date in here somewhere but, um, no-one's really ever been able to explain it… (Simon, p.1)

> they make announcements, like they say at the bottom here that, um, it's committing nations to restoring like, you know, so many hectares of forests by a certain date and it's like I don't know whether I can believe that… (Alex, p.3)

The presence of the voice of others could potentially be associated with a simple restatement of part of an article, however, I was not able to identify evidence of such restatement in the responses of either group of participants. In the examples above the reader has used the voice of another for a purpose. For example, in the quote above, Lee (p.8) links what he has read to a more general views of experiments. Alex follows his *external* statement with an opinion.

Affect

A *personal* or *internal loci of knowing* was also found in the responses of both groups. A *personal* knowing theme emerged where the focus is on the individual participant and how

they have processed information and their thinking about what they have read or been asked. Within this theme are three sub-themes. The *affective* is when the response from the interviewee is associated with an emotion or feeling:

> Err, well, it's, it was interesting, it's stuff that I hadn't, it's a new development that I hadn't really heard of before. (Becky, p.1)

> It, it's not my field, it's not…**Yeah.** It's not something I'm really that interested about, to be honest. (Becky, p.8)

Interest here is taken to be a feeling. The second quote here is somewhat surprising as one of the reasons for adjusting the methodology of the second round of data collection was to overcome the potential problems with motivation to read the news stories in the first round by allowing participants to select articles of their choice.

There were not always reasons associated with interest in news stories but in some cases these were given. A thread through Alex's response was an interest in things that could effect his life:

> And how, with science reports, I'm always interested in things that are like impacting on my life and like… **Mm-hmm.** What can we do differently to change them, um, 'cause often with things like this, it's, we hear a lot of talk but not a lot of action, so that's what drew me to this report and, um, sort of said, you know, well, it's, again, it's, this report is sort of showing that, you know, again, clear evidence of like they're talking about it but they're not actually doing anything about it… **Mm-hmm.** And that's why I sort of was interested in reading it, to see if it actually came up with any action… (p.1)

While interest is probably the main emotion associated with reading the news stories for both history and science trainee teachers there was other occurrences within the theme of *affect*. An example is surprise*:*

> So I was quite surprised actually, like when we just turned the page there, that there was a lot of background to it… **Right.** But I suppose it's because it's a relatively new but still quite big idea… (Lee, p.15)

With the responses, not all references to emotion were associated with scientific ideas. Sheila explained:

> It did make me laugh, about the live webcast crashed. [Laughs]. I thought, well, it sounds about right, [laughs], you know, anything like this, that they never seem to be able to gauge the amount of interest in it and… **[Chuckles].** And whenever they do live casts, webcasts or anything like this, it does tend to crash, doesn't it? (p.15)

This is perhaps not surprising given that any reading of science news stories takes place within a wider context that includes the means of communication.

On a small number of occasions, readers demonstrated somewhat stronger feelings. Nick had selected an article about nuclear power:

> I really do feel quite strongly about that, um, because I, I can see accidents happening, you know, I think, I, I do, I do think that they will happen, um, [tuts], and I, I just don't think with, um, with other viable alternatives, um, that they're not necessarily as popular but, but still very viable, very safe, um, such as wind energy, such as, you know, offshore, offshore, um, windmills… **So how, when you were reading the text, I, I got a sense that you'd have felt quite strongly about what you were reading.** I just feel that it's the wrong way to go, just feel it's the wrong way to go… (p.8)

Some of the articles in this study are associated with SSIs. Nick's article described above is about whether more nuclear power stations should be built. Becky selected an article about GM crops and Alex read an article about deforestation. In the interpretation of this theme, I would agree with Sadler and Zeidler (2005) who point out that while it might be possible to identify the affective it is closely linked to the approach readers take and thus cannot be isolated from the other aspects of a response. It might be expected that there would be stronger emotions associated with SSI than other scientific areas that do not have an obvious

social or political element. Other than relying on readers' self-reported emotions and my ability as an interviewer to identify emotions, the current research strategy does not permit feelings to be identified readily so it is not possible to offer strong support for a hypothesis that SSI would be expected to be associated with stronger feelings.

Within the responses, however, there is some difference between individual participants' responses. Alex and Lee, in particular, use stronger language than was generally found e.g. "that would be brilliant" (Alex, p.7) and "it was pretty cool" (Lee, p.9), however, it is not clear whether this language use is necessarily associated with stronger emotion.

"I think…"/Cognition

The second sub-theme is within a *personal loci of knowing* and using participants' words can be labelled: "I think…". Readers commonly gave an opinion on something or stated an outcome of their thinking. Included here are statements which begin with things like "I like", "I believe", "I think", "I know that", "I see", "I wasn't sure" and "I suppose". The locus here is with the knower: what the knower thinks, reasons or says. Included in this category are verbal manifestations of the processes of reading, remembering, agreeing, storytelling and so on. These manifestations of cognition may include an argument, a decision or a question. This theme also includes when participants talk about something that they have done or seen. The verbalisations during the interview are evidence of some cognition having taken place. Perhaps not surprisingly all readers demonstrated the kind of cognition described above.

Lee, when talking about the article about glucose fuel cells, appears to be remembering part of the article content when he says "I think it… mentions it somewhere" (p.1) and later in the quote expresses doubt about whether prosthetic limbs have batteries:

> As a computer in a mind, it's probably to do with like powering limbs and stuff for, um… **Yeah, yeah, yeah.** Yeah. **And does it actually say that there?** I think it, yeah, I think it mentions it somewhere, um, yeah, so prosthetic limbs and, 'cause I suppose that's one of the problems is if you've got this mechanical thing, you've got, if you changed, well, I don't know if they have batteries per se, but you know… (p.1)

Thus recalling what has been read previously is obviously an essential part of responding to a news story and was seen across all participants.

Further, readers referred back to their previous studies:

> Err, well, err, I know from my degree that they are searching for dark matter… (Joseph, p.7)

> Oh definitely, yeah, like the factual evidence here about, like the positives of having a forest and the fact that they trap the carbon, it doesn't allow it to be released into the, um, atmosphere. Through studying geography, I, I know that's [inaudible 03:29]… (Alex, p.3)

This deliberately broad theme includes "I believe…" and "I know…" type statements. It is not possible to distinguish between them because the precise meanings of these are relative and do not refer to different ways of thinking (Smith, 1992). I agree with Smith who points out that these words are "simply statements about states of affairs, not descriptions of different brain states and processes or different forms of understanding" (1992, p.99).

At times readers articulated what seemed to be evidence of 'cognition about cognition'. As raised in Chapter 5 above, Kitchener (1983) defines metacognition as about the use and monitoring of strategies. At one level an awareness of the sort of 'internal uncertainty' described by Kahneman and Tversky (1982) could be considered a metacognitive monitoring strategy:

> **Mm-hmm, mm-hmm and, um, you, you know, is, how willing were you to accept what you've read there?** Err, quite willing… [Inaudible 11:02], mm-hmm. Because I, I

> didn't know anything about it at all. **So yeah, I mean…** So it, it, as long as it doesn't say something really crazy… **You'd think it was true?** Yeah, just because I, I don't have any previous knowledge about space crafts, so… (Becky, p.7)

Here Becky expressed her lack of knowledge of the topic. However, elsewhere the usefulness of this kind of self-assessment has been shown to be quite unreliable, including how well readers have understood recently read material (Dunning et al., 2004). Similarly, it can be argued that the "I think…" type statements described above might be evidence of some metacognition, including possibly checking against previous learning. The above argument about the limitations of self-monitoring are still valid in this context, however.

Epistemic

Kitchener (1983) suggest that epistemic cognition includes limits of knowing, certainty of knowing and criteria of knowing, in other words 'knowing about knowing'. The evidence from the thematic analysis here concurs with the findings discussed in section 5.5.2. There is very limited evidence from the interviews that readers engage in such thinking. Joseph, in his response to an article about supervolcanoes said:

> And the, the, the author's managed to present it in such a way that it, it kind of supersedes all the previous work and… **Right, okay.** You know, this clearly shows that, um, that it's this way and not, not how it was thought of before… **Mm-hmm, mm-hmm.** And there was no kind of, um, you know, it doesn't happen like that in science, in the kind of scientific community… **Mm-hmm.** And there was no, um, none of that process in the article at all, if that makes sense. (Joseph, p.1)

Here was an unusual statement where he examines *how* the article presented the scientific idea. Rather than focussing on the ideas themselves, he focuses on the processes of science. Elsewhere in the interview Joseph comes back to this point:

> Err, well, actually, I thought it was, it was a really good article, um, you know. Previous, when they're talking about super volcanoes, they don't focus much on, err, you know,

> this is the, um, err, they're not presenting the, way they presented the research is kind of as the truth, err, even though they probably didn't mean it, it's just the way they focussed on it. **Mm-hmm.** Here, it was very much a kind of, um, you know, this, err, this study means that textures are however many per cent unlikely to exist, err, which I thought was much closer to the, the actual science… (p.10)

He shows an awareness of limitations of science here by talking about likelihood of veracity of scientific ideas in terms of percentages.

There is also some evidence of epistemic cognition in the interview with Sheila. Having worked in a forensic science context, Sheila raised the Fingerprint Enquiry and spoke about how in court DNA evidence is always couched in terms of statistical likelihood, however, when fingerprint evidence is given in court a fingerprint expert states simply whether it is a match or not. Sheila, thus, shows an awareness of the limitations of scientific evidence.

In her interview, Becky raises two points that I would consider to be evidence of some sort of epistemic thinking:

> So it doesn't say anything more about milk. They've only done it on mice. Um, they've said IBS is affecting more people, but then that could be just due to if you're looking for it, you're more likely to find it, so I wouldn't say that IBS is, IBDS has increased. You could just, I mean, if you do research, you're more likely to find it than if you don't do research. It could be undiagnosed in people, so I wouldn't, to be honest, I'd take that with a pinch of salt because there's, it doesn't tell you how they found out. (p.6)

> So it looks like it's quite early on to just, 'cause they're basing their conclusions just on mice. **And you, you're kind of implying that that's an issue**. Well, we're, we're nothing like mice… (p.8)

The first quote makes the point that doing research is more likely to lead to findings than not doing research and the second is the idea that the study must be in its early stages because the trials are currently on mice.

The sort of ideas raised by Joseph, Sheila and Becky share features with 'ideas-about-science' (Millar, 2006; Osborne et al., 2003; Jarman and McClune, 2007) which try to summarise, for pedagogic purposes, what science is like and how it operates. In the context of scientific literacy these idea have been seen to be necessary to understand science as it appears in the media. The responses above seem to be more than the application of declarative statements about science.

In Chapter 5 I suggested that readers made links between ideas and that this was evidence of the metacognitive processes of linking and checking. Further I suggested that in their analysis there was relatively little evidence of epistemic cognition, in the form of networked ideas about interconnectedness, and that this was the case for both science and history trainees. The more open approach used in this section gave some other examples of higher level cognition as defined in this study.

6.4 Second main theme: Knowledge focus

In this section attention shifts to knowledge itself rather than the 'location' of the knowledge attributed by the participant. Within this broad theme there are three sub-themes: knowledge *production*; *knowledge* and *communicating knowledge*.

6.4.1 Knowledge production

Producer

In their responses some readers referred to the people or organisations that are *producers* of scientific knowledge, this is distinct from those who are reporting the original research. Readers sometimes focus on the researchers, in this quote Lee talks about collaboration between research groups:

> Yeah, there's one in Spain and it says China and then I think America as well… **Mm-hmm.** Um, yeah, so quite a few people have, I imagine they collaborate at some point, um, and it'll be known to them that these other people are going on and doing it a different way… **Mm-hmm, mm-hmm, mm-hmm.** But they all seem to come out with the same ending, but… (Lee, p.18)

A similar response comes from Nick, a history trainee teacher:

> [Pauses]... Um, yeah, the, the fact that, um, some of the world's best scientific minds are on this… **Mm-hmm.** Which is, which is, yeah, which, which is great. Obviously, you know, St Andrews, very good, um, for medical research and, err, Stamford University working together, so yeah. (Nick, p.17).

These quotes suggest that readers have an appreciation of science as being an enterprise which does not depend on single studies or single researchers; it also offers the reader some confirmation of the findings in that there is corroboration from more than one research or research group. However, many of these ideas were present in the story text and so they did not emerge spontaneously. Becky, however, independently noticed the absence of collaboration:

> It could be, well, it, it, at the moment, it says it's just been, well, it looks like it's just been done by one study, not a lot of other… **Mm-hmm, mm-hmm.** It hasn't been tested by a lot of other people, so they've only actually looked on, looked at what one person has said about it or one company. (p.2)

Few of the responses to individual articles include such ideas. Becky and Lee, both scientists, raise the issue of bias. Becky suggests that someone might be selling a material.

Some years ago Norris (1995a) drew on the work of Hardwig to build the argument that "the object of [students] scepticism should be the believability of experts, not the evidence supporting scientific claims." (p.216). He suggested that independence from scientists was impossible and that trust is necessary. It is perhaps surprising that there is not more reference

made to the expertise of those who originally produced the knowledge that is being reported. This may be because in many of the articles this information is not prioritised.

Producer, here, is used in a broad sense and has the potential to be applied to scientific knowledge or other kinds of knowledge. Alex referred to a UN report and suggested that this was a reliable source. This conception of 'producer' is preferable to using 'researcher' because it implies a broader view of what knowledge is and thus includes those who do research, but also bodies such as the UN or universities. It is interesting to note that all participants included ideas in this category except for Joseph and Simon, both scientists. In Chapter 4 I reported the heuristics "If research is conducted by scientists or is published then decrease epistemic distance". There is further evidence of this heuristic here, but there is also references to bias and doubts about the producers of knowledge, something which increases epistemic distance.

Process

It was quite common for readers to refer to the processes by which scientific knowledge is produced – the focus in this theme is not on the person or organisation themselves but on equipment, apparatus, what people *do* in science, evidence and methods of science. It also includes reference to peer review processes, for example.

In some cases the processes of science cannot really be considered separately from the producers. For example, Sheila, when talking about fingerprint evidence, explains that computer software was developed:

> I think they managed to sell it to America, um, because America have seen so many issues now with this that they're more inclined to look at it in a bit more depth and see if, well, you know, well, can we get this out…Of the hands of the finger print experts and start looking at it a bit more… fairly and consistently." (Sheila p.7)

The producer of knowledge here is the fingerprint expert. The reader also mentions the wider American context and computer software, implying a concern for how the fingerprint evidence is framed and its status. The concern for this stemmed from Sheila's previous career and so she had substantial background knowledge on the topic. Her use of language shows advanced understanding of the issue around fingerprints:

> …the misidentifications, exposed weaknesses and methodology of fingerprint comparison and in particular, where it involves complex marks (p.5)

Lee also draws upon ideas of the processes of science. He builds on a reference in the news story about Titan and the evidence that came from the Cassini spacecraft:

> Like I'm not, I'm not sure what evidence they've actually put forward for it. Um, I imagine it'd just be [inaudible 10:23] a picture or an absorption value or something, um (p.7)

> As with any, like almost any experiment, you find an anomaly or something, you go closer and… **Mm-hmm.** And shorten the range around it… **Mm-hmm.** Which I'm sure is like similar to what they did but just using photography instead of some other measurements… (p.8)

Lee reads between the lines here and speculates about how evidence emerged that Saturn's moons had methane at the poles. Further he draws upon vocabulary such as absorption value and anomaly, which may not be available to all readers. Lee completed one year of a Physics with Astronomy degree, before shifting focus within Physics in his second year to biophysics. Thus he has significant background in the field of astronomy.

Similarly Joseph selected an article on dark matter which was related to the content of his degree:

> Err, well, err, I know from my degree that they are searching for dark matter… **Mm-hmm.** And there's, there's, you know, there's a lot of technology being invested in it

> and, err, I know a few bits and bobs about the, you know, the processes and how they might start to try and detect dark matter… **Mm-hmm.** Um, and it fitted in that quite nicely but it didn't say much about that… (p.7)

Zimmerman et al. (1998) claim information about the suitability of research methods is important for judgements about credibility research findings. Although this primacy of methodology is contested elsewhere (Norris, 1995a), Norris does concede that methods of science offer some additional potential to evaluate science (1995a). When talking about a news story about forests, Alex explains that "…there was no evidence of how they collected the data, so you don't know how reliable it is…" (p.5) and thus makes a link between method and evaluation of science. Therefore, there is some evidence that those without advanced science qualification see the significance of methodology. The limited information on scientific methods found in the news story seems to be similar to that found in Mallow's review of news stories (1991).

In one case it was interest in the process of development of a new technology that led the reader to select the article:

> But I was just interested in this in terms of the science of it, in actually, well, how can they actually create something like this, it sort of, sort of drew me into the article that way… (Alex, p.10)

However, as the article here was about a Microsoft Tablet, the link to science is perhaps weaker.

Nick in his response to a news story about sharks spoke at length about the limitations of the evidence that had been presented in the news story:

> Well, that's the, yeah, that, that's the, that's the only method they've done really is with, err, with data logging tags, um, and from that, they've, they've made… [pauses]... like a couple of different assumptions. (p.20)

Although he did not study science after his GCSEs his response included a detailed argument about the speed of the sharks and how that data was collected. He demonstrated scepticism about the research findings based on this argument.

Nick, in his response to an article about stem cells raises an inherent ethical issue:

> I don't know a lot about stem cells and how they're produced, um, but I know that they, um, that, you know, the, the, the, one of the popular arguments is about, um, whether you are, err, producing a life in order to produce the stem cells for the research, um, [tuts], so there's a whole ethical argument there of… (p.16)

Thus the ethical issues present in the process of 'doing' science is identified and raised as problematic. Overall, there were few references to ethical issues.

I would argue that the theme of *process* would cover references to peer review, which can be viewed as both important and necessary within the production of scientific knowledge and a point which emerged from the Osborne et al. (2003) Delphi study of experts views about what "ideas-about-science" should be taught in school science. I was not able to identify any specific references to the peer review process, although there were indirect references about the work being published in a journal.

All readers made reference to the process of science knowledge production, and placed a greater emphasis on it than on the producers of that knowledge, thus the evidence here suggests that an advanced education in science does not lead to more references to the process of knowledge production. In Chapter 4 I raised doubts about the potential of methodology to give the reader leverage to increase epistemic distance appropriately. The category *process* has the advantage of including social aspects, such as peer review, and therefore thinking in this category is likely to offer richer insights than by considering specific methodological aspects, such as sample size, alone.

Personal experience

I have previously mentioned personal experience in section 5.5.2. *Personal experience* is a source of knowledge in itself and thus it comes within the overarching theme of knowledge production. The knowledge is of a different status to the public knowledge identified in the categories *producer* and *process* as it is within the personal realm and not been subject to public scrutiny. Readers in their responses to news stories sometimes drew upon their personal experiences, but to different extents. Lee, Joseph and Becky made very limited use of personal experience in their responses. Sheila compared her experiences of seeing an eclipse in France to the transit of Venus, suggesting that both were a 'once in your lifetime' event (p.13). She also was prompted to select an article about a solar aeroplane because it reminded her of work completed by a student while on school placement. In neither of these references to personal experience was there any hint that the status of this knowledge might be comparable to public knowledge. However Simon, when discussing the article about warm water freezing suggested that he would want to experiment himself in order to test the truth of a claim, indicating personal experience having a significant status for him.

Nick draws on his personal experiences of password breaches, his father-in-laws heart attack and how he watches Frozen Planet programmes. These three things are reasons for being interested in the particular news stories that he selected. Alex explains his familiarity with the American patterns of eating, however, it should be noted that this was the only such references he makes. Katie drew on her experiences of school and university, partly because the article she had selected contained vocabulary that she had encountered during her time at school.

Although both science and history trainee teachers drew upon personal experience in these directed conversations, it was mainly drawn upon to illustrate their interest or motivation. It was not used as a means of evaluating the scientific ideas contained within the news story, however as discussed in Chapter 5, making links to ideas does serve the purpose of checking and linking. Personal experiences were also absent from Kolstø et al's (2006) list of criteria used by education students to evaluate the reliability of news stories. However, Kolstø et al.'s finding is somewhat at odds with the findings discussed in Chapter 4 where a number of readers use specific experiences to support their arguments. One possible explanation for the discrepancies with my study is the methodology adopted. In the first set of interviews, readers made and justified a decision about the likelihood of veracity of knowledge claims but in the second, a decision was not necessary. Perhaps readers in the first round were searching for a reason and personal experience is a source of such justification.

6.4.2 Knowledge

Claims

Claims are statements which might also be considered statements of 'fact'. For example, one participant quoted statistics from an article about the weight of humanity being 287 million tonnes (Alex, Marshall, 2012). The propositions found to be 'spokes' on the concept maps in Chapter 5 are very similar, but have been identified in a different way. The claims may be present in the article and restated by the participant but they can also be made by the participant. An example of a claim made by a participant is the "idea of combining someone with a computer… wouldn't need to bother with any sort of hard work." (Lee, p.1). This theme includes when participants state their own opinion, state the opinion of others or make a claim about actions undertaken e.g. "I've just taught this". The theme does not include questions about scientific knowledge.

Previous research into news stories has focused on the evaluations of certainty of knowledge claims (Kolstø, 2001; Norris and Phillips, 1994; Phillips and Norris, 1999). Kolstø, for example found that readers either accepted or evaluated claims using 'reliability indicators'. In the first phase of this study, during the interview, participants were asked to make a judgement about the likelihood of veracity of the headline knowledge claim. However, it was found that the headline claim was not necessarily representative of the content of the news story and that within the news story there were also many other claims. Thus, this suggests that the claims as a subject of analysis have a somewhat limited usefulness.

Neilsen (2012), drawing upon examples from the field of human gene therapy has explored how scientific ideas are *used* in arguments. He suggests that when talking about SSIs scientific ideas are used by speakers to frame discussion and to benefit the speaker. In their responses, readers in the present study made scientific or scientific sounding claims. Some of these were taken from the news story and others were made specifically by the reader. For example, as Lee spoke about the glucose fuel cell he said "I know that it's, [chuckles], ridiculously hard to think about combining them with anything rather than a person…" (p.2). Thus here he is making a claim that is not present in the news story. Later he states that the lakes found by scientists on Titan are methane, a claim taken from the news story. These two kinds of claim are found throughout the data. What is interesting is the use to which these different kinds of claim are put. In the case of the fuel cell example above Lee thought that it sounded "pretty cool". For the Titan claim, Lee linked that Titan had lakes of methane to the search for life, again something which had stimulated interest. What is different here, however, compared to Neilsen's context is that gene therapy is one which is contentious and which divides opinion. Lee is talking about things that have neither that emotional nor social weight.

Taken together, this discussion about claims highlights that readers use claims in different ways, and also generate their own. The restatement of claims from a news story should not necessarily be seen as a low-level strategy. The reader may use the scientific ideas for a reason, also the process of selecting a particular claims from a wide range of others suggests that this can be a higher level process than simply restating what is in the news story. Claims can potentially fall into the two broad categories of internal and external described above and thus the category here can co-exist with the category for 'loci of knowledge'.

Changes

The sub-theme *changes* includes comments about how public or private knowledge has changed or is changing over time. Again the notion of knowledge used here is broad. There was no evidence found in this category for Becky, Nick and Simon, and therefore for both science and history participants. Within this theme I identified quotes where readers showed an awareness of how scientific knowledge had changed over time:

> They have a pretty good idea of what Titan looked like and then suddenly they find these lakes. (Lee, p.8)

This is an example of an awareness of changing scientific ideas.

The idea of change being significant when reading news stories echoes with the exploration of the nature of science in Chapter 2. That scientific knowledge is subject to change is a similar to thinking of science as tentative (Abd-el-Khalick et al., 1998) and the hypothetico-deductive model.

Issue

An *issue,* for my purposes here, is when something is disputed or whether there is more than one perspective on the matter. It may or may not be resolvable. For example an issue is

drawn from "it started [me] thinking about whether, um, methane could sustain life instead of water…". (Lee, p.5). So this issue is whether methane can sustain life. Another example of an issue is where Alex (p.7) raises the point that it is newsworthy that a woman is going to space. In this case the participant is 'taking issue' with the status quo. An issue might be identified by a question, but a question is not necessarily an issue. For example, the question "How can a company take people to space?" (Alex, p.7) is more about a general absence of knowledge than an issue with two sides. The category of *issues* can co-exist with the *claims* category. Sheila (p.6), for example, makes assertions about fingerprints and DNA which are associated with an issue.

It was possible to identify issues for five participants, but not Simon and Joseph, who are both scientists. It is possible that history participants are more used to dealing with issues on which people disagree compared to science participants, who have a lot of experience in science where there is considerable consensus. It is interesting that Christensen (2009) found, in a study of contested science, that in matters on which reasonable people disagree, students were not prepared by their formal education to make appropriate responses.

Limits

The theme *limits* is about what is known and what is held to be true or correct, it also extends beyond what is known to what is not known. It includes things like "I don't know whether I believe" and "I am not sure". The data units identified here could also potentially be categorised in the 'loci of knowing' category. All participants in the second phase of the interviews mentioned things in this category.

Participants made specific reference to phenomena, Joseph, for example, stated "this study means that textures are however many percent unlikely to exist" (p.11). Participants also

talked in a more epistemological way, for example, Sheila stated that "just seeing is believing and all that sort of stuff" (p.20), which is noteworthy because it is *about* limits of knowledge rather than actually the content of those limits. Further, Joseph explained that an article does "mention the fact that, err, you know research isn't 100% accurate" (p.2) and that the same article does not indicate how conclusive the finding was (p.4). As originally mentioned in Chapter 5, there was relatively little evidence of readers raising ideas *about* knowledge.

Within the data there is some evidence to suggest that readers, particularly those with science backgrounds, do not "really approach is thinking right or not" (Lee, p.3). Similarly, Sheila found that an article was interesting but did not think in terms of whether she believed it or not (p.10). Katie, a history trainee, stated:

> "It's a little bit more open to opinion, whereas that, I found all I could really say was, oh yes, it's kind of interesting." (p.13)

In a range of responses, some stated that they did not think in terms of true/untrue, however, some stated that they did not really challenge or question conclusions. For example, Katie "took the conclusion at face value" (p.6) and was able to "take it as read" (Lee, p.8). This is consistent with findings by Dodds et al. (2008) in the context of advertisements and Kolstø (2001) in the context of news stories. A possible explanation of this is that the participants did not have sufficient knowledge to challenge the claims, an idea that was backed up by participants' explicit responses (Lee, p.4; Becky, p.10).

As mentioned in Chapter 2, work by Norris and Phillips (1994) and Norris et al. (2003) found evidence for a certainty bias where university and secondary age students tended to misjudge the reported truth of claims. Norris and Phillips (2003) found that students found it difficult to make sense of situations with ambiguity and were better able to understand the binary

positions of true/false. There was not significant evidence to support these two findings in the present study.

Kuhn (2007), in her study at a railway station, found that people who did not have a college education will say, something, anything, rather than deliberating; whereas those with a college education were more willing to hold off on judgements. Similarly, in the data reported here there is a lot of evidence of a tentative attitude and an unwillingness to directly reject claims. Since science knowledge is understood to be tentative in nature, it might be expected that those with a first degree in science would have a better understanding of this, however, I was not able to identify any significant difference between the two groups within this theme. All readers in this study were graduates and overall there was found to be a reluctance to quickly dismiss knowledge claims.

Hofer (2000) who found that first year science college students had a different perspective of knowledge compared to psychology students: science students saw knowledge as more certain. Such a difference did not emerge strongly in the data. However, it was reported in Chapter 4 that history trainees seemed to be more willing to accept what they read on the basis of the reported methodology.

A further sub-category of responses includes what could be considered a quick check on plausibility. For example participants say things like "sounds alright" (Becky, p.2) or "nothing outlandish" (Lee, p.12) and similar (Lee, p.23; Joseph, p.9; Becky, p.7; Becky, p.7; Becky, p.3). Korpan et al. (1997) produced news reports with different plausibility and concluded that plausibility influences participants' requests for information. However, what is not clear in the Korpan study is the direction of causation and how plausibility information might be used by readers.

Taken together the discussion in this section suggests that certainty, and likelihood of veracity, are not central in participants thinking, and that they take a broader perspective on what they have read. I would point to two reasons for this. The first is the point made by Bromme at al. (2010, pp.169-170) who draws a distinction between first- and second-hand evaluation. For Bromme et al., in first-hand evaluation, participants examine "What is true?" and in second-hand evaluation participants consider "Who to believe?". Thus there are matters of trust in evaluation as well as truth. The second point is the idea of perspective, or significance. It is interesting to note that within the history curriculum understanding of significance is considered a core skill (Katie, first interview, p.3). There is some evidence of use by history trainees, for example, Nick questions whether Varroa virus in bees is "really that bad" (p.8). Another participant challenges the significance of the cancer risk associated with diesel fumes by saying that it is "not the world's biggest problem now" (Joseph, p.14). Further, it is touched upon by Simon (preliminary interview, p.2) who says that too long was being spent on examining the genome of tomatoes when his friend had suffered injuries which would benefit from scientific inquiry.

6.4.3 Communicating knowledge

Teaching

In this category comes discussion of teaching and use of news articles in teaching. This theme can co-exist with other themes within the wider theme of *knowledge*. Six of the participants talked about teaching, but Nick and Katie did not, both history trainees. I do not think it is possible to draw significant conclusions from this. I would suggest that this omission says more about participants understanding of the interview task than about their own capacities.

All of the participants had taught in secondary schools prior to the interviews, and given that the interviews were being conducted by a teacher educator it is understandable readers would make such a link. There were a number of points made within this theme. Firstly readers talked about using news stories to generate interest and to motivate secondary school pupils. Secondly, they have talked about what ideas are part of the school curriculum and which are not. Finally, there was reference made to what might be included in the curriculum, for example space travel being included in the geography curriculum (Alex, p.9)

The theme *teaching* is important for two reasons. Firstly it helps to contextualise this study. Its inclusion here is a reminder that participants' thinking is informed by their classroom experience, including how they have used news stories and how they may use them in the future. Further, it is likely their classroom experience informs their thinking. Secondly, *teaching* falls into a wider category of *communicating knowledge* and how scientific ideas are passed on to others. Scientific ideas may well 'travel' from a research journal article, via a press release, to a news story. Teachers making use of news stories in their teaching add a further level and more distance from the original research. I am not suggesting here this is a particular problem, just that this lengthens the communication chain.

Source

In this theme the focus is on how scientific ideas are communicated. This includes references to the news story, and how it is written. An example is from Lee where the news publisher "Got a lot of like fairly interesting information … in a short amount of space" (p.6). Originally I give this theme the title *article,* referring to the news article and any original research article, but this categorisation was found to be too narrow as some participants made use of other sources, such as web links, as they explored a particular article that they had

selected. The focus of the theme source is on the communicated knowledge rather than the original research, which is found in the producer theme.

In participants' reasoning there were some positive references to the news publisher, for example:

> Maybe but, um, no, I didn't really think that. I, I mean, as I say, I think kind of always when you read, read things on the BBC, they tend to be quite balanced (Katie, Older fathers, p.4)

and:

> Um, I would consider The Guardian a fairly reliable source as far as newspapers are concerned, um, and especially having followed it up with, with other… (Simon, Voyager 1, p.7)

The frequency of instances in this category is relatively small, however.

There were instances where participants raised specific points about communication:

> I knew as soon as I read the title that this would be, um, you know, this wouldn't be as clear cut as it, as it's probably going to… **Mm-hmm.** talk about it, um, so I was just interested in how, how it's going to present it. (Joseph, p.13)

One participant stated that they were "trying to think of an angle" (Katie, p.7). This point has commonality with the participant who wanted to explore the purpose of the article they were reading (17FH/B).

Within the news stories there are sometimes voices other than the researcher being represented. This is associated with the issue of balance which was raised above in the sections about consensus and peer review. It is also relevant under the heading of communication. One participant (17FH/B) stated that the representative from the British Heart Foundation in the article about heart disease did not "seem willing to sort of commit

specifically to this study". This was not something that emerged frequently in participant responses.

It emerged in the second phase of data collection, where participants selected their own news stories, that they included reference to related items of information. This was highlighted by Alex (p.5) who talked about things which did not appear in the main news story but that was present on webpages that were linked to the original. Hyperlinking to other web pages is common in web based news stories. It follows that the approach readers take will be different to reading a newspaper without the potential to follow up on hyperlinks.

My original conception for this study was to explore how participants might read and respond to a story, as if they were on a train before technology were available. However, it became clear that this was not how much online reading is done. In the evidence from the second phase of this study I do not know, unless participants mentioned this, if they read associated news stories or other websites.

6.5 Concluding comments for Chapter 6

In this chapter I have discussed themes that emerged during the data analysis stage. The main themes that came from this study are *loci of knowledge* and *knowledge focus*. These two themes are not mutually exclusive but sit alongside one another. For example an issue can be seen from both an *external* or a *personal* focus. These themes offer a means of examining the data.

A finding central to this study can be seen in the themes. Compared to the earlier part of this study there is a shift from the language of science, e.g. researcher and methodology, to broader language associated with more personal responses to second order literature. This

language includes affective, producer, process and personal experience. Thus readers of news stories draw on both the language of science *and* wider vocabulary.

Overall, the findings presented here show that there is not very much difference in the sorts of responses given by science and history trainee teachers. Further, there is at least as much variation among the group of science trainees as between the groups of science and history trainees. In Chapter 7 I will explore in more detail how looking at trainee teacher understandings offers more potential than trying to evaluate news stories using quality criteria such as veracity.

CHAPTER 7: DISCUSSION, IMPLICATIONS AND FUTURE WORK

7.1 Introduction

In this research project I set out to address two broad aims. The first aim was to further explore graduates' responses to news stories about science. The second aim was to look at any relationship between advanced study of science and these responses. The nagging problem for me throughout this study has been to try and understand what might be appropriate and achievable for someone who is generally well educated, but is not an expert in the topic of the news story. Given the breadth of scientific study, even those with an advanced education in science will often operate outside of their expertise. These were ambitious aims and, in this chapter I will examine what has been achieved in addressing these aims and bring together some of the key findings and concepts.

7.2 Overview of the three main methodological approaches.

In this section I will examine the three main analytical approaches and how these fit together. For the three pairs of research questions I used different analytical approaches to examine readers' responses to news stories, where the second two approach emerged from the first. The literature review identified that exploration of rule-based approaches would be worthwhile, however, such approaches were found to decontextualise the evidence and thus reduce potential for any future use of the findings. The concept of "interconnectedness" addressed these problems with contextualisation by identifying concepts in readers' responses and locating them within a concept map of the full interview response. The approach to identifying the extent of "interconnectedness", however, omitted significant evidence that was available from the interviews because it looked primarily at the extent the concepts formed part of a network and left out other aspects of the interview discussion. A deeper and richer

analysis was undertaken by the use of a thematic approach, which I reported in Chapter 6 and which I have called “understandings”.

In Figure 7.1 I have summarised these methodological perspectives by ‘plotting’ the approaches on two dimensions, with the extent of contextualisation of the units of analysis on the y-axis and the size of the unit of analysis on the x-axis. This chart emphasises that using three analytical frameworks enables different insights to be gained from the interview evidence. In section 7.5.2 I discuss how the identified heuristics could be used in teacher education by contextualising the heuristic. Thus I offer a way of utilising findings that could be considered decontexualised. The chart also demonstrates that there is a tension between the size of units of analysis and the extent of contextualisation. The “understandings” approach, which relates to the final research question, permits in-depth exploration of readers’ responses and also allows the evidence to be located within the wider interview context and so offers a compromise between the other two approaches.

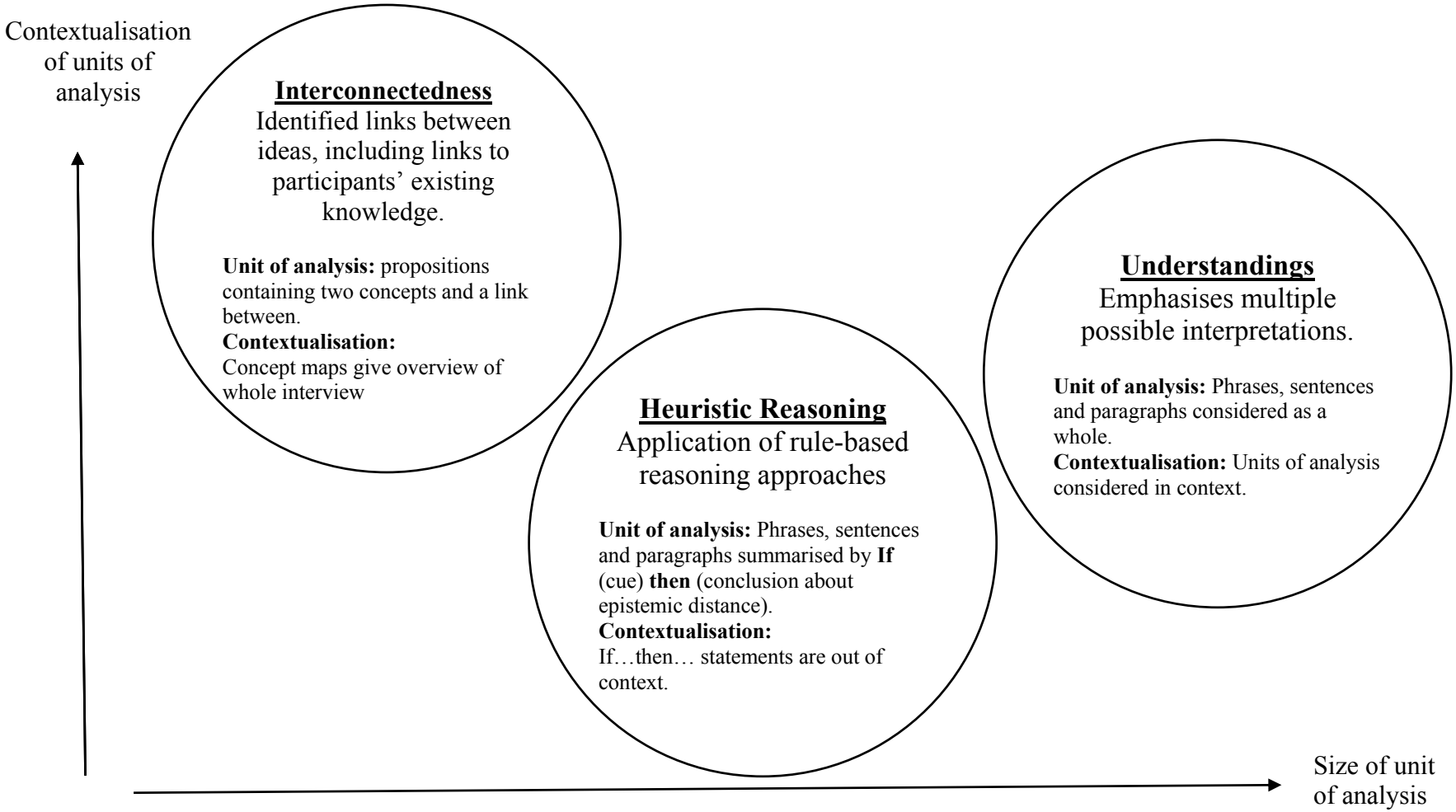


Figure 7.1: Summary of analytical approaches used to examine cognitive engagement with news stories about science

7.3 Key theoretical elements in the study and relationships between them

In section 7.3 I will articulate the meanings of by concepts used this thesis and also examine the links between these concepts. Firstly, I offer a brief summary of the main concepts I used in the study, including references to where these concepts are discussed in the thesis. Secondly, in Figure 7.2, I highlight how these concepts are linked to one another. The overall goal of this section is to show how the various parts of the study work together. The emphasis is on the first research question from each pair of research questions articulated in section 7.2 above. The three questions begin "What heuristics are used…?"; "To what extent do readers integrate…" and "How do readers understand…?", thus they are not looking for difference between groups of trainee teachers but instead focus on the process and outcome of identification. The key findings in relation to the research questions are given in section 7.4.

Heuristic reasoning:

This is reasoning that assumes that readers possess a set of rules which they apply to the new contexts that they encounter. (This is discussed in more detail in sections 2.5.3. Chapter 4 gives details of the five heuristics groups identified in the study.)

Epistemic distance:

An epistemic distance of zero is when a reader is fully accepting of the veracity of knowledge claims. An epistemic distance of one is when a reader rejects completely the veracity of a claim they encounter. (Epistemic distance is explained in section 2.5.5)

If…then… statements:

These are statements which make a link between a cue and a conclusion about epistemic distance. For example: *If* small sample size *then* increase epistemic distance. These

statements are summaries of utterances made by readers. (The approach to identifying If…the… statements is given in section 4.2.1.)

Interconnectedness:

Concept maps are used to identify the extent to which readers made links between concepts during the interviews. A fully networked concept map where there were multiple links between concepts was taken as evidence of metacognitive activity. This linking of ideas was also seen as a check on the contents of the articles. From the concept maps it was possible to identify 'clusters' of interconnected ideas which share a common theme. ('Interconnectedness' is introduced in section 2.7, where I make links to metacognition. The findings are discussed in Chapter 5.)

Clusters of ideas about interconnectedness:

A sub-group of clusters taken from the concept maps include "ideas *about* interconnectedness". These clusters are *about* interconnectedness and include ideas about how knowledge is produced. They also include comments about the peer review process and who might be an expert. In other words they are evidence of participants' epistemic knowledge and their 'knowledge about knowledge'. (Clusters of ideas *about* interconnectedness are discussed in Chapter 5 and in particular in section 5.5.)

Understandings

The term 'understandings' is used here to emphasise that there are multiple possible interpretations of news stories. Each individual draws upon their different backgrounds, knowledge and experience, and thus their reasoning and conclusions will be different. (The thematic analysis described in Chapter 6 was an attempt to capture key features of these

understandings. The themes and links between themes are shown, with illustrative examples, in section 6.2 and Appendix IX.)

External and personal perspectives

Within the thematic analysis I identified a theme which I have called the "external perspective". In this theme the readers draw upon ideas that can be considered to be public knowledge. A reader's response might begin "it is known that…" and show that references is made to knowledge with a loci outside of themselves. The personal perspective is identified when a reader's response includes something like "I know that…". Statements such as this emphasise personal knowing. (The loci of knowing, including external and personal perspectives, are discussed in section 6.3.)

In Figure 7.2 I have included these main theoretical ideas and shown links between them. I will now explore the links shown in the figure. In red I have made a link between 'likelihood of veracity' and 'understandings'. In the first phase of this study I specified that readers would look at the news stories through the lens of veracity. However, as described earlier in the thesis, readers wanted to talk more broadly than this and drew upon other ideas. Thus readers in the second round of interviews used a wide range of approaches. During the interviews I tried not to specify the nature of participants' responses too much. In the methodology here, however, there is a tension between giving sufficient guidance to obtain meaningful responses and being open-ended enough to allow the reader to interpret the news story as they want to. The shift in the current study's methodology towards exploring 'understandings' was in an attempt to capture some of these wider ranging responses. There was not found to be evidence of a narrow set of critical processes being used by readers, instead they used a wide range of approaches. Rather than adopting the position that there is a

single possible authoritative likelihood of veracity, the shift in the methodology of this study towards emphasising 'understanding' signals that experienced readers do not make use of a single quality measure of the science they read. In dark green I have made a link between 'interconnectedness' and 'understandings' to show that in each of these analysis a very wide range of different responses are demonstrated.

In purple on Figure 7.2 I have made a link between specific knowledge identified during the first phase and the scientific ideas found in the concept map analysis. Throughout the study there is evidence of readers mentioning specific scientific ideas. In Phase one readers talked about their knowledge of heart disease, for example, and in the first phase readers mentioned a wide range of specific scientific ideas. These are distinguishable from more general ideas that might have a use beyond a specific topic. An example of this is ideas about the processes of peer review. In Figure 7.2 I have shown in blue the links between parts of the study that emphasise knowledge that could be used by non-expert readers when they encounter a news story on a topic of which they have limited knowledge.

Finally on Figure 7.2 I have made a link in light green between networked concept maps and metacognition. This link is to show that in making links between ideas, readers are demonstrating metacognition. They are adopting, consciously or unconsciously, strategies to make links, to compare to their existing knowledge or to check the new ideas they encountered.

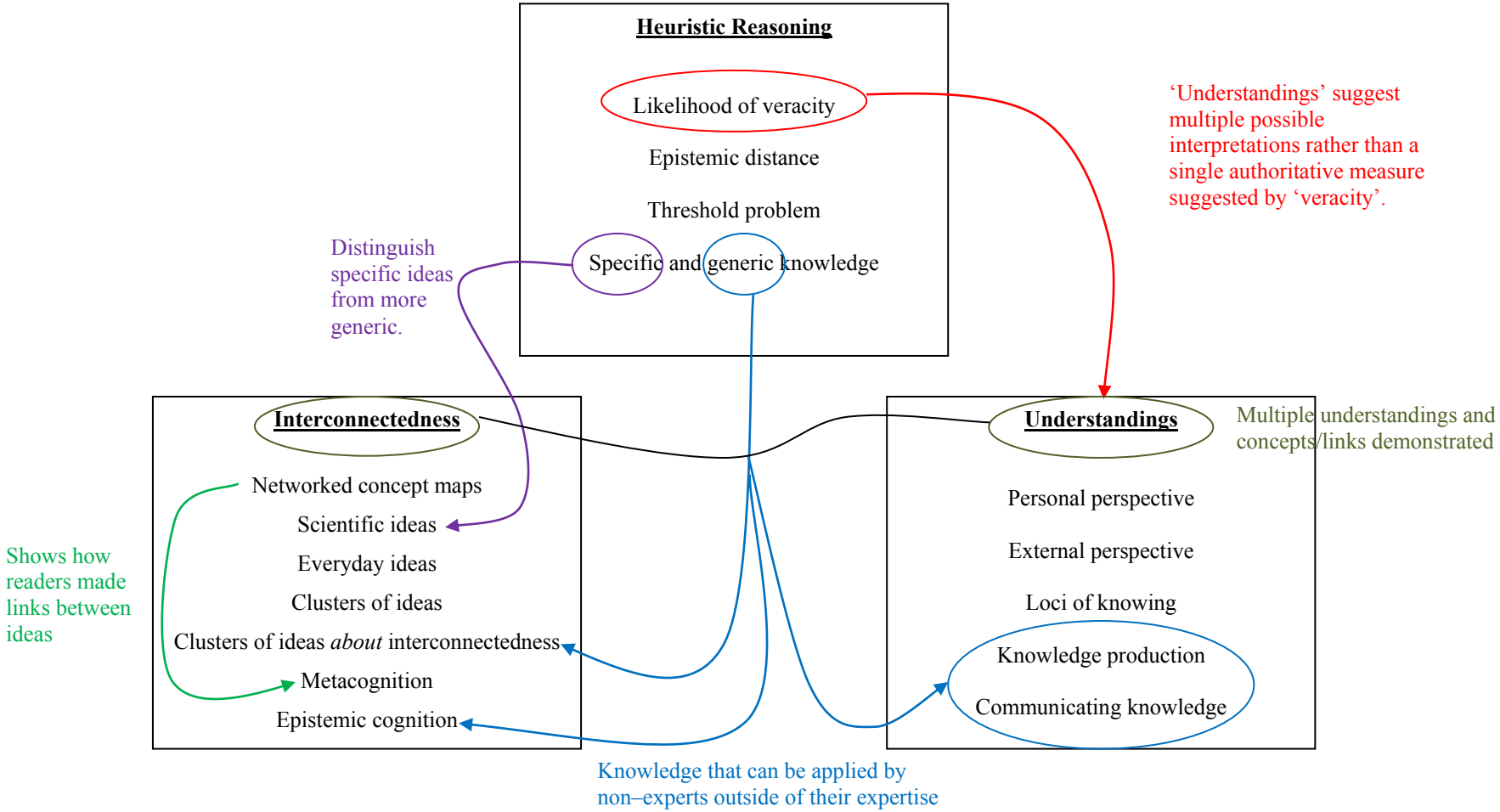


Figure 7.2: Diagram to show the links between concepts from different parts of the study

7.4 Key findings in relation to the research questions

In this section I will draw together the main findings linked to each of the research questions. The first two research questions were:

> What heuristics are used by readers when they reason about the quality of science published in the media? Are there differences in heuristic use based on readers' formal education in science?

There was evidence of a range of heuristics used by readers in deciding on the likelihood of veracity of a claim. Heuristics used by participants include when they generated alternative factors to those found in news stories, or challenge the published relationships between factors. In both these examples the heuristics offer a means of creating epistemic distance.

Further, it was found in the heuristic analysis that there are problems with non-experts using certain specialist information, such as methodological information. The 'threshold problem', where a reader decides if a value, such as sample size, is big enough, suggests that certain information does not offer the non-specialist much help in deciding on the likelihood of veracity of a claim. For a non-expert it is very difficult to know when a sample size is large enough to give them confidence in a study.

There was some evidence that history trainees were less critical of methodological information. However, overall the heuristics were not substantially different for those with history first degree subjects and those with science first degrees. Thus it can be concluded from this part of the study that an advanced education in science did not offer a substantial advantage for the reader. A further finding is that readers made use of both specific scientific knowledge and also more generic knowledge about science in their reading and responding to news stories.

As mentioned in Chapter 2, Moore (2011) suggests that an understanding of indeterminacy is an important part of critical thinking. By indeterminacy, I mean that a clear answer is not available, or perhaps unachievable. Examples of things which are indeterminate are the issues raised earlier about whether there should be nuclear power stations built or what should be done about global warming.

Norris and colleagues (1994; 2003), in their work on news reports, operationalize responses by identifying three areas: certainty of statements; status of statements; and role of statements. A group of experts decided on which category statement should be placed in. For example, the news text:

> Now, scientists are focusing on the potential of resistance training to reduce the risk of heart disease (p.130).

was placed in the category 'uncertain of truth status.' Thus this approach relies on experienced readers interpreting and making judgements about certainty, status and role of statements. This discussion raises the question about the basis on which these expert readers are making judgements and what is the particular significance of the three areas being explored.

The point here is that it is unlikely that there is such a thing as a single authoritative response to news stories. The response of an educated but non-expert reader could be different from that of an experienced journalist, which will be different again from the response of an expert research scientist. These three imaginary readers would potentially be looking for different things. However, within science more widely there are mechanisms for reaching consensus and for reaching an authoritative response.

Donnelly (2004) in his paper "Humanizing Science Education" is critical of science education curriculum reforms which he claims are strongly associated with the features of the humanities. He discusses 'radical indeterminacy' and suggests that in the humanities it is not possible to obtain an authoritative answer:

> One of the most significant and challenging aspects of the humanities is the potential for the acknowledgement of a radical indeterminacy to lead to a facile relativism. Under relativism, any judgement or interpretation is taken to be potentially as good as any other… (p.678)

Donnelly contrasts this to science which has a tendency to towards closure and reaching agreement on scientific ideas. However, news stories have both scientific and meta-scientific components. It might be possible for scientists to reach agreement on the nature of claims in the phenomenal component of the articles. Given limited expertise and limited information, however, readers of news stories are presented with something that is indeterminate *for them*. This is a kind of 'internal indeterminacy' using language inspired by Kahneman and Tversky (1982). It would be misleading to imply to university or school students that answers are necessarily obtainable for the likelihood of veracity of news stories using only that news story and non-expert knowledge.

For things that are 'internally indeterminate', one possible approach is to hold knowledge claims in abeyance, until further information is available. This prevents the problem of accepting claims or knowledge as true when it is not accepted by a wider scientific community. Another approach is for readers to interpret news stories within their experience and from a personal perspective, something which Donnelly (2004) points out is associated with relativism. There is, thus, a tension here.

The second two research questions were:

> To what extent do readers integrate what they read about science in the media with other knowledge? Is there any relationship between the extent of integration and readers' formal education?

It was found in the study that both science and history trainee teachers made links between ideas such that analysed concept maps for both groups were networked. For both groups of trainee teachers there was evidence of participants making use of spoke-like propositions in their responses, indicated on concept maps with a green dot. There was also evidence of highly integrated and interconnected maps for both group. For both groups there was much less evidence of 'clusters of ideas *about* interconnectedness' and for some readers there was almost no evidence of the epistemic thinking associated with 'ideas *about* interconnectedness'. It was found that the vocabulary used by science trainees was, on the whole, richer if they had studied a topic in their advanced education. However, there were exceptions to this.

The final two research questions were:

> How do readers understand news reports of science? Are there differences in the understandings of readers with advanced formal education in science and those without?

It was found that readers' understandings include what I have called loci of knowledge, in other words, where the ideas can be attributed to. The distinction between external and personal was found to be useful and highlights that understandings do not only include reference to objective type frames, even for those with advanced education in science. Subjective references to personal experience were drawn upon. These subjective references are part of participants' understandings.

Furthermore, in the knowledge focus theme, readers were found to draw upon understandings of knowledge production, knowledge itself and also how knowledge is communicated. These themes were too broad to be able to be defined by a single 'quality' measure such as certainty, likelihood of veracity, plausibility or validity. The breadth of the ideas raised by readers is better described in a broad sense as 'understandings' rather than an outcome of a process of analysis using criteria.

7.5 Implications from the research

7.5.1 Academic debate and policy

A key contribution of this study is to debates about non-specialists' understanding of news stories. This study builds on work by Norris and colleagues who claimed that readers should look to the expert as a focus for critique rather than the autonomous evaluation of scientific claims. Here I claim that news stories are largely indeterminate for the non-expert reader because both the scientific ideas are too specialist to challenge and the news story contains insufficient information to make such autonomous evaluation. I make links to work on critical thinking and suggest that instead of trying to critique the scientific ideas only, readers can scrutinise the wider news story. Further I build on tentative work by Moore (2011) who suggests that critical thinking includes making links to other ideas.

My conclusion is that news stories are largely indeterminate to the reader and that experienced readers show a wide range of understanding rather than any single interpretation or use of any single quality measure. This is not to suggest that reading news stories does not have a place in science education, but that the goal of reading them could be more aligned to understanding and interpreting rather than making judgements about quality, plausibility, veracity or certainty, for example. From my perspective, one desirable outcome from this

research would be a recognition that a legitimate outcome from reading a scientific news story is to hold ideas in abeyance until further information become available.

7.5.2 Practice

The readers in this study demonstrated a wide range of understandings of news stories. While it is not possible to generalise from this study it does contribute to 'case law' (Robson, 1993) and so those in teacher education may recognise aspects of the context and be able to compare it to their own. Drawing on this study, teacher educators may wish to reflect on the metacognitive and epistemic reasoning undertaken by their own students. They may decide that their students would benefit from discussing the potential of ideas *about* interconnectedness in understanding news stories outside of their own specialist knowledge.

Further, the heuristics identified above could serve as a starting point for discussion with trainee teachers. The heuristics could be probed and questions asked such as: In what circumstances would you agree with this heuristic? In which circumstances would it not be useful? Thus, the identified heuristics could be used in teaching interventions. In particular, a range of examples of news articles could be built up where the heuristic is considered to be able to be applied successfully and where its application is inappropriate. The heuristics can thus be 'tuned' to specific contexts. The heuristics offer a framework for exploration of news stories which would also be suitable for use in secondary schools.

Grandy and Duschl (2007) have suggested that learners should have opportunities for the "development of dialogical processes for both the construction and the evaluation of knowledge claims" (p.158). They make the link here between dialogue and learning to evaluate claims. What has emerged from this study are certain approaches and methods that have been used by experienced readers as they read and respond to news stories. Parallels can

be drawn here with the work of Ford (2008) who posits the existence of a common resource which has both constructor and critiquer elements and is associated with an appropriately critical perspective on knowledge claims. The focus of the points made by Ford, and Grandy and Duschl, is on the 'phenomenal' or in other words scientific ideas. Thus the main concern is with practical scientific work. However, as discussed above, news stories also have a metaphenomenal component because the news source is a second-order interpretation. Building on the constructor/critiquer arguments above it would follow that students should have experience of constructing a news story to develop their capacity to critique it. Eilks et al. (2011) offer an interesting approach where students adopt certain roles, journalists for example, to understand more about societal practices and the associated filtering of information. Thus they would experience what it was like to be a constructor of a news story and be better equipped to critique it.

From my own perspective as a teacher educator I have realised it would be a mistake to suggest to the trainee teachers I work with that a news story can be simply decoded using the tools of science. For the educated but non-expert reader the specific details of the research strategy used in reported scientific research would not be helpful in deciding if claims where true or not. Instead I would emphasise the need for readers to interpret the news story using a set of tools that is wider that the tools of science alone. It is very important for trainee teachers to not have a false sense of confidence in the capacity to read and understand news stories from the presented information alone. If readers are able to make use of metacognitive and epistemic thinking then they will have more chance of responding appropriately to the news stories they encounter. This is because such metacognitive and epistemic knowledge is more likely to be general enough to be applicable to stories outside of their immediate

expertise. These points are important for trainee teachers as they themselves will work with pupils as they in turn read news stories.

In the future I intend to try two activities with trainee teachers I work with. First I will present some of the heuristics identified in this study and ask trainees to suggest when these heuristics might apply to scientific research that is reported in the news. I will then ask them to identify news stories that have appeared on new websites that both offer evidence in support of that heuristic and that do not offer supporting evidence. In this way contexts are added to the heuristics and a pool of example news stories which both support and do not support the heuristic can be established.

In a second activity I will ask trainees to read a news story and then discuss the article in pairs or small groups. As part of the discussion I will ask trainees to produce a concept map of their discussion and explore how they have made links to ideas other than those included in the article. I will then ask them to consider the strength of the links that have been identified in the concept map, for example by looking at whether two different pieces of similar research are actually comparable. I will also ask trainees to look at the extent to which their concept map is networked and whether it contains any clusters of ideas *about* interconnectedness. Both of these activities offer the potential to make explicit use of both the methodology and findings of the study.

7.6 Future research and scholarship

While the starting point for this study was different from the work done on argumentation, the heuristics described above, which follow the formulation 'If…then…', are perhaps not substantially different from the simple arguments used by Zohar and Nemet (2002), for example, where an argument is a conclusion with at least one relevant justification. Thus in

further work it might be possible to link work done in the field of argumentation with that conducted in this study.

Further research could also be conducted to explore any relationships between critical thinking and scientific literacy. In particular, opportunities exist to further examine the role of scientific ideas, compared to general critical thinking, when people read news stories about very specialist science. One possible way of doing this is to develop ideas about interconnected, which in this study are in embryonic form.

7.7 Limitations of the study

The main research method used in the study is semi-structured individual interviews. This research strategy is consistent with the interpretivist perspective adopted in the study, however this approach relies on the skill of the interviewer and their ability to establish effective relationships with the interviewee.

A further limitation of this study emerges in the methodology of the second phase of data collection. By opening up the research methodology and allowing readers to select their own articles I made it harder to compare the responses. In particular some of the selected articles were not reporting scientific research. This meant the articles readers selected may well have had a more significant effect on the outcome than any differences between the groups of participants. Thus the interview responses perhaps need to be seen as a set of 'cases' rather than assuming there are similarities between them.

The concept maps described in Chapter 5 where produced by me as the researcher. This means that another researcher could have interpreted these in a different way. Although this is consistent with an interpretivist approach to research a further interesting perspective would have been to ask the readers to comment on the concept maps.

7.8 Contribution to knowledge

The main contributions to knowledge that emerge in this thesis are that the experienced and well qualified readers in this study tended to interpret, and try and understand, news stories, rather than evaluate them using criteria. Further the readers examined the news stories from both a scientific perspective and as a second-order source of information. There was not found to be major differences between the responses by the science trainee teachers and the history trainee teachers. Although science participants drew upon richer vocabulary in their discussion on topics that were related to their advanced studies in science. Thus an advanced education in science does not appear, in the three analytical frames used here, to offer readers of news stories substantial advantage.

The theoretical concepts of "interconnectedness" and "clusters of ideas about interconnectedness" form part of a methodological contribution to knowledge. Furthermore, concept maps offer potential for exploring an interview as a whole and in particular help to identify how readers make links between ideas. These concepts also offer an alternative perspective on critical reading and critical thinking.

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APPENDICES

APPENDIX I: INFORMATION SHEET FOR FIRST PHASE OF INTERVIEWS

Looking at media reports of science

John Kirkman is undertaking a research project as part of his PhD studies. He is interested in exploring how people read and think about reports of science that appear in the popular press and on news websites such as the BBC website.

You have been asked to be part of this research project. Your participation will have three parts:

- You will be asked to read some media reports of science on your own
- In an interview you will be asked to explain what you think about the contents of the reports you have read
- You may be asked if you would be willing to talk to the interviewer at a later date on the telephone

The interview will last no longer than an hour. It will be recorded on a digital voice recorder. The interview is not a test or an assessment of any kind. Nobody, other than the interviewer, will know it was you who gave the answers you gave as any transcription will not have your name on it. You may be asked some question and you are asked to answer them as fully as you can. In many cases there is no right or wrong answer and you are encouraged to just say what you think.

The interview recording will be stored on the University of Birmingham computer systems. Your name will not be associated with the recording or any transcription that is made of the recording. In other words what you say will remain anonymous.

The recordings will not be used for any other purpose other than for this study. The only person to listen to the recording will be the interviewer or a colleague within the University

Of Birmingham School Of Education. Quotations from the transcriptions might be used in a PhD Dissertation or in written material derived from this. However, quotations will remain anonymous.

Your name will be kept along with a contact email address and telephone number but these will not be associated with the interview recording or transcription.

If at any time during the interview you feel like you would like the interview to stop you are encouraged to tell the interviewer and the interview will be stopped immediately. It is up to you if you would like to continue. If there is a question which you don't wish to answer you are free not to answer the question.

If after the interview you change your mind and would like the recording to be destroyed you should explain this to the interviewer who will delete the recording. Please let John know within 14 days of the recording if you wish it to be deleted.

Following the interview you are asked not to discuss the articles you encountered. This is because other people participating in the study might be shown the same articles and it might affect their responses. However, if you would like to receive further information about this study once all of the interviews have been completed please tick the appropriate box on the Consent Form.

If you have any other questions about the interview process, please speak to John before or after the interview has taken place.

APPENDIX II: INFORMATION SHEET FOR SECOND PHASE OF INTERVIEWS

Looking at media reports of science

I am undertaking a research project as part of my PhD studies at the University of Birmingham. I am interested in exploring how people read and think about reports of science that appear in the popular press and on news websites such as the BBC website.

You have been asked to be part of this research project. Your participation will have a number of parts:

- Meet with me to talk about your background and your reading about science (less than an hour)
- Identify two articles each week about science that interest you and read these
- Speak on the telephone each week about your reading and thinking (about 10 minutes)
- Meet again to speak about the articles you have read (around an hour)
- You may be asked to comment on a transcription of the interviews or be part of a follow up conversation.

The interviews, including the telephone interviews, will be recorded on a digital voice recorder. The interview is not a test or an assessment of any kind. Nobody, other than me, will know it was you who gave the answers you gave as any transcription will not have your name on it. You will be asked some question and you are asked to answer them as fully as you can. In most cases there is no right or wrong answer and you are encouraged to just say what you think.

The interview recording will be stored on the University of Birmingham computer systems. Your name will not be associated with the recording or any transcription that is made of the recording. In other words what you say will remain anonymous.

The recordings will not be used for any other purpose other than for this study. The only person to listen to the recording will be the interviewer or a colleague within the University Of Birmingham School Of Education. Quotations from the transcriptions might be used in a PhD Dissertation or in written material derived from this. However, data will remain anonymous.

Your name will be kept along with a contact email address and telephone number but these will not be associated with the interview recording or transcription.

If at any time during the interview you feel like you would like the interview to stop you are encouraged to tell me and the interview will be stopped immediately. It is up to you if you would like to continue. If there is a question which you don't wish to answer you are free not to answer the question.

If after the interview you change your mind and would like the recording to be destroyed you should explain this to the interviewer who will delete the recording. Please let me know within 14 days of the recording if you wish it to be deleted.

If you would like to receive further information about this study once all of the interviews have been completed please tick the appropriate box on the Consent Form.

If you have any other questions about the interview process, please speak to me before or after the interview has taken place.

Thank you very much for your help and willingness to participate in this study.

John Kirkman

APPENDIX III: CONSENT FORM FOR BOTH PHASES OF INTERVIEWS

Looking at media reports of science

I have read the Participant Information Sheet and agree to take part in the interview as described on the Participant Information Sheet (see overleaf).

Name in capital letters: _____

Email address: _____

Contact telephone number: _____

Signature: _____

Date: _____

I would like to receive further information about this study, via email, once all of the interviews have taken place. YES/ NO

APPENDIX IV: ABRIDGED ETHICS FORM

UNIVERSITY OF BIRMINGHAM

APPLICATION FOR ETHICAL REVIEW

TITLE OF PROJECT: Pre-service teachers' evaluations of newspaper reports of scientific research: inferences made with reference to scientific methodologies

SUPERVISOR: Professor Gary Thomas

ESTIMATED START DATE: October 2008

ESTIMATED END DATE: Sept 2013

SUMMARY OF PROJECT:

Describe the purpose, background rationale for the proposed project, as well as the hypotheses/research questions to be examined and expected outcomes. This description should be in everyday language that is free from jargon. Please explain any technical terms or discipline-specific phrases.

Pre-service secondary school science teachers are required to teach a curriculum that emphasises scientific literacy. One manifestation of scientific literacy is the capacity to evaluate reports of science that appear in the media. This study explores how pre-service teachers approach media reports of science, in particular in how they make use of information contained within the media report that relates to scientific methodologies. Pre-service science teachers are relevant to this study because they are a subset of the population who are educated in science but also who will be expected to be able to teach pupils how to approach media reports. Pre-service teachers' inferences from the information within the text of the report will be examined and patterns of reasoning will be identified. These will be compared to the patterns of reasoning of pre-service teachers whose main subject is not science.

The main research questions are:

What kind of reasoning do pre-service teachers demonstrate when asked to justify their judgements of the plausibility of short newspaper reports of scientific research?

Does prior knowledge of scientific methods help pre-service teachers judge the plausibility of short newspaper reports of scientific research?

What are pre-service teachers able to infer from references to scientific methods in short news reports of scientific research?

Are there differences between the reasoning demonstrated in relation to judging the plausibility of short news reports of scientific research by those who are training to teach science and those who are training to teach non-science subjects?

CONDUCT OF PROJECT

Please give a description of the research methodology that will be used

The primary method of data collection will be individual semi-structured interviews. The interview will be recorded using a digital voice recorder. There will be a list of questions which will be used at the interviewer's discretion. There will be cues which will be used if required. Prior to starting the main part of the interview participants will be given a small number of media reports to read. These will be newspaper reports or reports that have been published online on a mainstream website, for example www.bbc.co.uk. After having been given a short period of time (perhaps 10 minutes) to read the report participants will be asked about what they have read.

DOES THE PROJECT INVOLVE PARTICIPATION OF PEOPLE OTHER THAN THE RESEARCHERS AND SUPERVISORS? Yes

PARTICIPANTS AS THE SUBJECTS OF THE RESEARCH

Describe the number of participants and important characteristics (such as age, gender, location, affiliation, level of fitness, intellectual ability etc.). Specify any inclusion/exclusion criteria to be used.

The participants will be at least 21 years old as they are all post-graduates and on an initial teacher training course. They will be male and female. Some will have higher degrees. The interview will take place either within the School of Education or within a state secondary school within the West Midlands area. The trainee teachers have all completed a Declaration of Health as part of the admission procedures for the PGCE course and have been deemed fit to teach within secondary schools. The exact number of participants is unclear at the moment but in total the number of participants will not exceed 40.

RECRUITMENT

Please state clearly how the participants will be identified, approached and recruited. Include any relationship between the investigator(s) and participant(s) (e.g. instructor-student).

The participants will be approached initially via email. PGCE course tutors within the School of Education will be asked to send out an initial email requesting participants for this study. Those participants who are interested in being involved in the study and have responded will

then be contacted directly via email and more information will be given. It is likely that all the participants will know of the investigator as he teachers on the PGCE course. For some participants the investigator will have been their tutor.

CONSENT

a) Describe the process that the investigator(s) will be using to obtain valid consent. If consent is not to be obtained explain why**.** If the participants are minors or for other reasons are not competent to consent, describe the proposed alternate source of consent, including any permission / information letter to be provided to the person(s) providing the consent.

Participants will be sent a copy of the Participant Information Leaflet by post or by email. The aim will be that this arrives a week before the interview date. However a minimum time will be 24 hours to allow the participant time to read and to think about the content of the Participant Information Leaflet. At the start of the interview participants will be given a further copy of the Information Leaflet and asked to sign the Consent Form.

b) Will the participants be deceived in any way about the purpose of the study? No

PARTICIPANT FEEDBACK:

Explain what feedback/ information will be provided to the participants after participation in the research. (For example, a more complete description of the purpose of the research, or access to the results of the research).

Participants will be sent a more detailed explanation of the purpose of the study after all the interviews have taken place if they request it on the Consent Form.

PARTICIPANT WITHDRAWAL

a) Describe how the participants will be informed of their right to withdraw from the project.

It will be explained to participants that the interview will be stopped if they wish it to and the recording of the interview will be destroyed at their request. It would seem reasonable to give a 14 day period for the participant to get in touch if they change their mind following the interview and the interview recording and other data will be deleted.

b) Explain any consequences for the participant of withdrawing from the study and indicate what will be done with the participant's data if they withdraw.

There are no consequences of withdrawing. All data will be destroyed if participants withdraw.

COMPENSATION

Will participants receive compensation for participation? No

CONFIDENTIALITY

a) Will all participants be anonymous? No

b) Will all data be treated as confidential? Yes

Describe the procedures to be used to ensure anonymity of participants and/or confidentiality of data both during the conduct of the research and in the release of its findings.

During the research process there will be nowhere that participants' data is stored alongside their name. Therefore, the data will be confidential. Within the data analysis and writing up participants will be identified using a pseudonym.

If participant anonymity or confidentiality is not appropriate to this research project, explain, providing details of how all participants will be advised of the fact that data will not be anonymous or confidential.

It will be explained on the Participant Information Sheet that data will be confidential but that individuals' names and details will be recorded separately from their interview data.

STORAGE, ACCESS AND DISPOSAL OF DATA

Describe what research data will be stored, where, for what period of time, the measures that will be put in place to ensure security of the data, who will have access to the data, and the method and timing of disposal of the data.

Interview recordings and transcripts will be stored, along with field notes from the interview and telephone follow up. The telephone follow up will not be recorded so there will be no interview recording. The recordings, transcriptions and analysis of the data will be kept within John Kirkman's files on the University of Birmingham computer systems. This information will be kept following the completion of the PhD studies for a period of 5 years.

OTHER APPROVALS REQUIRED**?** e.g. Criminal Records Bureau (CRB) checks: Not applicable

SIGNIFICANCE/BENEFITS

Outline the potential significance and/or benefits of the research

The research might give insights into the sort of reasoning undertaken as adults read media reports of science. This might be of benefit for two reasons. Firstly there might be implications for teacher training and the teaching that takes place on Science PGCE courses. It might help to clarify the sort of help that pre-service teachers need to make sense of media

reports of science. And further to this point it might help them to understand more about how to help their pupils make sense of media reports of science. Secondly it might indicate some elements of scientific reasoning which are undertaken by those who have had significant training in science. This in turn might offer additional insights to secondary school curriculum designers and those who design resources for use in school.

RISKS

a) Outline any potential risks to **INDIVIDUALS**, including research staff, research participants, other individuals not involved in the research and the measures that will be taken to minimise any risks and the procedures to be adopted in the event of mishap

The risks to research participants are minimal. The media reports may contain issues which are slightly sensitive to participants e.g. health or environment. If the participant looks uncomfortable with the topic of the report they will be asked if they would like to look at a different media report. The risk to the researcher is minimal. While the interview will take place in a room with just the interviewer and participant they will take place in public buildings with other people about.

b) Outline any potential risks to **THE ENVIRONMENT and/or SOCIETY** and the measures that will be taken to minimise any risks and the procedures to be adopted in the event of mishap.

There is no risk to the environment or to society from this research.

ARE THERE ANY OTHER ETHICAL ISSUES RAISED BY THE RESEARCH? No

APPENDIX V: RESPONSE TO THE ETHICAL REVIEW COMMITTEE'S CONDITIONS:

Condition 1:

"Please consider whether students may feel any pressure to participate in the study if the request for participants is sent out via course tutors, and if so how this issue will be addressed."

It is possible the students may feel pressure to participate if the request is made via course tutors. However it will be made clear to the students that it is not in any way associated with the course requirements or with the course assessment process. It should be added that all the potential participants will be post-graduates and some will have had a previous career before joining the course. The students would not, therefore, be easily pressured into doing something which they do not wish to do by reason of their age and maturity.

Although the History, Science: Biology and Science: Chemistry PGCE students are likely to have been taught by the researcher, his contact with them will have been limited to a few hours. Furthermore, he is not their course tutor. While the course tutor for these subjects might forward the request to students it will be made clear that the course tutors will be unaware of any involvement or non-involvement with the research. Therefore, the risk of feeling pressure is very low.

There is more of a risk associated with Science: Physics students because the researcher is also their course tutor. The two main reasons for the student potentially feeling pressure to take part are trying to please the tutor or related to concerns about assessment. In the case of trying to please the tutor it would seem unlikely as the students are adults and have an independence of thought. In the case of concerns about assessment, the outcome of the research is only tangentially associated with the assessment criteria of the course, therefore, the student would have no need to try and show competence in the area of the research. While the tutor does have some say in the assessment process there are many other people involved too. Students who are at risk of failing the course will be excluded from participation in the research, in order to avoid charges of the research influencing the outcome of the course and also because their time would be better spent on other things.

Condition 2:

"Please clarify whether it may be possible to identify the participants of this research as student as at the University of Birmingham, from the research outputs. If so, please consider whether there may be a negative effect on the reputation of the course and/or its students in the event that the findings are negative, and explain how such a risk will be addressed."

It will be possible to identify University of Birmingham students as participants from this research. Taking the potential for negative effects on the reputation of the course first - the research is interested in exploring student responses to media reports of science. The PGCE course of study is about preparation for teaching in secondary schools, and while response to media reports of science are part of the school science curriculum, this is a relatively new inclusion in the curriculum. The field of research associated with media reports of science is small and it is not clearly defined. Furthermore, competence in this field is difficult to define as it is a contested area more generally. Science PGCE courses nationally would be expected to make some reference to media reports of science but this would be very limited in nature. Therefore, any negative outcome of the research is associated only in a very small way with any teaching that might go on during the course. From a national perspective, that a course tutor was involved in researching this area and seeking to improve student teachers performance with regard to media reports of science would be seen as a very positive thing – it might help students deal with this area more effectively. As students come from a wide range of backgrounds and from a range of undergraduate courses and institutions, and their performance would be partly dependent on their undergraduate study, the link between the PGCE course and performance on the research task would be very weak. History PGCE students are included as a type of control and would not be expected to have a wide range of knowledge in science.

The second point raised was whether a negative outcome might have an effect on the students themselves. I think that this is very unlikely. Individual students will not be able to be identified. Furthermore, students are likely to have obtained jobs prior to the publication of research findings. Performance on the research task might be a learning experience for some students and therefore actually benefit them. That their tutor had an interest in this field and included aspects of it in the course would also be seen as a positive thing.

Condition 3:

"Please be aware of the data storage and retention requirements in the University's new Code of Practice for Research (available at http://www.as.bham.ac.uk/legislation/docs/COP_Research.pdf). In particular, please note that following completion of the research, data should normally be preserved and accessible for ten years." The code will be read and adhered to.

APPENDIX VI: QUESTIONNAIRE FOR FIRST PHASE OF INTERVIEWS

Questionnaire (completed at start of interview and revisited at end)

Please supply the following information:

Age: 21-25 26-35 36 or above

Gender: male/female

Educational background:

A-level (or AS or A2) subjects studied**:**

_____

Bachelor degree subject(s) studied (including degrees started and not completed):

_____

Higher degree subjects or other courses of study (please supply details):

_____

Do you have any specialist knowledge of the following topics? (For example have you studied them beyond GCSE level, undertaken a project, worked in an environment concerned with this topic or have a family member / friend for whom this is of special interest.)

Topic	Do you have specialist knowledge of this topic?	Indication of level and nature of specialist knowledge
Cockroaches	yes / no	
Heart disease	yes / no	
Ketamine (Class C drug)	yes / no	
Lasers	yes / no	

For each of the following statements decide how likely you think they are to be true. Circle the statement that you most agree with.

Cockroaches can 'recommend' good food sources to one another

very unlikely to be true	unlikely	neither likely or unlikely	likely	very likely to be true

How sure are you about the choice you made?

very sure	quite sure	neither sure or unsure	not sure	very unsure/ guessed

Brushing teeth can prevent heart disease

very unlikely to be true	unlikely	neither likely or unlikely	likely	very likely to be true

How sure are you about the choice you made?

very sure	quite sure	neither sure or unsure	not sure	very unsure/ guessed

Ketamine, a class C drug, harms human memory

very unlikely to be true	unlikely	neither likely or unlikely	likely	very likely to be true

How sure are you about the choice you made?

very sure	quite sure	neither sure or unsure	not sure	very unsure/ guessed

Lasers can 'sense' vapours released by explosives

very unlikely to be true	unlikely	neither likely or unlikely	likely	very likely to be true

How sure are you about the choice you made?

very sure	quite sure	neither sure or unsure	not sure	very unsure/ guessed

APPENDIX VII: EXAMPLE ANALYSIS FOR TWO PARTICIPANTS FROM THE FIRST PHASE

Data ID	Art-icle	Quote from transcription	If	then	Category (Heuristics)
102	A	Um, yeah, it's interesting. Um, it says that they're communicating with chemicals but then it says that they need to identify the chemicals so, which suggests they don't actually have any evidence that there are chemicals being exchanged.	suggestion there is no evidence for chemical communica tion	increase epistemic distance	
103	A	and then when they've got the cockroaches grouping together, they suggested they're communicating about the food but, um, I don't know whether there could be some other reason, like it's defensive if they're clustered together, might decrease the chance of them, excuse me, being, um, hit or eaten by a predator or something or, I don't know, if they're, like penguins all group together, don't they…	can suggest alternative reason for eating together	increase epistemic distance	can suggest an alternative explanation to that offered in the news story
104	A	From, to protect them from the elements, um, so yeah, err, I mean, it's interesting but it, it doesn't really sort of, it doesn't really, from the article, it doesn't really give enough information to, to make me say, oh yeah, I definitely believe that…	article does not give enough information	increase epistemic distance	do not have enough information
106	A	Um, yeah and I, I think really, um, they're just assuming that there's some chemical communication, when there could perhaps be some other reason and it, they don't really, err, suggest any alternative sort of theories, yeah.	no alternative theory suggested	increase epistemic distance	

Data ID	Art-icle	Quote from transcription	If	then	Category (Heuristics)
107	A	Yeah, well, I mean, if they dropped them all down in one corner of the arena, then they're probably going to feed on the one bit of food closest to where they are but, err, I mean, it would be more convincing if they said, oh, we, we spread them evenly around the arena, err, in some way and then they all walked over this or walked around one piece of food, to go to this other piece of food, because there was some, possibly some communication going through them, err, going through the, err, group but it, it doesn't give any details as to whether that's the case and I think that's probably quite important, um… [pauses]... yeah and it doesn't mention that at all.	cockroaches distribute evenly in arena	decrease epistemic distance	positive point made about methods
108	A	Um, and yeah, the stuff about chemicals seems to be, um, conjecture really.	explanation which includes chemicals for communication	increase epistemic distance	scientific explanations given in the news stories are identified as problematic
110	B	it's the BBC, but I'm not sure if I'm convinced.	BBC website	decrease epistemic distance	positive reference to news publisher
110	B	I'm, I'm not convinced that there really would be a link between brushing your teeth and heart disease. Um, I think, I mean, maybe it, it contributes but I mean, they do say there's other factors, smoking and diet, exercise, um,	other factors contribute	increase epistemic distance	can suggest other possible factors

Data ID	Art-icle	Quote from transcription	If	then	Category (Heuristics)
111	B	and I, I mean, it doesn't really make clear exactly how they've, um, sorted out this data and how they've accounted for other factors, or if they have accounted for other factors fully, um, so I'd say, if anything, that more research would be needed and perhaps the study shouldn't be limited to one sort of geographical area, um, yeah.	not fully accounted for all the factors	increase epistemic distance	
111	B	and perhaps the study shouldn't be limited to one sort of geographical area, um, yeah.	only one geographic al area	increase epistemic distance	method queried
112	C	**So the same question, what do you make of this one or think about, what's the content.** Err, I'd probably be more likely to believe this one, um, because I've heard of other drugs causing, having effects on memory, like cannabis,	heard other drugs have an effect on memory	decrease epistemic distance	consistent with existing knowledge
113	C	but it doesn't, well, I don't remember it mentioning other drugs that these people in the study will have used, because if they're regular Ketamine users, they probably use other drugs as well, so and maybe cannabis, so what effect that's had on their memory. **Mm-hmm.** And whether it's just the Ketamine	other confoundin g factors	increase epistemic distance	suggested other possible factors
114	C	Um, I, I have seen somebody take Ketamine actually at a party… **Mm-hmm.** And they just kind of vegged out in a corner and it didn't seem very appealing. [Laughs]. They were literally just sat there, eyes glazed, um, in a world of their own, um, but yeah, I mean, it, it, I think a drug that's sort of that strong, um, I could, I could believe that it could have an effect on, on the brain in some way, definitely, yeah.	personal observation s of drug use	decrease epistemic distance	draw upon own observation or experience
115	C	Yeah, so they've used, um, 120 people, which isn't a particularly large sample.	not particularly large sample	increase epistemic distance	concerns about sample size

Data ID	Art-icle	Quote from transcription	If	then	Category (Heuristics)
116	C	Err, they split them into five groups, so they've got a control group, which is the people that don't use it, but then they've got the other groups, um, who have varying amounts of use. Um, I mean, the fact that it says that the regular users were worse on memory, but the other groups didn't show much difference, does again make me wonder what, maybe, maybe what other drugs or what other factors are in those people's lifestyles, if they were heavy drug users, um, and, err, yeah, 'cause it doesn't say anything about that, err,	other possible causal factors	increase epistemic distance	can suggest other possible factors
117	D	Yeah, um, it's quite interesting, it's interesting technology. Um, I, I mean, biology's not my strong point but I think when it said the word sense, that sort of implied sort of an intelligence to me, um, or well, maybe that's just an (inaudibe 11:02) thing, sense, but, um, obviously, there is an intelligence there, 'cause it's just a laser, but it's, I guess it's like a little circuit, it'll, it'll switch it off, um, so it, it can, it can kind of communicate to you the fact that there's explosives but, err, I think the sort of tag line that it senses it is perhaps a little misleading, maybe.	use word 'sense' and implication of intelligence	increase epistemic distance	metaphor use a concern
118	D	and there's a lot of, um, believes, suggests, um, it kind of sounds like, that they've not really fully perfected it and they've certainly not, well, they've certainly not trialled it in any sort of practical application, um, so I'd, I'd, what I take from the article is that it's, this technology is really in its infancy and it's probably some way away from something that they could use…	not trialled in practical situations	increase epistemic distance	
120	D	Um, are there people able to repeat, um, the experiment somewhere else and get similar results? Um, it, it doesn't say anything about that, because ultimately, the, you'd want to be able to replicate the technology and research it in different places, use it in different places.	experiment able to be completed and to get similar results	decrease epistemic distance	

Data ID	Art-icle	Quote from transcription	If	then	Category (Heuristics)
121	D	**Well, when you looked at this, you said, you said it was unlikely to be true.** Yeah. **Um, have you changed your thoughts or opinion on that?** Yeah, I would say, I was probably taking the word sense too literally, so… **Mm-hmm.** Um, I would probably go with it being likely.	take word 'sense' too literally	decrease epistemic distance	

Table 4.1: Data for participant 07MC (Male Chemistry trainee teacher) to serve as an illustration of the analysis

Data ID	Art-icle	Quote from transcription	If	then	Category (Heuristic)
148	A	Um, I'm not sure if I really agree that it's to do with them communicating, as it were, 'cause if you think about with humans, it tends to be just follow the majority. If somebody goes… **Mm-hmm.** A lot of people follow… **Mm-hmm.** Not necessarily because they're saying this one's better or whatever, um, I think it's difficult to prove it, but that doesn't necessarily mean that it isn't true…	alternative explanation for behaviour conceived	increase epistemic distance	can suggest an alternative explanation to that offered in the news story
149	A	With the evidence they were given, although it's limited, I'd probably say that it's quite sure, yeah.	evidence appropriate	decrease epistemic distance	
150	B	Whether that's a direct link to, if you don't brush your teeth, you're going to get heart disease, I think that's going a bit far, um, but I can understand why people would say it, but the lady over here that was saying about, if you want to help your heart, you should have your balanced diet and avoid smoking, I think again, that's automatically linking other factors… **Mm-hmm.** With heart disease,	linking other factors with heart disease	increase epistemic distance	Can suggest other possible factors
151	B	I'm not sure how far I'd agree exactly. I think it's an indicator, but I don't think it necessary says, you are going to get heart disease if you don't do it… **Yes, yeah.** 'Cause you may not brush your teeth as often, but you may be perfectly healthy… **Mm-hmm.** So…	identify teeth cleaning as an indicator	increase epistemic distance	Scientific explanation given in the news story is identified as problematic
152	B	But… [pauses]... eight years is a fairly significant amount of time,	8 years	decrease epistemic distance	time scales judged appropriate

Data ID	Art-icle	Quote from transcription	If	then	Category (Heuristic)
153	B	cardiovascular events, ‘cause that could be anything relating to the heart and by 170 of those 555 being fatal doesn’t necessarily mean that that’s because those 170 people didn’t brush their teeth.	conceive that cause of death in sample not caused by teeth cleaning	increase epistemic distance	
154	B	So… [pauses]... I don’t think that, I think you'd have to take a much wider sample and just ‘cause you’ve got a medical history, it doesn’t necessarily mean that everybody puts on [inaudible 08:35] of their, I mean, I know they usually say how much exercise do you do, but it doesn’t always ask you how, what the intensity of that… **Mm-hmm.** Exercise is… **Yes.** And I think that also plays a part with how healthy you are or not.	use of self reportintg of health	increase epistemic distance	method questioned
155	B	If they're, no, I think that there's far more that needs to go into it, to be able to support it fully.	judge need more research	increase epistemic distance	research incomplete or more needed
156	C	They’ve definitely gone about getting the evidence and the research from a variety of different… **Mm-hmm.** Um, places,	evidence from a variety of places	decrease epistemic distance	
157	C	but again, the sample’s only small, 120 people’s not many and	small sample	increase epistemic distance	concerns about sample size

Data ID	Art-icle	Quote from transcription	If	then	Category (Heuristic)
158	C	when they say about, um, splitting the group up into the different categories… **Mm-hmm.** I don't know how, how they'd have decided. Um, would it have been that the participants filled in a questionnaire to how often they used it? Um, if so, would it be reliable, would they lie? I don't know… [pauses]... and with drugs or anything,	participants grouped according to self reported use	increase epistemic distance	method queried
159	C	I think that the whole stigma attached to them is that all drugs are bad and one of the things they always throw out is the fact that it can harm your memory… **Yes.** Or it can kill you.	happens with other drugs	decrease epistemic distance	consistent with existing knowledge
160	C	**That Ketamine, a Class C drug, harms human memory. Now what's your thinking now?** To me, all drugs have that kind of side effect, so I would still stick with that.	other drugs harm memory	decrease epistemic distance	compare to similar phenomena
161	D	I like the idea that something could detect explosives, but I don't know how much I would trust it to actually go out into a mine field or a roadside, because at the moment, it seems like they haven't really tested anyway in particular… **Mm-hmm.** Other than the university's had a look at, the university's carried out this study.	not tested on the field	increase epistemic distance	
162	D	I don't think that, I think there's more research needs to be carried out on it, before I would trust it to,	more research required	increase epistemic distance	research incomplete or more needed
163	D	but I think there's such a long way to go on it. I think at the moment I'm just a bit cautious, that's probably the best word.	consider research has a long way to go	increase epistemic distance	research incomplete or more needed

Data ID	Art-icle	Quote from transcription	If	then	Category (Heuristic)
164	D	But how much are St Andrew's going to do, I don't know. I think they need to look further afield. I think a lot more people need to get involved and try to really test it properly, but I don't know how they could test it, without putting it actually into the context they want to test it in.	more testing required	increase epistemic distance	research incomplete or more needed

Table 4.2: Data for participant 23FH (Female History trainee teacher) to serve to illustrate the analysis

APPENDIX VIII: INTERVIEW QUESTIONS FOR SECOND PHASE PRELIMINARY INTERVIEWS

Preliminary Interview

In the first part of this conversation, I will ask you about what you have studied at school and at university, and any work experience you have.

1. Please can you describe your science education up to GCSE/O-level level? What did you study?
2. What did you study at A-level?
3. What is your degree subject? Can you summarise the content of your degree?
4. Did you study any courses on the history or philosophy of science, or something similar?
5. What did sort of thing did you learn on that course?
6. Have you any work experience in science or related area (in a broad sense)?
7. Do you use any of the things you learned about science, from school, college or in your degree, not in work but in your everyday life?
8. From your experiences so far of teaching, how much do you think you use your knowledge from your first degree in your teaching?

Now I will ask you about your reading about science.

9. Do you follow science news stories?
10. Do you read about science, for example in the press or on websites?
11. What are your reading habits? When do you read? Why?
12. Do you read popular science books?
13. How about watch television programmes about science?
14. What have you read recently?
15. What did you think?

I want to ask you now about your teaching and news report or science media

16. Have you taught anything in school about news reports of science? What did you do?

17. Have you asked students to read or watch news reports? What did you do?
18. Have you asked students to look up information on the internet? How did you go about this?
19. Have you spoken to teachers about reading news reports of science? What did they say?

I will be asking you to read about four news reports about science. They can be ones that interest you and then I would like to be able to talk to you about them.

Then:

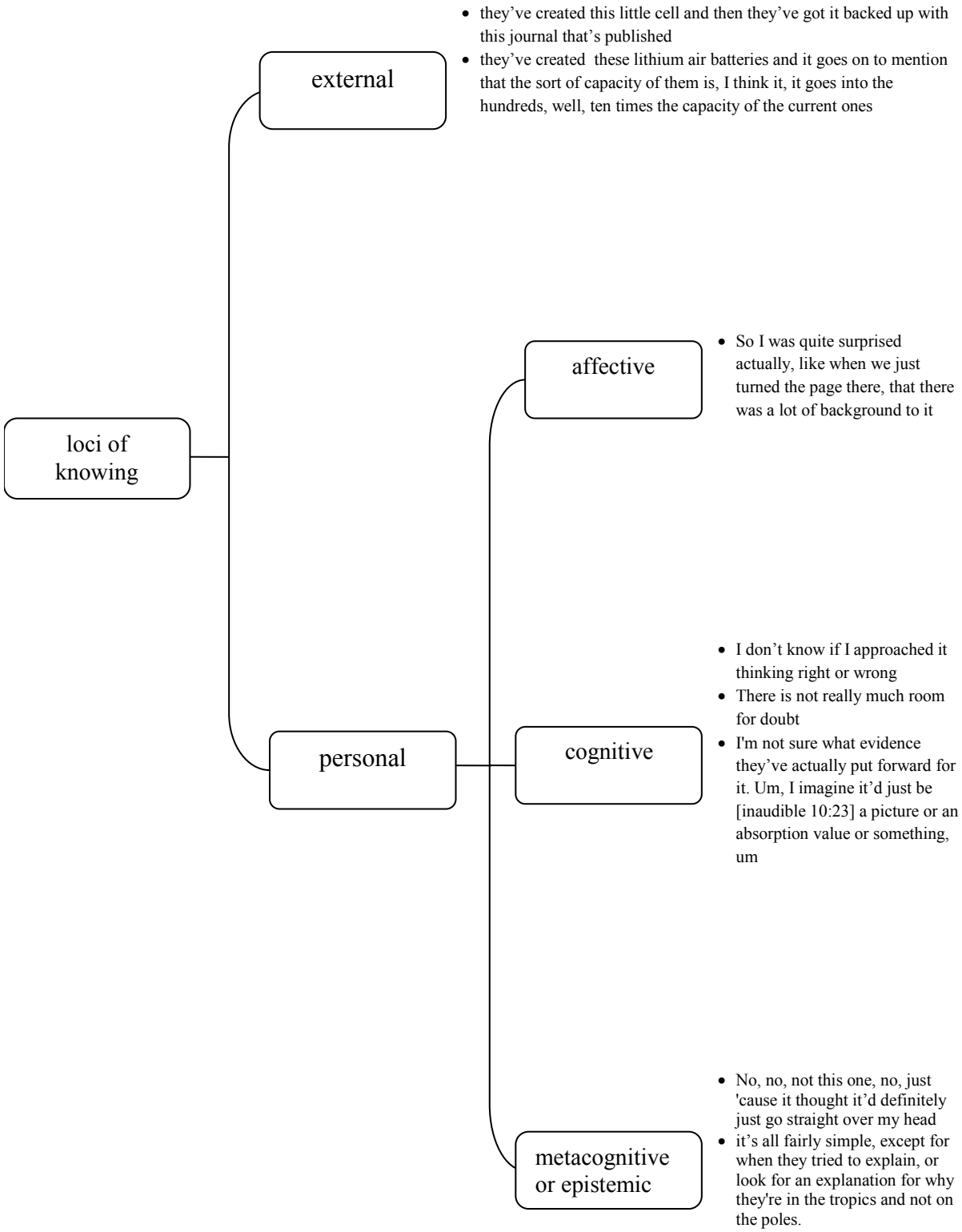
- Make arrangements for second interview (if possible)
- Explain would like informant to read an article about science in a newspaper, website, magazine etc. For example:

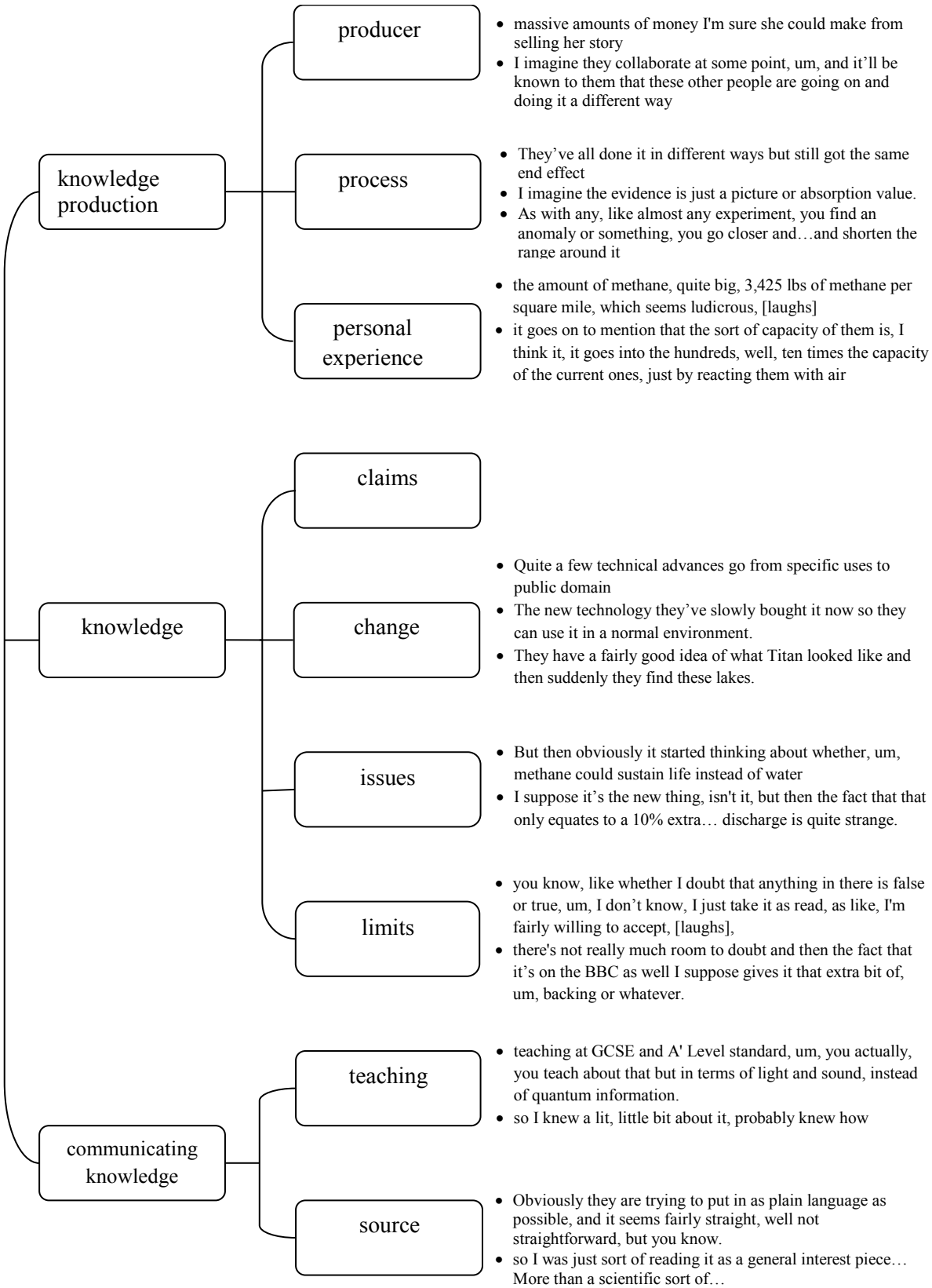
http://www.bbc.co.uk/news/
http://www.guardian.co.uk/
http://www.telegraph.co.uk/news/
http://www.independent.co.uk/

- Ask informant to email links if possible.
- Do you have any lesson plans for how you have taught about science in the news? Please bring to next interview or email them to me.

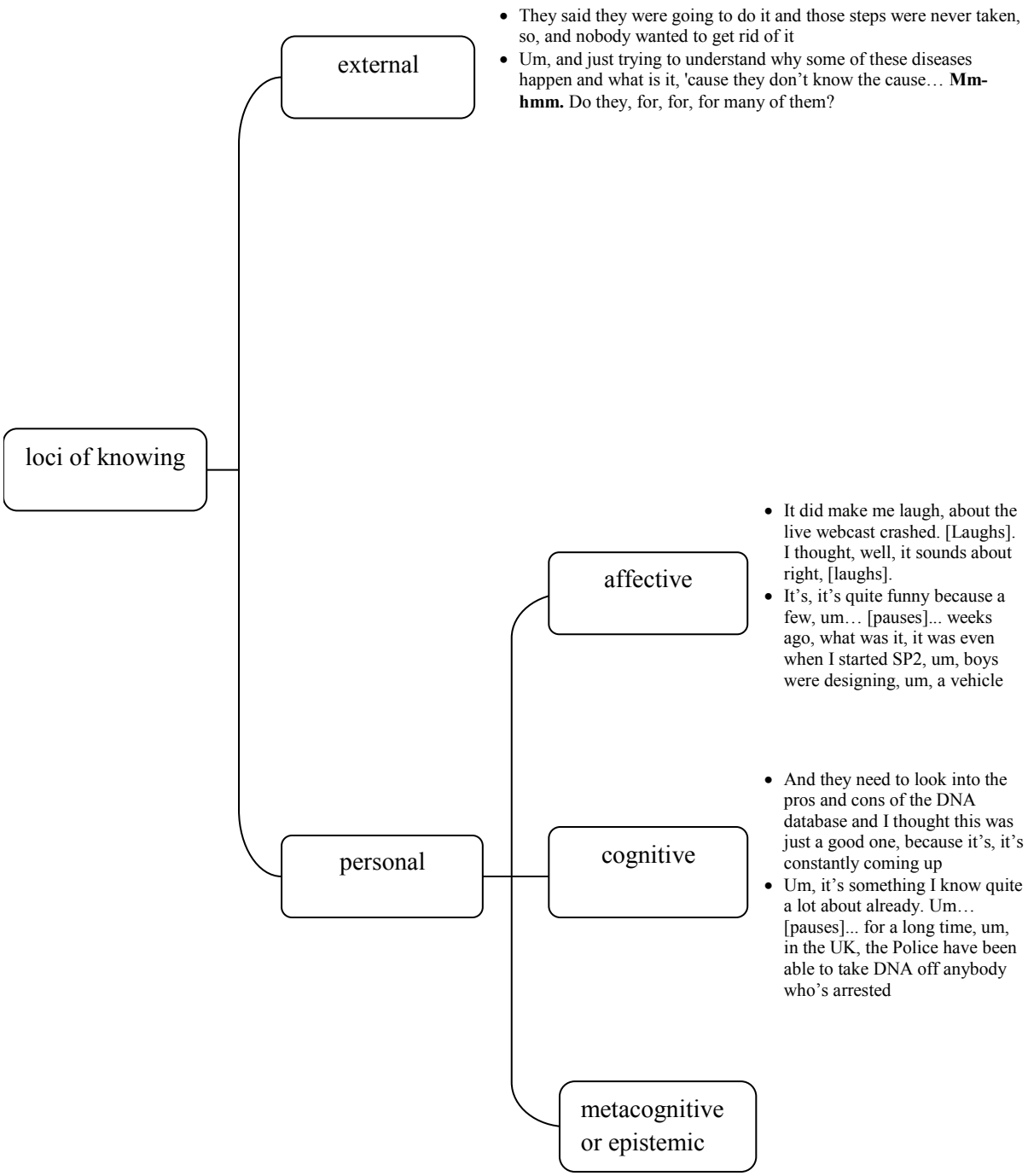
APPENDIX IX: NETWORK MAPS FOR PARTICIPANTS IN THE SECOND PHASE OF THE STUDY

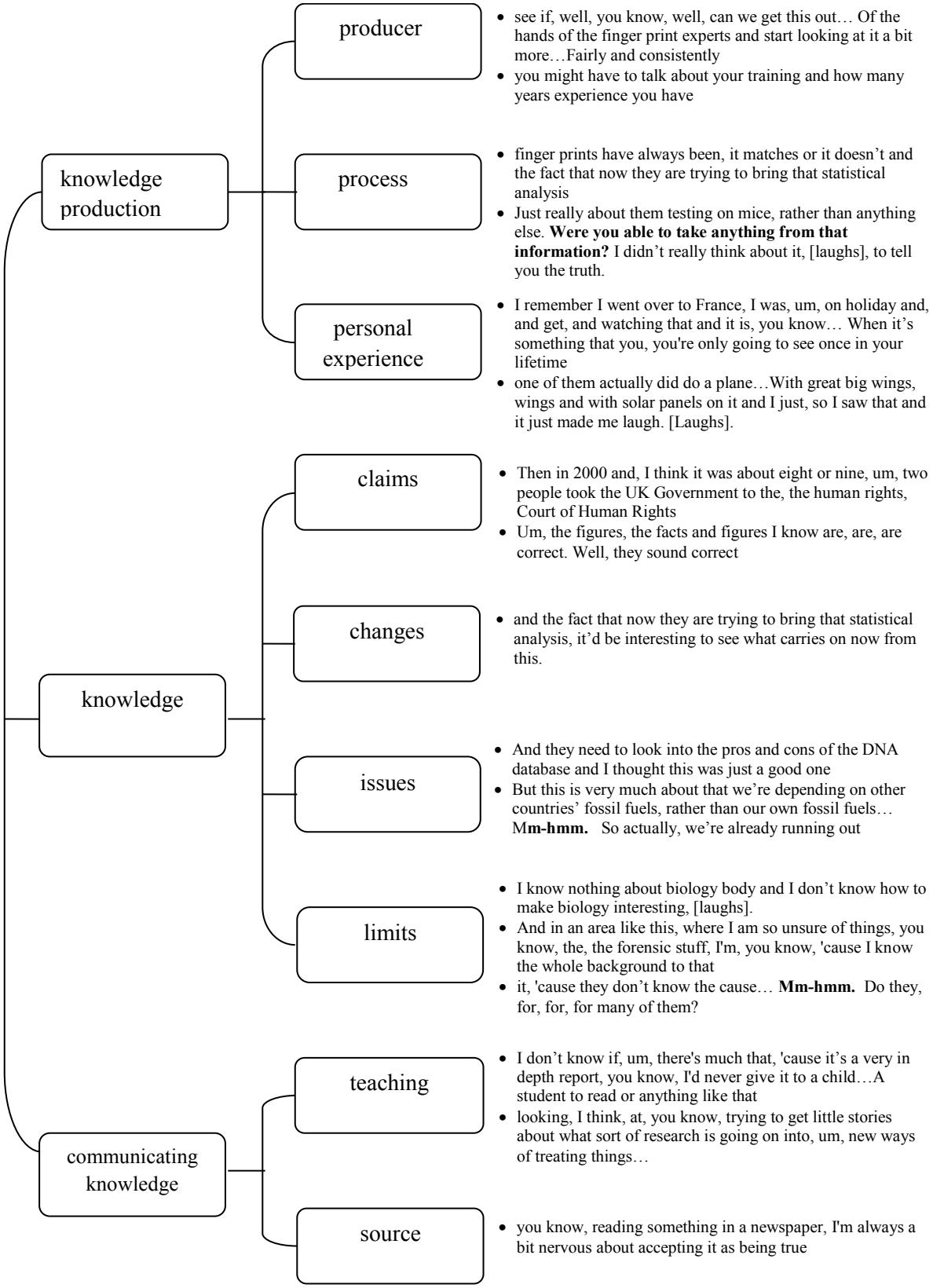
Lee


loci of knowing
external
they've created this little cell and then they've got it backed up with this journal that's published
they've created these lithium air batteries and it goes on to mention that the sort of capacity of them is, I think it, it goes into the hundreds, well, ten times the capacity of the current ones
personal
affective
So I was quite surprised actually, like when we just turned the page there, that there was a lot of background to it
cognitive
I don't know if I approached it thinking right or wrong
There is not really much room for doubt
I'm not sure what evidence they've actually put forward for it. Um, I imagine it'd just be [inaudible 10:23] a picture or an absorption value or something, um
metacognitive or epistemic
No, no, not this one, no, just 'cause it thought it'd definitely just go straight over my head
it's all fairly simple, except for when they tried to explain, or look for an explanation for why they're in the tropics and not on the poles.

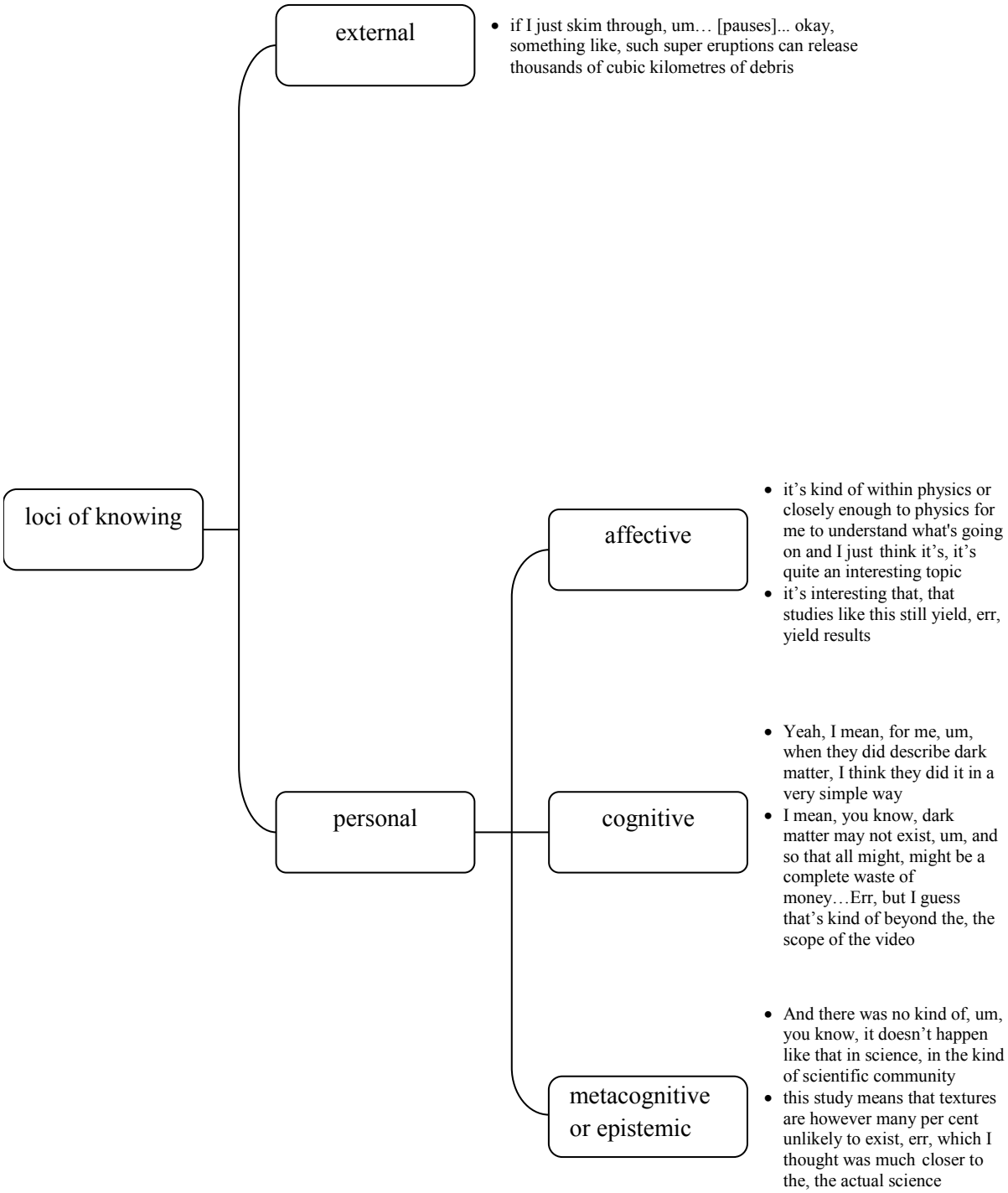

knowledge production
producer
massive amounts of money I'm sure she could make from selling her story
I imagine they collaborate at some point, um, and it'll be known to them that these other people are going on and doing it a different way
process
They've all done it in different ways but still got the same end effect
I imagine the evidence is just a picture or absorption value.
As with any, like almost any experiment, you find an anomaly or something, you go closer and…and shorten the range around it
personal experience
the amount of methane, quite big, 3,425 lbs of methane per square mile, which seems ludicrous, [laughs]
it goes on to mention that the sort of capacity of them is, I think it, it goes into the hundreds, well, ten times the capacity of the current ones, just by reacting them with air
knowledge
claims
change
Quite a few technical advances go from specific uses to public domain
The new technology they've slowly bought it now so they can use it in a normal environment.
They have a fairly good idea of what Titan looked like and then suddenly they find these lakes.
issues
But then obviously it started thinking about whether, um, methane could sustain life instead of water
I suppose it's the new thing, isn't it, but then the fact that that only equates to a 10% extra… discharge is quite strange.
limits
you know, like whether I doubt that anything in there is false or true, um, I don't know, I just take it as read, as like, I'm fairly willing to accept, [laughs],
there's not really much room to doubt and then the fact that it's on the BBC as well I suppose gives it that extra bit of, um, backing or whatever.
communicating knowledge
teaching
teaching at GCSE and A' Level standard, um, you actually, you teach about that but in terms of light and sound, instead of quantum information.
so I knew a lit, little bit about it, probably knew how
source
Obviously they are trying to put in as plain language as possible, and it seems fairly straight, well not straightforward, but you know.
so I was just sort of reading it as a general interest piece… More than a scientific sort of…

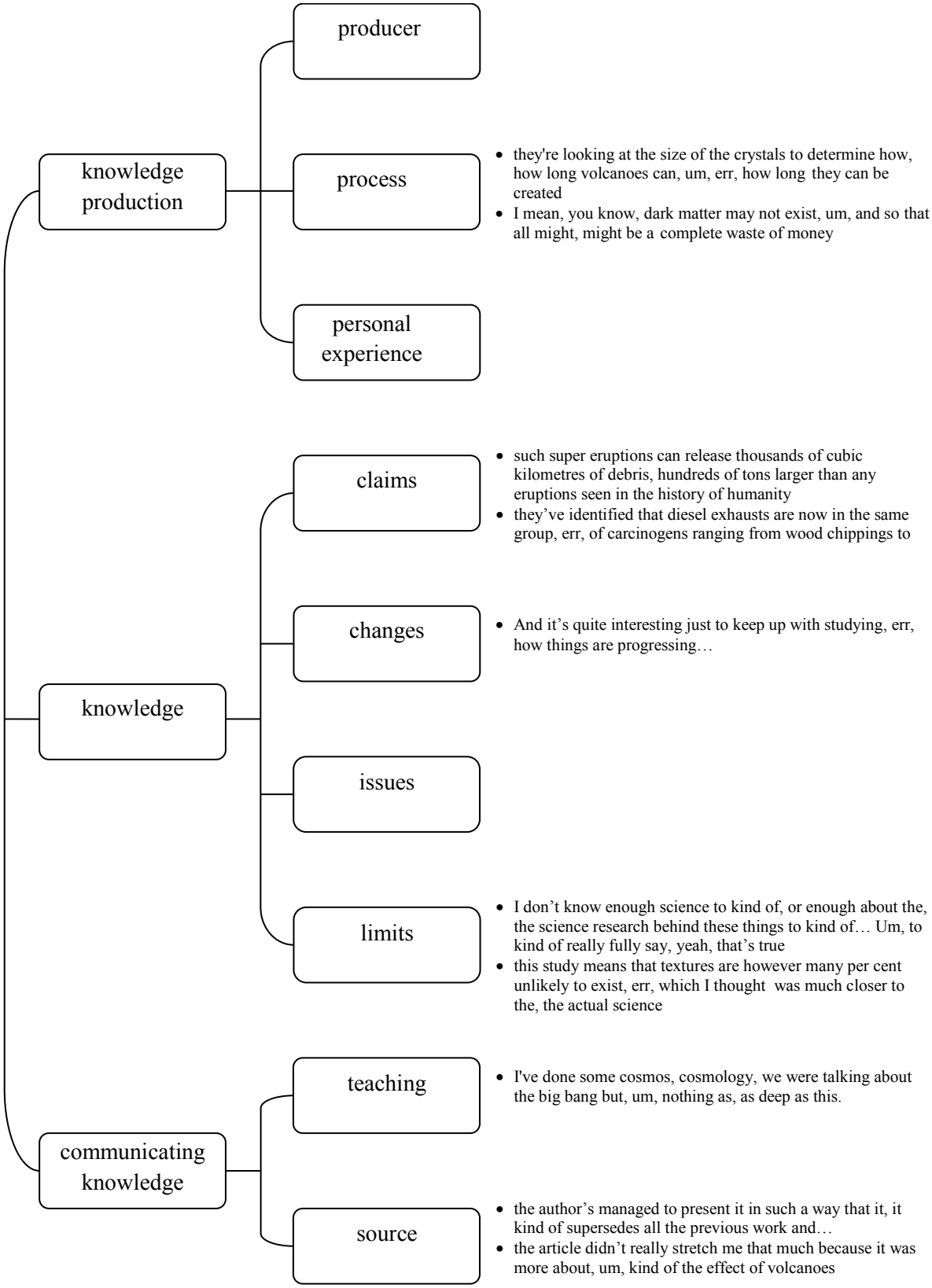
Sheila


loci of knowing
external
They said they were going to do it and those steps were never taken, so, and nobody wanted to get rid of it
Um, and just trying to understand why some of these diseases happen and what is it, 'cause they don't know the cause… Mm-hmm. Do they, for, for, for many of them?
personal
affective
It did make me laugh, about the live webcast crashed. [Laughs]. I thought, well, it sounds about right, [laughs].
It's, it's quite funny because a few, um… [pauses]... weeks ago, what was it, it was even when I started SP2, um, boys were designing, um, a vehicle
cognitive
And they need to look into the pros and cons of the DNA database and I thought this was just a good one, because it's, it's constantly coming up
Um, it's something I know quite a lot about already. Um… [pauses]... for a long time, um, in the UK, the Police have been able to take DNA off anybody who's arrested
metacognitive or epistemic

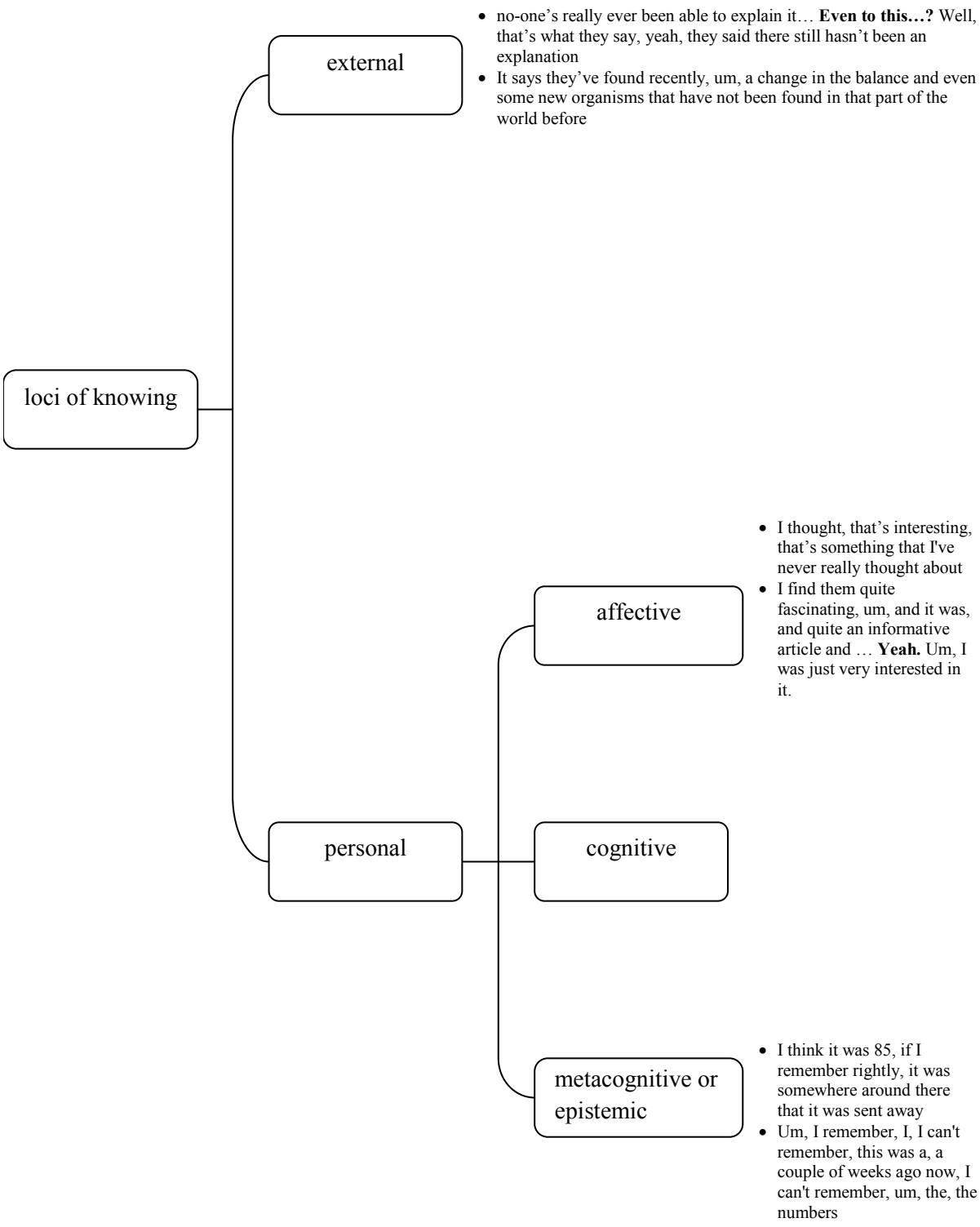

knowledge production
producer
see if, well, you know, well, can we get this out… Of the hands of the finger print experts and start looking at it a bit more…Fairly and consistently
you might have to talk about your training and how many years experience you have
process
finger prints have always been, it matches or it doesn't and the fact that now they are trying to bring that statistical analysis
Just really about them testing on mice, rather than anything else. **Were you able to take anything from that information?** I didn't really think about it, [laughs], to tell you the truth.
personal experience
I remember I went over to France, I was, um, on holiday and, and get, and watching that and it is, you know… When it's something that you, you're only going to see once in your lifetime
one of them actually did do a plane…With great big wings, wings and with solar panels on it and I just, so I saw that and it just made me laugh. [Laughs].
knowledge
claims
Then in 2000 and, I think it was about eight or nine, um, two people took the UK Government to the, the human rights, Court of Human Rights
Um, the figures, the facts and figures I know are, are, are correct. Well, they sound correct
changes
and the fact that now they are trying to bring that statistical analysis, it'd be interesting to see what carries on now from this.
issues
And they need to look into the pros and cons of the DNA database and I thought this was just a good one
But this is very much about that we're depending on other countries' fossil fuels, rather than our own fossil fuels… M**m-hmm.** So actually, we're already running out
limits
I know nothing about biology body and I don't know how to make biology interesting, [laughs].
And in an area like this, where I am so unsure of things, you know, the, the forensic stuff, I'm, you know, 'cause I know the whole background to that
it, 'cause they don't know the cause… **Mm-hmm.** Do they, for, for, for many of them?
communicating knowledge
teaching
I don't know if, um, there's much that, 'cause it's a very in depth report, you know, I'd never give it to a child…A student to read or anything like that
looking, I think, at, you know, trying to get little stories about what sort of research is going on into, um, new ways of treating things…
source
you know, reading something in a newspaper, I'm always a bit nervous about accepting it as being true

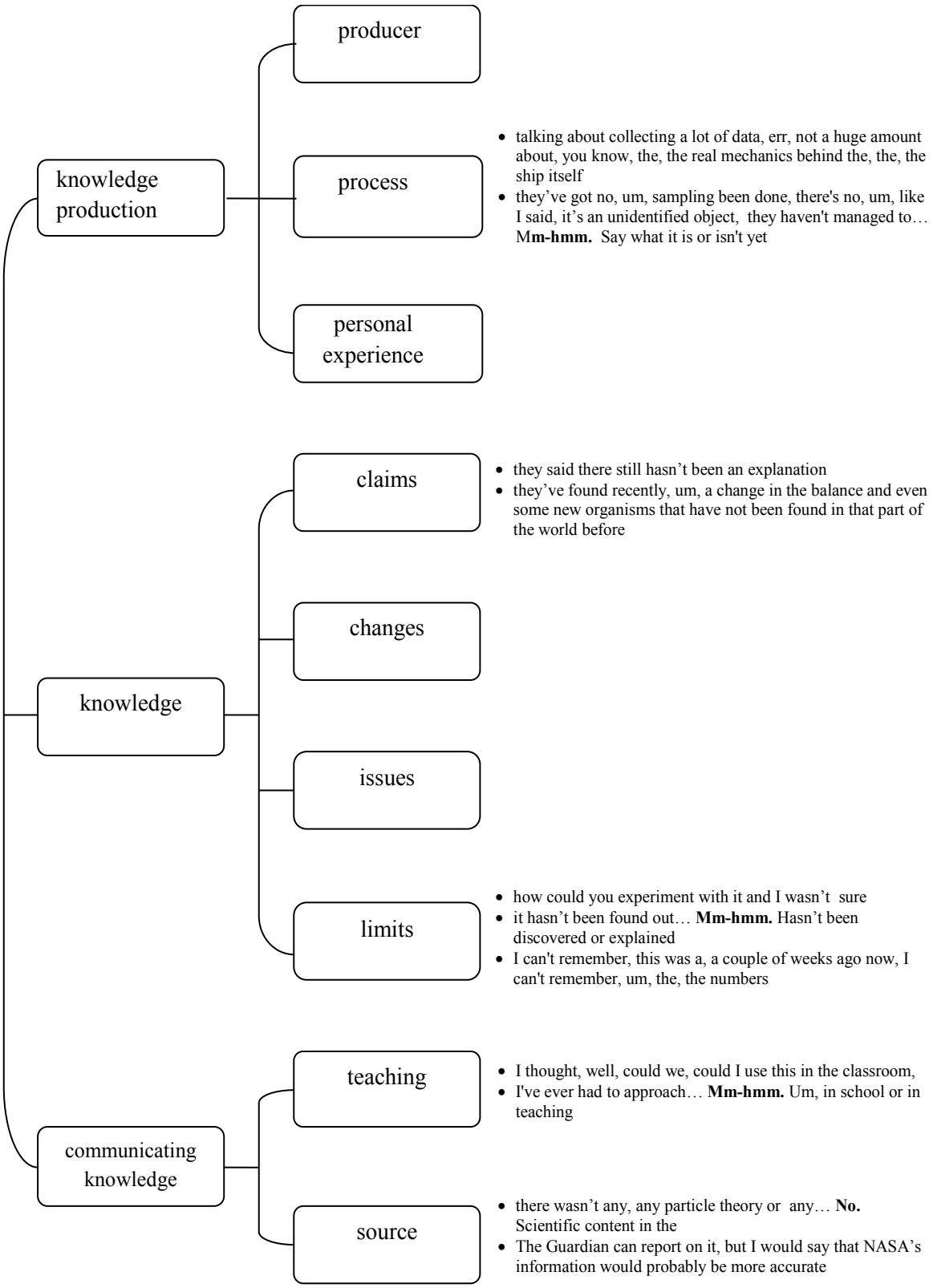
Joseph


loci of knowing
external
if I just skim through, um… [pauses]... okay, something like, such super eruptions can release thousands of cubic kilometres of debris
personal
affective
it's kind of within physics or closely enough to physics for me to understand what's going on and I just think it's, it's quite an interesting topic
it's interesting that, that studies like this still yield, err, yield results
cognitive
Yeah, I mean, for me, um, when they did describe dark matter, I think they did it in a very simple way
I mean, you know, dark matter may not exist, um, and so that all might, might be a complete waste of money…Err, but I guess that's kind of beyond the, the scope of the video
metacognitive or epistemic
And there was no kind of, um, you know, it doesn't happen like that in science, in the kind of scientific community
this study means that textures are however many per cent unlikely to exist, err, which I thought was much closer to the, the actual science

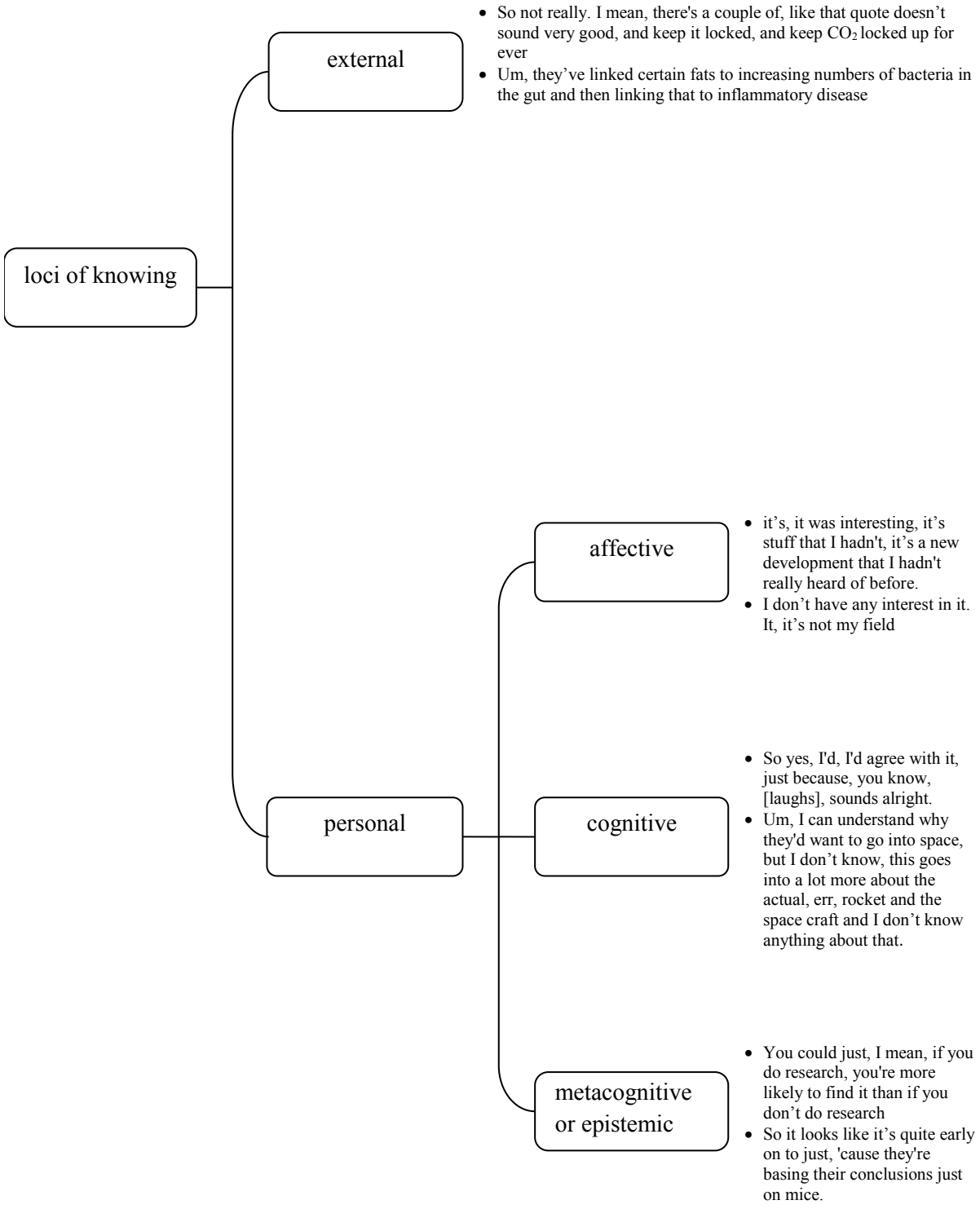

knowledge production
producer
process
personal experience
they're looking at the size of the crystals to determine how, how long volcanoes can, um, err, how long they can be created
I mean, you know, dark matter may not exist, um, and so that all might, might be a complete waste of money
knowledge
claims
such super eruptions can release thousands of cubic kilometres of debris, hundreds of tons larger than any eruptions seen in the history of humanity
they've identified that diesel exhausts are now in the same group, err, of carcinogens ranging from wood chippings to
changes
And it's quite interesting just to keep up with studying, err, how things are progressing…
issues
limits
I don't know enough science to kind of, or enough about the, the science research behind these things to kind of… Um, to kind of really fully say, yeah, that's true
this study means that textures are however many per cent unlikely to exist, err, which I thought was much closer to the, the actual science
communicating knowledge
teaching
I've done some cosmos, cosmology, we were talking about the big bang but, um, nothing as, as deep as this.
source
the author's managed to present it in such a way that it, it kind of supersedes all the previous work and…
the article didn't really stretch me that much because it was more about, um, kind of the effect of volcanoes

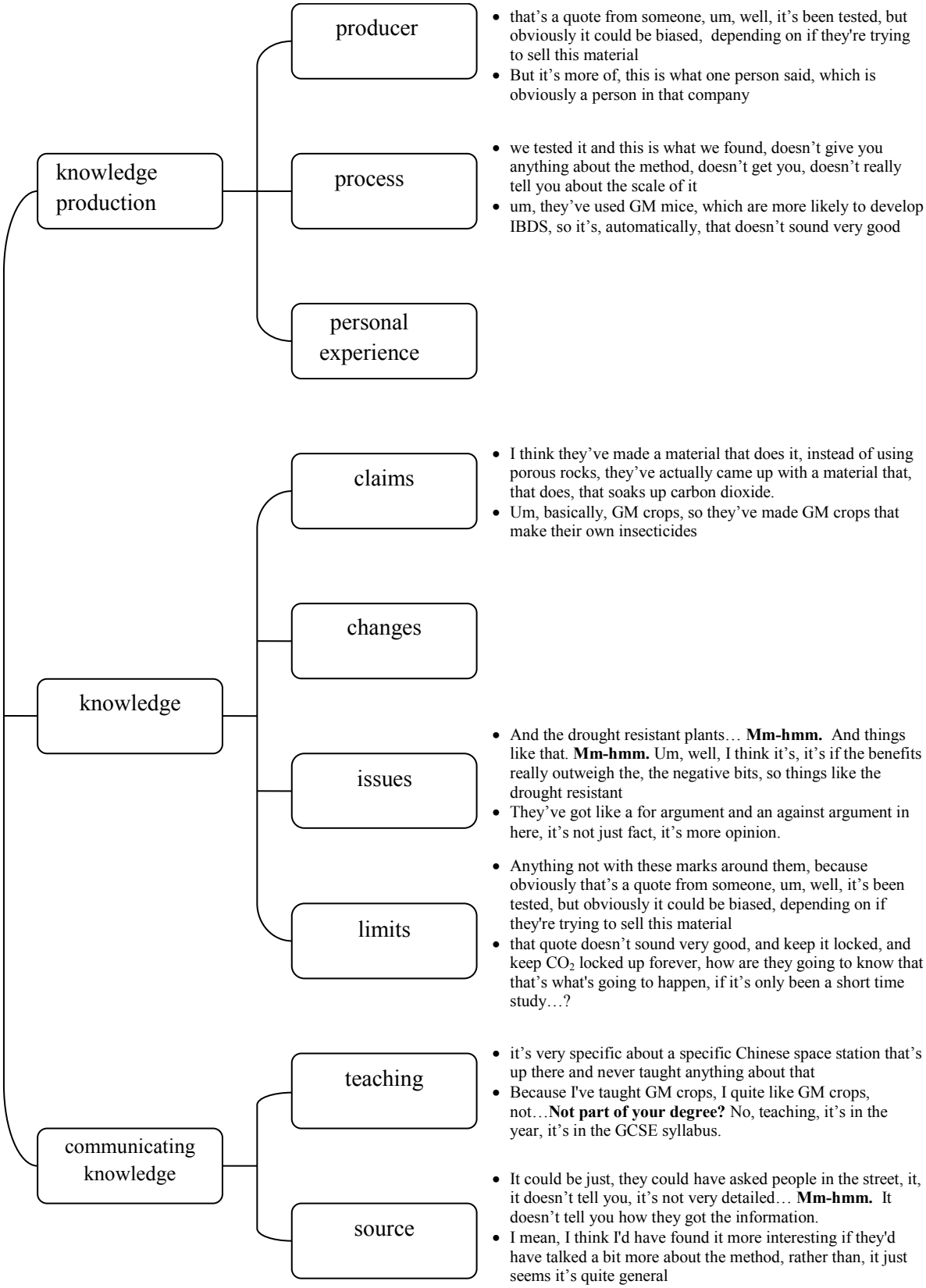
Simon


loci of knowing
external
no-one's really ever been able to explain it… **Even to this…?** Well, that's what they say, yeah, they said there still hasn't been an explanation
It says they've found recently, um, a change in the balance and even some new organisms that have not been found in that part of the world before
personal
affective
I thought, that's interesting, that's something that I've never really thought about
I find them quite fascinating, um, and it was, and quite an informative article and … **Yeah.** Um, I was just very interested in it.
cognitive
metacognitive or epistemic
I think it was 85, if I remember rightly, it was somewhere around there that it was sent away
Um, I remember, I, I can't remember, this was a, a couple of weeks ago now, I can't remember, um, the, the numbers

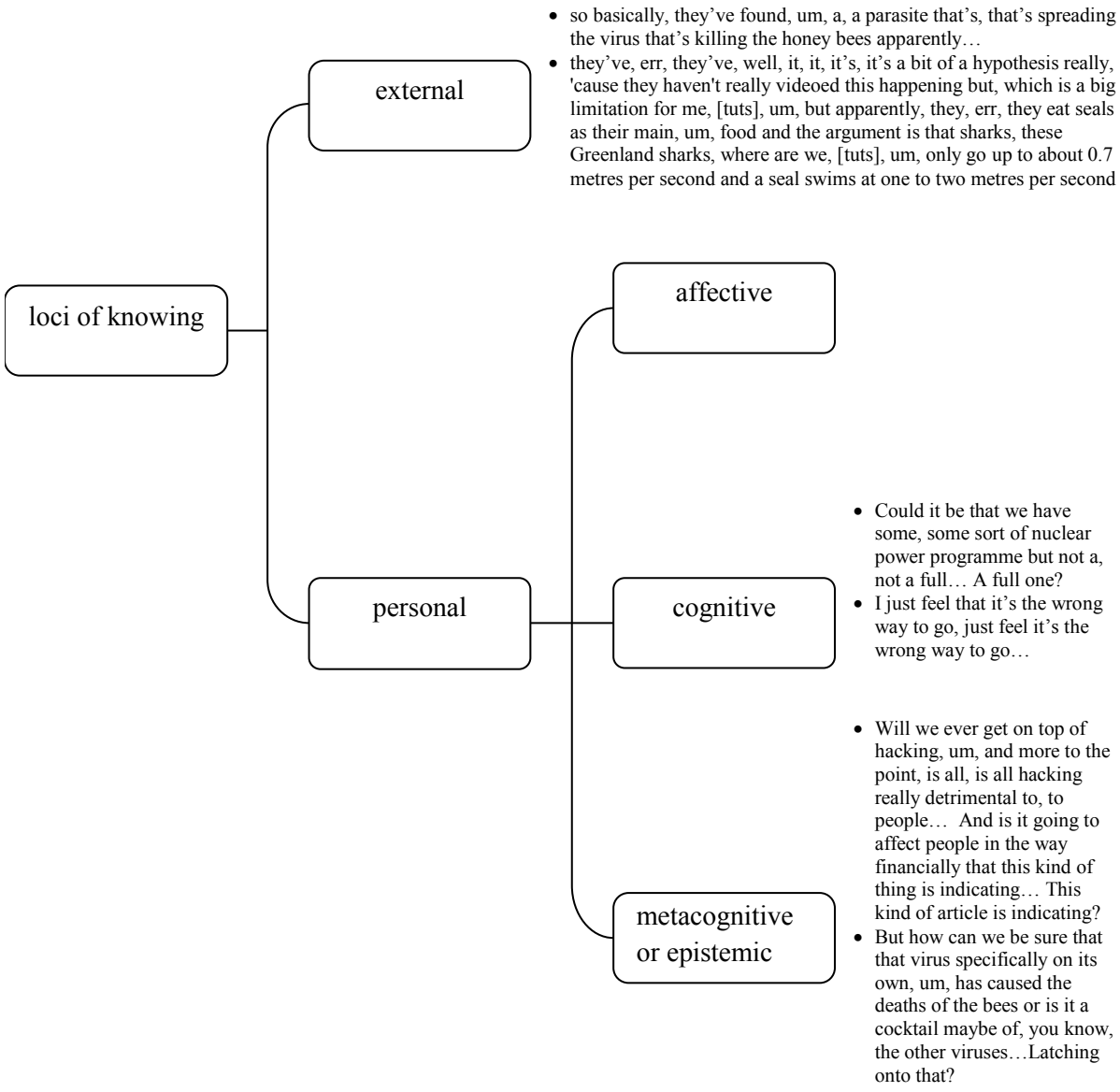

knowledge production
producer
process
personal experience
talking about collecting a lot of data, err, not a huge amount about, you know, the, the real mechanics behind the, the, the ship itself
they've got no, um, sampling been done, there's no, um, like I said, it's an unidentified object, they haven't managed to… Mm-hmm. Say what it is or isn't yet
knowledge
claims
changes
issues
limits
they said there still hasn't been an explanation
they've found recently, um, a change in the balance and even some new organisms that have not been found in that part of the world before
how could you experiment with it and I wasn't sure
it hasn't been found out… Mm-hmm. Hasn't been discovered or explained
I can't remember, this was a, a couple of weeks ago now, I can't remember, um, the, the numbers
communicating knowledge
teaching
source
I thought, well, could we, could I use this in the classroom,
I've ever had to approach… Mm-hmm. Um, in school or in teaching
there wasn't any, any particle theory or any… No. Scientific content in the
The Guardian can report on it, but I would say that NASA's information would probably be more accurate

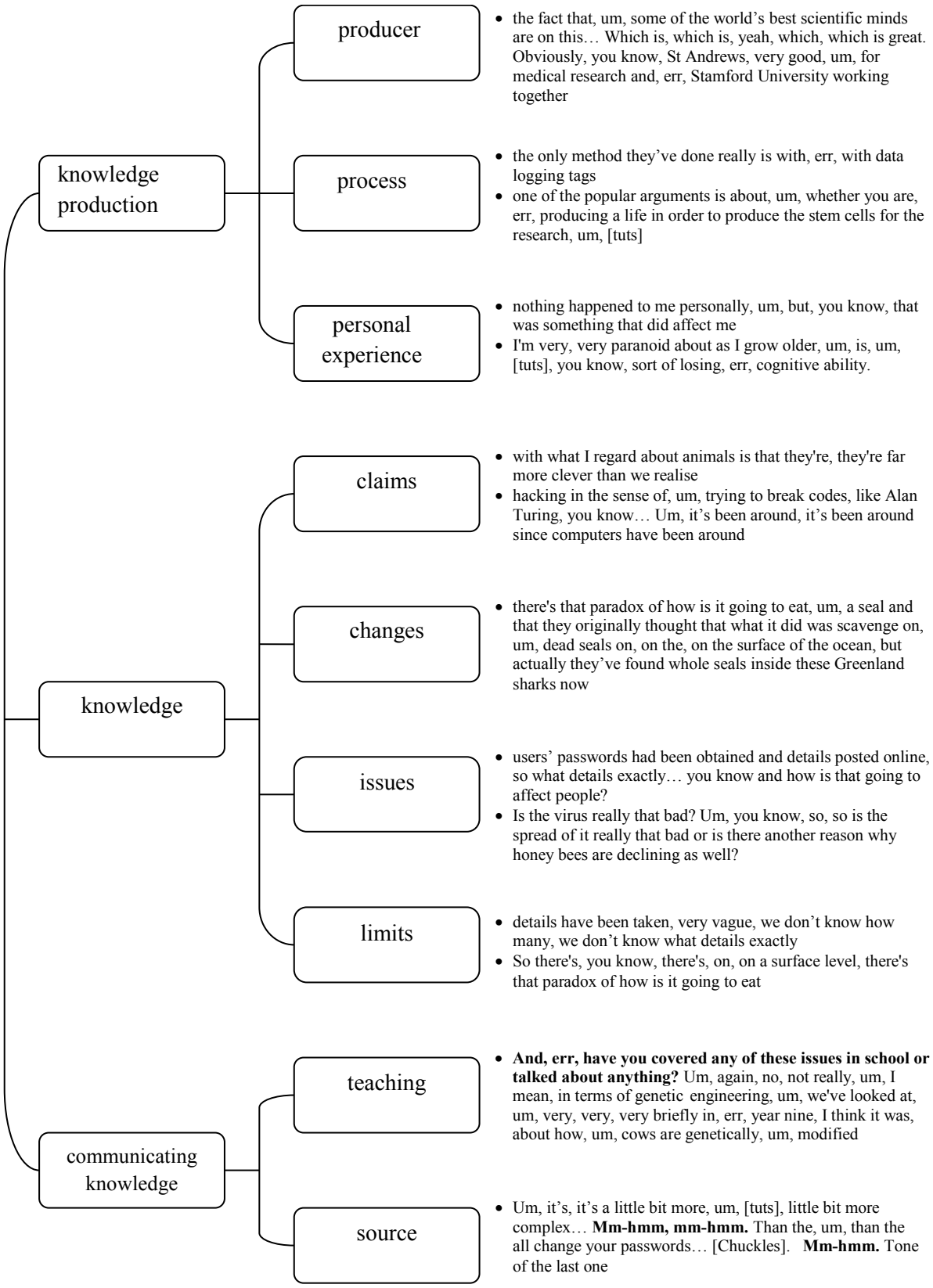
Becky


loci of knowing
external
So not really. I mean, there's a couple of, like that quote doesn't sound very good, and keep it locked, and keep CO_2 locked up for ever
Um, they've linked certain fats to increasing numbers of bacteria in the gut and then linking that to inflammatory disease
personal
affective
it's, it was interesting, it's stuff that I hadn't, it's a new development that I hadn't really heard of before.
I don't have any interest in it. It, it's not my field
cognitive
So yes, I'd, I'd agree with it, just because, you know, [laughs], sounds alright.
Um, I can understand why they'd want to go into space, but I don't know, this goes into a lot more about the actual, err, rocket and the space craft and I don't know anything about that.
metacognitive or epistemic
You could just, I mean, if you do research, you're more likely to find it than if you don't do research
So it looks like it's quite early on to just, 'cause they're basing their conclusions just on mice.

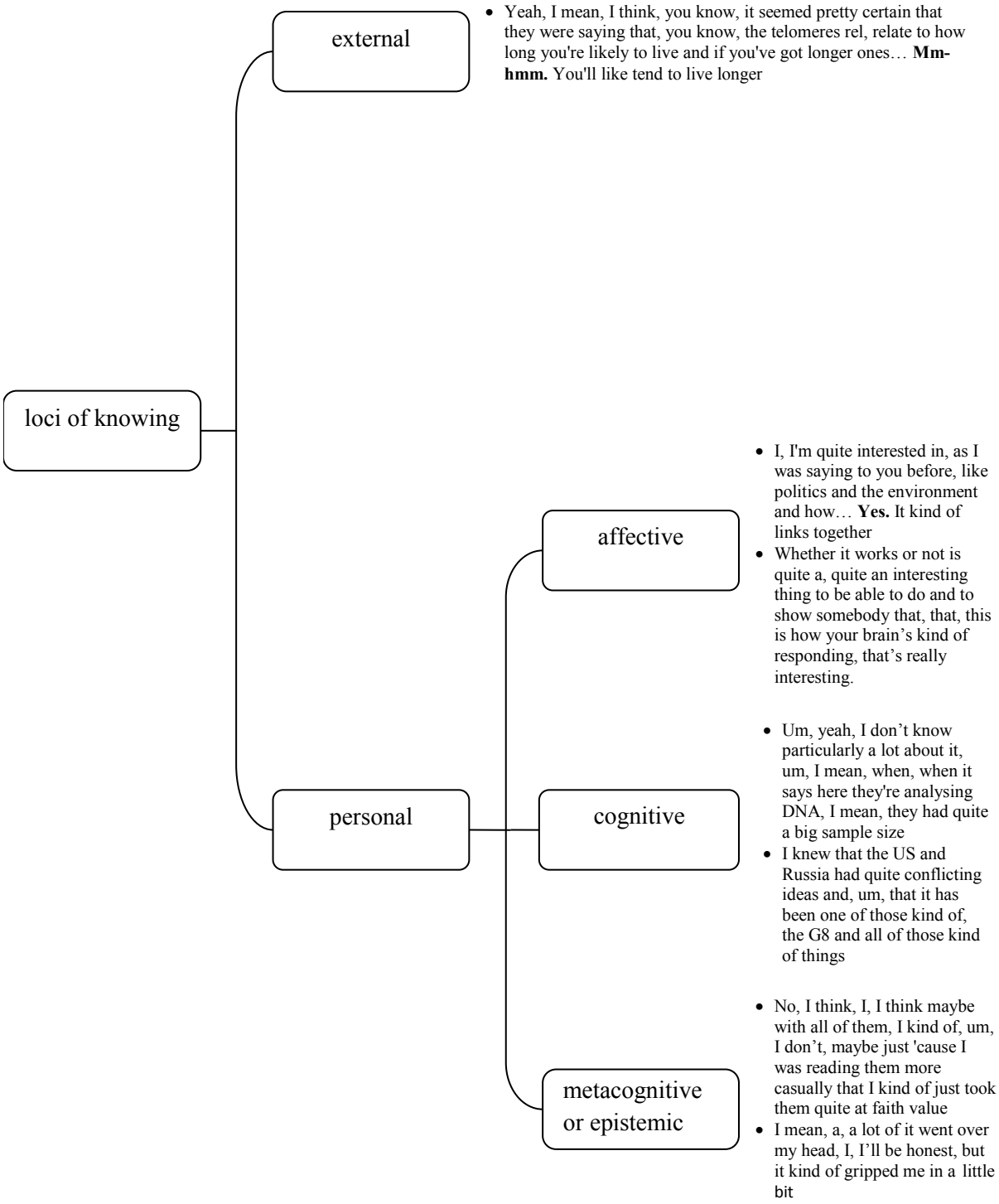

knowledge production
producer
that's a quote from someone, um, well, it's been tested, but obviously it could be biased, depending on if they're trying to sell this material
But it's more of, this is what one person said, which is obviously a person in that company
process
we tested it and this is what we found, doesn't give you anything about the method, doesn't get you, doesn't really tell you about the scale of it
um, they've used GM mice, which are more likely to develop IBDS, so it's, automatically, that doesn't sound very good
personal experience
knowledge
claims
I think they've made a material that does it, instead of using porous rocks, they've actually came up with a material that, that does, that soaks up carbon dioxide.
Um, basically, GM crops, so they've made GM crops that make their own insecticides
changes
issues
And the drought resistant plants… Mm-hmm. And things like that. Mm-hmm. Um, well, I think it's, it's if the benefits really outweigh the, the negative bits, so things like the drought resistant
They've got like a for argument and an against argument in here, it's not just fact, it's more opinion.
limits
Anything not with these marks around them, because obviously that's a quote from someone, um, well, it's been tested, but obviously it could be biased, depending on if they're trying to sell this material
that quote doesn't sound very good, and keep it locked, and keep CO2 locked up forever, how are they going to know that that's what's going to happen, if it's only been a short time study…?
communicating knowledge
teaching
it's very specific about a specific Chinese space station that's up there and never taught anything about that
Because I've taught GM crops, I quite like GM crops, not…Not part of your degree? No, teaching, it's in the year, it's in the GCSE syllabus.
source
It could be just, they could have asked people in the street, it, it doesn't tell you, it's not very detailed… Mm-hmm. It doesn't tell you how they got the information.
I mean, I think I'd have found it more interesting if they'd have talked a bit more about the method, rather than, it just seems it's quite general

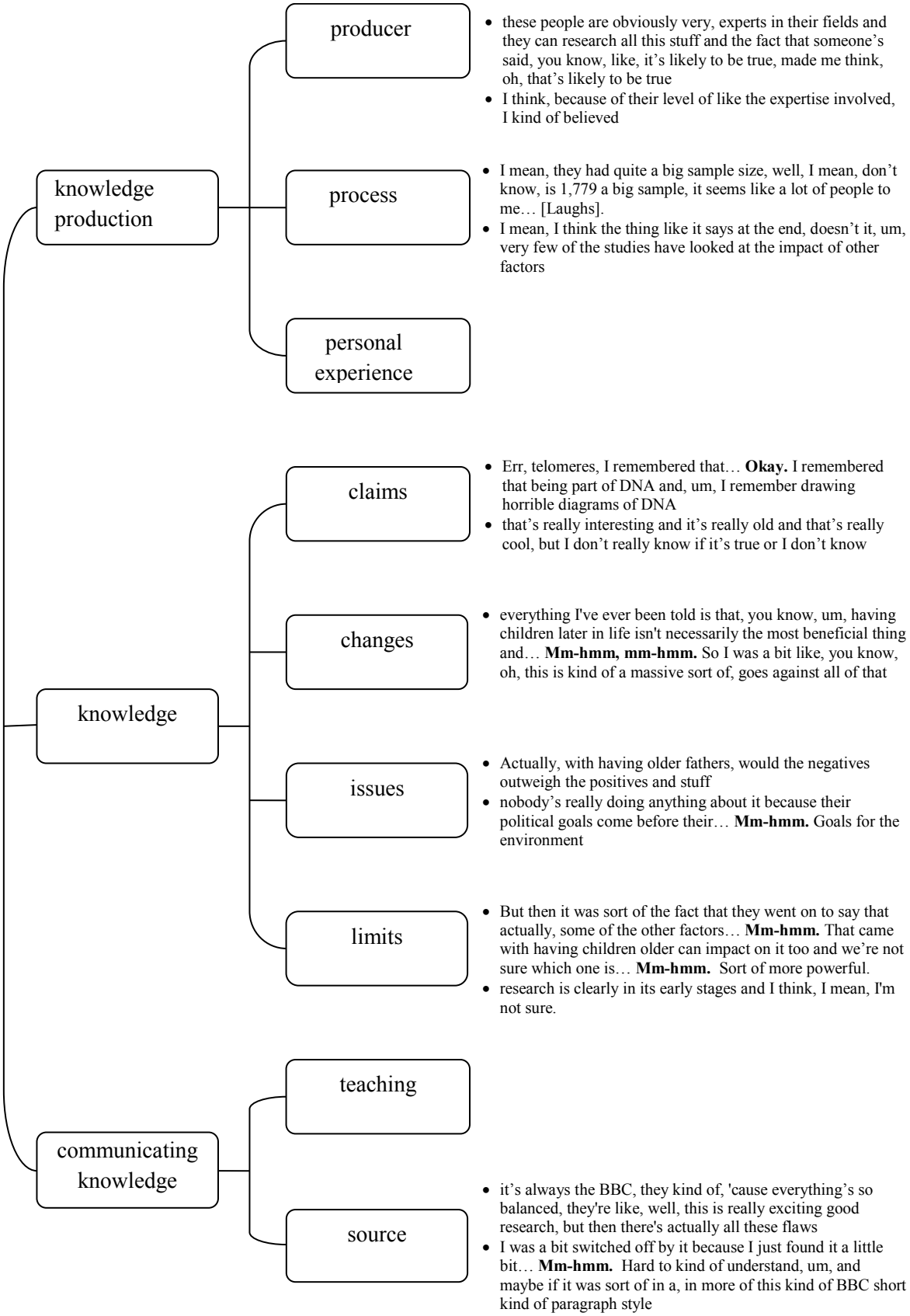
Nick


loci of knowing
external
so basically, they've found, um, a, a parasite that's, that's spreading the virus that's killing the honey bees apparently…
they've, err, they've, well, it, it, it's, it's a bit of a hypothesis really, 'cause they haven't really videoed this happening but, which is a big limitation for me, [tuts], um, but apparently, they, err, they eat seals as their main, um, food and the argument is that sharks, these Greenland sharks, where are we, [tuts], um, only go up to about 0.7 metres per second and a seal swims at one to two metres per second
personal
affective
cognitive
Could it be that we have some, some sort of nuclear power programme but not a, not a full… A full one?
I just feel that it's the wrong way to go, just feel it's the wrong way to go…
metacognitive or epistemic
Will we ever get on top of hacking, um, and more to the point, is all, is all hacking really detrimental to, to people… And is it going to affect people in the way financially that this kind of thing is indicating… This kind of article is indicating?
But how can we be sure that that virus specifically on its own, um, has caused the deaths of the bees or is it a cocktail maybe of, you know, the other viruses…Latching onto that?


knowledge production
producer
the fact that, um, some of the world's best scientific minds are on this… Which is, which is, yeah, which, which is great. Obviously, you know, St Andrews, very good, um, for medical research and, err, Stamford University working together
process
the only method they've done really is with, err, with data logging tags
one of the popular arguments is about, um, whether you are, err, producing a life in order to produce the stem cells for the research, um, [tuts]
personal experience
nothing happened to me personally, um, but, you know, that was something that did affect me
I'm very, very paranoid about as I grow older, um, is, um, [tuts], you know, sort of losing, err, cognitive ability.
knowledge
claims
with what I regard about animals is that they're, they're far more clever than we realise
hacking in the sense of, um, trying to break codes, like Alan Turing, you know… Um, it's been around, it's been around since computers have been around
changes
there's that paradox of how is it going to eat, um, a seal and that they originally thought that what it did was scavenge on, um, dead seals on, on the, on the surface of the ocean, but actually they've found whole seals inside these Greenland sharks now
issues
users' passwords had been obtained and details posted online, so what details exactly… you know and how is that going to affect people?
Is the virus really that bad? Um, you know, so, so is the spread of it really that bad or is there another reason why honey bees are declining as well?
limits
details have been taken, very vague, we don't know how many, we don't know what details exactly
So there's, you know, there's, on, on a surface level, there's that paradox of how is it going to eat
communicating knowledge
teaching
And, err, have you covered any of these issues in school or talked about anything? Um, again, no, not really, um, I mean, in terms of genetic engineering, um, we've looked at, um, very, very, very briefly in, err, year nine, I think it was, about how, um, cows are genetically, um, modified
source
Um, it's, it's a little bit more, um, [tuts], little bit more complex… Mm-hmm, mm-hmm. Than the, um, than the all change your passwords… [Chuckles]. Mm-hmm. Tone of the last one

Katie


loci of knowing
external
Yeah, I mean, I think, you know, it seemed pretty certain that they were saying that, you know, the telomeres rel, relate to how long you're likely to live and if you've got longer ones… **Mm-hmm.** You'll like tend to live longer
personal
affective
I, I'm quite interested in, as I was saying to you before, like politics and the environment and how… **Yes.** It kind of links together
Whether it works or not is quite a, quite an interesting thing to be able to do and to show somebody that, that, this is how your brain's kind of responding, that's really interesting.
cognitive
Um, yeah, I don't know particularly a lot about it, um, I mean, when, when, when it says here they're analysing DNA, I mean, they had quite a big sample size
I knew that the US and Russia had quite conflicting ideas and, um, that it has been one of those kind of, the G8 and all of those kind of things
metacognitive or epistemic
No, I think, I, I think maybe with all of them, I kind of, um, I don't, maybe just 'cause I was reading them more casually that I kind of just took them quite at faith value
I mean, a, a lot of it went over my head, I, I'll be honest, but it kind of gripped me in a little bit


knowledge production
producer
these people are obviously very, experts in their fields and they can research all this stuff and the fact that someone's said, you know, like, it's likely to be true, made me think, oh, that's likely to be true
I think, because of their level of like the expertise involved, I kind of believed
process
I mean, they had quite a big sample size, well, I mean, don't know, is 1,779 a big sample, it seems like a lot of people to me… [Laughs].
I mean, I think the thing like it says at the end, doesn't it, um, very few of the studies have looked at the impact of other factors
personal experience
knowledge
claims
Err, telomeres, I remembered that… Okay. I remembered that being part of DNA and, um, I remember drawing horrible diagrams of DNA
that's really interesting and it's really old and that's really cool, but I don't really know if it's true or I don't know
changes
everything I've ever been told is that, you know, um, having children later in life isn't necessarily the most beneficial thing and… Mm-hmm, mm-hmm. So I was a bit like, you know, oh, this is kind of a massive sort of, goes against all of that
issues
Actually, with having older fathers, would the negatives outweigh the positives and stuff
nobody's really doing anything about it because their political goals come before their… Mm-hmm. Goals for the environment
limits
But then it was sort of the fact that they went on to say that actually, some of the other factors… Mm-hmm. That came with having children older can impact on it too and we're not sure which one is… Mm-hmm. Sort of more powerful.
research is clearly in its early stages and I think, I mean, I'm not sure.
communicating knowledge
teaching
source
it's always the BBC, they kind of, 'cause everything's so balanced, they're like, well, this is really exciting good research, but then there's actually all these flaws
I was a bit switched off by it because I just found it a little bit… Mm-hmm. Hard to kind of understand, um, and maybe if it was sort of in a, in more of this kind of BBC short kind of paragraph style