Young adults' accounts of scientific knowledge when responding to a television news report of contested science

There is now a groundswell of support for reform in science education towards the goal of citizenship (Aikenhead, 2006; OECD, 2006; Roberts, 2007). Central in this perspective is the role of decision making on contemporary social issues involving scientific knowledge, or socioscientific issues, for example, global warming, genetically modified crops and foods, the risks of mobile phone use or of living near high voltage power lines or toxic landfill sites. In many cases this scientific knowledge is not the reliable knowledge of school science but the contested knowledge of 'science-in-the-making'. Such knowledge is commonly presented in the popular media and frequently accessed through the medium of television news and current affairs programmes.

An increasing number of studies are now exploring how students engage with socioscientific issues and potential learning outcomes (reviewed by Sadler, 2004). Few studies in science education, however, have examined how young people carry out such decision making after leaving school or how they respond to the science presented in television news reports. Although in the years immediately following formal schooling there are many influences in young adults' lives and a variety of sources of information and knowledge available to them, exploring young people's discussion in this context is likely to provide insights into how school science (particularly their concept knowledge and their understanding of the nature of science) has prepared them for socioscientific decision making. Implications can be drawn about the kinds of knowledge which may be useful for this activity.

This paper reports on young adults' (recent school-leavers) views of science in the context of their decision making on mobile phone safety, an issue where scientists still disagree about potential health risks. It lies within the research domain of the *public understanding of science*. Studies in this domain are distinguished from traditional science education research in several ways. Firstly, their setting is not classrooms or schools but the wider community and thus is concerned with 'real life' in contrast to structured (and possibly contrived) classroom activities. The focus of the studies is adult engagement with science in a variety of community settings, which often involves participation in personal or collective decision making. Secondly, researchers interested in the public understanding of science include sociologists as well as science educators, and the theoretical frameworks referred to draw on the sociology of science. At the same time, many of these researchers draw important implications for science education. Such studies are of great relevance to science educators because they reflect back to us the kind of experiences with science that our students are likely to encounter in their future lives, as new technologies and products of science proliferate. Ryder (2001, 2002) has drawn on this literature, reviewing 31 studies of adult engagement with science, to develop a framework for epistemic learning in school science directed towards the goal of citizenship.

Within the domain of traditional science education research, this study can be viewed as examining an enactment of the *scientific literacy* of these young people. Scientific literacy is variously defined but here it is useful to draw upon Roberts' *Vision II* of scientific literacy, which "derives its meaning from the character of situations with a scientific component, situations that students are likely to encounter as citizens" (Roberts, 2007, p. 730) in their present or future lives. This is not to reject Roberts' *Vision I,* "looking inward at the canon of orthodox natural science" (p. 730) but rather to see these two visions as complementary. The interest of this study was to start from the situation that these young people find themselves in and look for what is relevant to them for decision making, *within* science and *about* science, and thus to consider what might be taught in school science to support such science-related assessment of issues in people's lives. It adopted initially what Solomon (1992, p. 432) called a "citizen-enabling" rather than a traditional school science perspective.

Norris and Phillips (2003) have distinguished 'fundamental' and 'derived' senses of scientific literacy and drawn attention to the need for science educators to attend to both. They describe the essential role of text (seen in terms of a cumulative discourse, not simply written words) in scientific literacy and see fundamental literacy as "comprehending, interpreting, analysing and critiquing texts" (p. 229). Derived literacy refers to knowledgeability, learning and education. Although Norris and Phillips have used 'text' mainly in the traditional sense of written materials, language educators have for a considerable time now included most other forms of communication in this term. Lemke (2002) has argued for science educators to engage with 'multimedia literacy'. Similarly, Jarman and McClune (2010) have urged science educators to address 'media awareness' and have developed a framework to assist teachers to incorporate approaches to media text into science teaching. They considered this in relation to print news media but their findings apply equally well to television reporting.

Since this research addresses young people's 'accounts of scientific knowledge' it is also related to science education studies concerned with understandings of the nature of science. The importance of such understanding in science education is undisputed, but research exploring how best to improve this knowledge for teachers and students is inconclusive (Abd-El-Khalick & Lederman, 2000). The present study will underline the importance of understanding how science works, but it is, however, distinguished from earlier nature of science studies in examining data from a real life decision making context, in contrast to studies which have used more contrived situations and survey data.

Closely-related studies of student engagement with socioscientific issues include Driver, Leach, Millar and Scott, (1996) and Sadler, Chambers, and Zeidler (2004), both of which focussed on student responses to disagreement between scientists, and were concerned with understandings of the nature of science. Kolstø's (2000) research explored a socioscientific issue of personal relevance to the participants since it affected their local community, but it did not share the focus of the other two studies cited on responses to conflict between scientists.

Driver et al. (1996) analysed the discussion of 16 groups of four 16 year old students considering two socioscientific issues (the Wegener continental drift dispute, and the safety of food irradiation) after reading written stimulus material. Their research question was, "How do students interpret conflicts of ideas in the science community?" which is very similar to the focus of this research. Student explanations involved both social and empirical factors. They generally considered lack of evidence to have caused the disagreement and saw empirical evidence as a source of facts which describe directly how the world is. Many acknowledged the contested nature of some 'facts' but did not seem to have a clear understanding of the role of social factors (both internal and external to the science community) in the construction of scientific knowledge, particularly the importance of debate. Instead they drew mainly on everyday ideas of bias and vested interests in explaining the scientists' disagreement.

Similarly Sadler et al. (2004) presented 84 students (14-17 years) in four average ability level biology classes with contradictory research findings (in written form) about global warming, to which they responded in writing to a series of open-ended questions; later 30 students were interviewed using the same questions. The researchers were interested in the students' views of science and how they interpreted conflict between scientists. They reported that students generally took account of the social embeddedness and tentative nature of scientific knowledge but showed limited understanding of the nature and role of data. Of particular interest here is that most students were 'comfortable' with contradictory findings. They explained the scientists' different interpretations by referring to the scientist's beliefs and opinions, different experimental approaches, different analyses and asking different questions. In decision making on the issue they tended to favour their own personal concerns and prior beliefs over the scientific knowledge on offer, leading the authors to suggest a tendency to compartmentalize scientific knowledge and personal experience.

Both these studies used written stimuli, in contrast to the viewing of a television news report used in this research. Few studies in science education have examined responses to television news reports viewed by participants. An early classroom study by Solomon (1992) used television reports of socioscientific issues as stimuli for unstructured discussion by 17 year old students. Interest lay in exploring the kinds of knowledge used, the nature of the discussions and their value for educational purposes. Solomon observed an interweaving of different kinds of knowledge (predominantly social and personal) together with attitudes of civic awareness and empathy. She noted that underpinning all the discussion was familiarity with simple science terms. However the usual logical forms of argument used in science were absent and the form of talk which predominated was rhetorical. Solomon concluded that small group discussion skills are paramount if the aim in science education is to produce citizens prepared for informed decision making on contemporary issues involving science.

The aim of the study reported here was to explore how young people who have recently completed their formal schooling (where science is generally portrayed as ‘certain’ or highly reliable knowledge) engage with the uncertain science of a contested issue. Contradictory research findings about the potential health risks of mobile phones were chosen as a topic likely to engage participants because this technology has now become an indispensable part of most young people’s lives, and because judging the risk to themselves is an example of personal decision making where scientific knowledge (concepts or knowledge about science) could be expected to play some role. An underlying motivation was concern about the extent to which current school science prepares students to engage with uncertain science in their lives.

The choice of a media report as stimulus to the discussion was seen as more adequately representing young people’s everyday experience of access to science-in-the-making than written information, as used in earlier studies. The particular news report chosen became available at the time of engagement of the participants. It was thought likely to interest them and stimulate responses about science partly because its findings were fairly dramatic, with a new study reporting findings directly opposite to a similar one published five years previously. As is typical of television news reports, it was very short (three minutes) and did not provide details of the scientific experiments. It included traditional images of scientists and footage of an industry representative expressing an opinion about the findings. The transcript of the news report is shown in Figure 1.

[Place Figure 1 about here]

Figure 1 Transcript of television news report

ABC 7 pm News, Friday 31 August 2002

Presenter: A major new Australian study has raised doubts over links between mobile phone emissions and cancer rates. Scientists in Adelaide say they found no connection between cancers in laboratory mice and mobile phone exposure.

Image: *White mice being loaded by white-coated scientists into compartments on a wheel-like structure*

Presenter: These white mice have a potential good tale for all Australia's 12 million mobile phone users. For an hour a day over 2 years, 1600 of them were exposed to mobile phone emissions to see if they'd get cancer.

Scientist 1: We found that there was no change, in the natural progression of tumours--

Presenter: Dr Kuchel's work seriously undermines the results of a landmark 1997 Adelaide study. It created worldwide concern after finding cancer rates doubled in mice exposed to mobile phone emissions.

Scientist 1: This study most certainly does not add any fuel to the fire. It in fact throws some water on the fire.

Image: *Person holding mobile phone which rings.*

Presenter: Not surprisingly it's a fire that the mobile phone industry is keen to see extinguished.

Mobile phone company representative: What the Adelaide mouse study does, is add to the weight of scientific evidence that for some time now has been showing that mobile phones do not cause adverse health effects.

Presenter: Others insist it's too early to judge. In Sydney and Melbourne Professor Bruce Armstrong is studying humans with cancer, part of an international effort to see if it's linked to mobile phones.

Scientist 2: My position really at this stage is one of agnosticism, that is I don't know. I think that it's possible that mobile phone use could increase risk of tumours--

Presenter: Then there are other health questions associated with mobiles, besides cancer. Dr Kuchel says his mice haven't got the answers but Professor Armstrong's study might.

Scientist 1: What we are <u>not</u> saying, is that we can say anything about headaches, sleep disorders, that's up to the human epidemiological studies.

Presenter: Those results are still some way off. The Armstrong study won't be completed until 2004. Simon Royal, ABC News, Adelaide. *End of news report*

The disagreement between scientists here was two-fold: in the directly contradictory experimental results, and in the second scientists' statement that an increased risk is possible, contrasting with the first scientist's assertion that his results "throw some water on the fire".

It can be argued that the limited information of such a news report provides a fragile basis for interpreting participants' views of science and that their responses may be different in a different context (such as another news report on the same issue, or a different issue). It is accepted here that findings represent only participant responses in this particular context. However, Sandoval (2005) has reported a growing body of research that suggests that "students' epistemological views of science are not stable, coherent frameworks, but inconsistent, fragmented and possibly unstable beliefs" (p. 12), which are unstable across contexts. Perhaps useful here is Sandoval's notion of 'practical epistemologies', being sets of beliefs constructed about one's own knowledge production in particular settings. In this setting young people are likely to apply their views of media activities and purposes in interpreting the science presented. The focus of the present research is the views of science participants espoused in this context and its implications for school science education. Findings are not claimed to be generalisable but to provide insights into young people's understandings or views of science in this everyday context. The news report acted as a stimulus for discussion. Data enabling exploration of views of science in this context was provided by subsequent individual interviews which linked back to participant contributions to the group discussion.

The overall research question guiding the study was:

> What are young people's *accounts of scientific knowledge* in the context of 'science-in-the-making', in particular the contested knowledge of recent research into the possible health risks of mobile phones?

The choice of 'accounts of scientific knowledge' was deliberate, for reasons similar to those of Kolstø (2001) in analysing his data about students' responses to a socioscientific issue in terms of 'content-transcending topics' rather than 'nature of science understanding'. It broadened the analysis to incorporate more dimensions of the young people's responses than the traditional categories of nature of science studies. Here the term 'account' was used to refer to the complex of concepts, beliefs and values which participants drew upon and articulate in applying their knowledge to the problem at hand. This is similar to the use of 'account' in ethnomethodology where an account (Cohen, Manion & Morrison, 2007) is speech which accompanies or follows an action, justifying it, serving to explain past, present and future oriented actions. Thus the young people's accounts included the reasons for their responses, their views of the nature of science, their attitudes towards science in this context and science in general, their concept knowledge, their positioning of science in their decision making, and aspects of their school science experiences.

The overall research question was investigated more specifically in terms of the following sub-questions:

1 How do these young people respond to the uncertainty of this knowledge, expressed in terms of disagreement between scientists about the interpretation of experimental data?

2 How is school science represented in these accounts in terms of (a) understanding of the nature of science and (b) concept knowledge?

3 How do they position scientific knowledge in their decision making on this issue? What other factors (including other knowledges) are involved? What is the role of risk assessment in their decision making?

This paper will focus on findings relating to questions 1 and 2. Here I present the young people's direct responses to the contested science, their elaboration of these responses, their views of the nature of science and the role of their science concept knowledge in this context. Their decision making on the issue will be reported in a separate paper.

Methodology

This research was based on a critical realist ontology (Bhaskar, 1975, 1979) and an epistemology of moderate social constructionism (Longino, 2002). From this perspective the cognitive practices of science (observation-experiment and reasoning) have a social dimension which provides part of their warranting force, introducing specific contextual influences on justification. Assessment of the adequacy of evidence involves deciding which aspects are relevant and what counts as sufficient evidence, which are socially influenced criteria. Further, the production of scientific knowledge involves social interaction in the form of criticism within the scientific community, this interaction being as vital as that with the natural world to the production of reliable knowledge.

Following foundational studies in public understanding of science research (Layton, Jenkins, MacGill & Davey, 1993; Irwin & Wynne, 1996) this research also assumed an 'interactive' model of public understanding of science, contrasting with the more traditional 'cognitive deficit' model. From this interactive perspective people interacting with science are not simply passive recipients or rejectors of science but rather they view scientific knowledge in the light of their other knowledges and make interpretations and judgments about the scientific knowledge accordingly.

The methods chosen were focus group discussions and semi-structured, individual interviews. Participants were 28 young adults (18-26 years) of whom 19 were aged 21 years or younger and thus very recent school leavers. 'Opportunity' (or convenience) and 'snowball' sampling (Brown & Dowling, 1998) were used to gather participants. The opportunity of personal contacts was used to select an initial participant for each focus group. This participant was invited to identify others who were friends for inclusion in the study ('snowball' sampling). They were selected across a range of socioeconomic and science education backgrounds. This information was ascertained through the completion of a short questionnaire in the individual interviews; as the study progressed participants with particular backgrounds were sought to achieve this range and balanced gender participation. The questionnaire also included details of participants' engagement with informal sources of scientific knowledge, such as magazines, newspapers, the Internet, membership of groups and parental interests and occupations. About half (13) of the participants completed their formal science schooling at Year 10 (aged 15 years) and 15 participants had continued into Year 11 and 12 science study. Of these 15, seven were engaged in tertiary study involving some science subjects. Six participants were in fulltime employment and not studying, five were in fulltime study and not working, 14 were studying and working part-time, and three were unemployed and not studying.

The use of focus groups was an appropriate method for three reasons. Firstly, interest lay in young people's spontaneous discourse around uncertain scientific knowledge; access to this required a situation where they could engage in discussion, constructing discourse in response to the stimulus provided. Secondly, focus groups are a source of rich data as there is a synergistic effect of engaging a group of people in discussion of a topic (Lidstone, 1996). Greater spontaneity and candour can arise in a group discussion and lead to the expression of a greater variety of perspectives than would occur in individual interviews. Thirdly, because mobile phones are the prime means of social communication for these young people with their friends (only 2 of 28 did not own mobile phones) it was considered that the topic would easily generate this kind of discussion.

Conversely, it can be argued that in focus groups one may obtain only a limited consensual view of the topic because of limiting group interactions. Awareness of this potential, however, allows the researcher to intervene where necessary, as was the case on several occasions in this study, to prevent these negative dynamics. Further, all of the participants were later interviewed individually to give them the opportunity to elaborate their personal views and to allow the researcher to explore more fully their contributions to the group discussion, particularly their ideas about science.

Participation in the focus groups was in their friendship groups. Involving friends in focus groups has two principal advantages: it provides more 'natural' data since participants may talk in everyday life about the topic with these same people and because of their relationship they are likely to make reference to shared experiences, 'collective remembering' (Kitzinger, 1994), which will stimulate discussion. Furthermore, in the focus group method group interaction is encouraged and this is more likely within a group of friends, provided, of course, that sensitive topics are not broached. Thus the participants included seven groups of friends and discussions took place in locations of their choosing rather than a more formal university setting.

Procedures

In order to contextualise these young people's responses to the news report, in the first 15 minutes of the focus group discussion the group of friends was invited simply to talk about their mobile phones, with no prompts provided by the researcher. During this time they elaborated on the role of this technology in their lives. To focus discussion on the issue of contested science, the group was then shown a video recording of a recent national television news report (For transcript see Figure 1). Following this viewing the participants were invited with the question, "What do you think of that?", to share their responses to the news item. If spontaneous discussion did not address the disagreement between the scientists I asked later, "Why do you think the scientists disagreed about findings and possible risks?" It was expected that the contradictory nature of the report would stimulate discussion about uncertain scientific knowledge and scientists or science in general and that links would be made with their own mobile phone use. I played a minimal role in the discussion, providing only an occasional question to ensure that topics of interest were addressed. These included: responses to the uncertainty or contestedness of the science, interactiveness in relation to the scientific knowledge, the positioning of the science in relation to other knowledges, the role of school science knowledge, and judging the credibility of the science.

On a second occasion (after preliminary analysis of the focus group discussions) all the participants were interviewed individually for 30-40 minutes, again at a location of their choosing. These interviews were semi-structured...I first asked each participant to suggest why the scientists in the news report had disagreed about experimental findings and possible risk. I then invited elaboration of this response. From a preliminary reading of the focus group transcripts I noted statements of interest in relation to ideas about science and invited the participant to elaborate on these. Through further questioning I probed their expectations of certain or reliable knowledge about mobile phone health risks. In these ways the interview was constructed as an opportunity or invitation to express their views of the nature of science in this context. Since the focus group discussions involved almost no mention of radiation I also probed their understanding of this concept to see if it was available to them as a knowledge resource. With permission from the participants all the focus groups and interviews were audiotaped and later transcribed.

Analysis

Data analysis involved the interaction of theory and empirical data, best described by Layder's (1998) adaptive theory approach, in which "prior theoretical concepts and models suggest patterns and 'order' in emerging data while being continuously responsive to the 'order' suggested or unearthed by the data themselves" (p. 27). This approach centralises 'emergent theory' but is distinguished from grounded theory in that "it makes use of elaborated conceptual models which stand prior to data collection at certain points in the research"….it simultaneously privileges (prior) theory and research data in the emergence of new theory". Thus the data was framed in terms of moderate social constructionism and an interactive model of the public understanding of science.

The main analytic tool was discourse analysis, conducted with the support of *NVivo* software. The term discourse analysis is used in a variety of ways to describe the analysis of words or chunks of text. Here a form of content analysis was used. The first stage of analysis involved a process of indexing or non-exclusive coding which identified the *points* or *issues* raised by participants in the focus group discussions. The term 'non-exclusive' means that some coding categories were overlapping or partly contradictory; this was allowed in order not to omit prematurely particular issues. An example of a point/issue is a participant's comment regarding the vested interest of a scientist speaking about scientific research findings in the television news report, which was coded as 'funding'. These codes were then interpreted in terms of *themes*, such as 'positioning of science' and 'responses to uncertainty'. These themes and issues (See Appendix A) were determined partly through induction but also linked back to the literature and theoretical framing of the study. Since the discourse analysis here was at the level of a content analysis, a low level of inference was involved. The coding was checked by an experienced researcher who read the transcripts of one group of participants and concurred with the coding attributed to the discourse data. Guba and Lincoln's (1989) four criteria for 'trustworthiness' were met within the constraints of this research setting (it was not appropriate to claim 'prolonged engagement' or 'persistent observation' and 'member checking' was not feasible).

RESULTS

Explanations of scientists' disagreement

In five of the seven focus group discussions, participants spontaneously addressed the issue of the scientific disagreement immediately following the news report. In another group (composed of the youngest participants) the spontaneous response was one of disbelief or denial that there could be a serious problem and a reference to trust that authorities, including phone companies and governments, would have published warnings if this was the case. In this and another group I specifically asked for their reaction to the disagreement between the scientists. That most groups addressed the disagreement spontaneously might be seen as a natural response to a news report presenting opposing viewpoints. On the other hand it could imply that they consider that scientists disagreeing is unusual and needs explaining.

Firstly I present a summary (Table 1) of frequencies of the reasons for the disagreement, referred to by the participants in the focus group discussions and the individual interviews. These frequencies are presented as data description only. Then the categories of response are elaborated with examples from the focus group and interview transcripts.

[Insert Table 1 about here]

Table 1 Frequency of responses

Reasons given for scientists' disagreement	Frequency of response	
	Focus groups (7)	Individual interviews (28)
Scientists' personal opinions on the issue of mobile phone safety played a role in producing the disagreement	5	24
The source of funding affected interpretation of results	5	14
Role of media – misinformation, omission, deliberate use of controversy, presenting opposing opinions to demonstrate objective journalism	5	8
Different questions were being investigated by different scientists	3	3
Different methods were being used by different scientists	3	15
The methodology was flawed	3	0
Human error by scientist(s)	0	6
Theoretical differences between scientists	0	3
Argument is necessary for consensus building	2	16
Reference to broader context:		
More time is needed for further research	5	2
Not all variables can be controlled	4	11
More time is needed for human symptoms to show up	5	0
More information is needed	0	2

This categorisation of responses does not reflect the richness of the talk, the flow of ideas and the shifting nature of the focus group discussion. In each group several different responses to the scientists' disagreement were offered. Participants would sometimes shift positions over time or suggest contradictory points of view. These contradictory positions, along with comments about never having thought or talked about the issue of mobile phone safety before, suggest that for many participants the focus group discussion was an exploration of ideas rather than a statement of a predetermined position. On the other hand there was a certain stability in their responses, since most re-iterated and often elaborated in the individual interviews the same points of view that they had offered in the focus groups.

The role of scientists' personal opinions on the issue of mobile phone safety

This response category was strongly represented across both the group and individual interview discussions. Participants in five of the seven groups and almost all (24 out of 28) of the participants in the individual interviews considered that scientists' "opinions" played a role in producing the disagreement.

In four of these five groups the "opinions" referred to were about the possible health risks of mobile phones, the socioscientific issue itself, rather than differing opinions on other topics such as theories or methods. Similarly in the individual interviews participants used "opinions" mainly to refer to positions held regarding the safety of mobile phones. Only three participants (across three groups) used the word "opinion" in relation to differing theories or theoretical assumptions underlying experiments. It can be argued that participants were not using the word 'opinion' in a lay sense, but rather meant a scientifically informed opinion, which is likely to be heavily theory-laden. However, ten participants explicitly described scientists as being like 'other people', in holding a variety of opinions on the issue of whether there is a potential health risk from the use of mobile phones and also in tending to make judgments influenced by these personal opinions. For example:

> People have their own opinions… if someone is dead-set that phones will give you cancer then they're going to aim to prove that. If people say that it's not going to then they're going to try and prove that it's not…so, they would look for something that they want. (Participant 1c)

Nowhere in the discourse data was the use of 'opinion' linked with scientific knowledge, thus it seems reasonable to assume that the term was used in an everyday sense, suggesting a strong role for personal rather than scientific opinions in the construction of scientific knowledge. In the above extract the participant appears to suggest that motivation to do the experiment is linked with *proving* an opinion on the issue of possible health risks. Four participants described experiments as a means used by scientists to *test* their opinions. They considered that scientists would be willing to change these opinions if they were not supported by the experimental data.

In the individual interviews participants who spoke about scientists' opinions as a possible cause of the disagreement between the scientists were invited to elaborate on how this might happen. Possibilities proposed included the use of different methods, differing interpretations of evidence, and the manipulation of data. Four participants saw different opinions on the issue itself as leading to differing interpretations of evidence. Thus participant 3d observed:

> If you're a scientist and you've got these differing views, often what you want to see you will see. So your view depends on your viewpoint and ah, yeah so you research something you want.

Two participants linked scientists' opinions on the issue with the possible manipulation of data, suggesting that if the results did not support the scientist's opinion, he or she may alter the results.

Six participants (who did not describe scientists as like 'other people') pointed out that scientists generally try not to let their personal opinions influence their work. They described scientists as engaged in a search for knowledge and defended the 'objectivity' of scientists. Most expressed this in the form of hope that this is true, acknowledging the possibility of the situation being otherwise. In four instances, the influences of scientists' opinions about mobile phone safety was linked with funding.

The role of funding sources

In five out of seven group discussions the source of funding was raised as possibly producing the scientists' disagreement. In the individual interviews half of the participants spoke of this possibility. In this view scientists who are funded by private organisations were seen as being very likely to provide interpretations of research which would favour the interests of their sponsors. This would lead to disagreement if such interpretations were contrary to what more independent scientists would be likely to offer on the basis of the same empirical data. There were varying perspectives amongst these young people regarding the likelihood and extent of influence funding sponsors may have on scientific results. Some considered that such influence was 'a possibility' or that it might depend on which area of science was involved. Others thought that some sources such as the World Health Organisation or the United Nations would be more trustworthy than governments who in turn are more reliable knowledge sources than commercial companies. On the other hand some participants were very cynical, arguing that nowadays it is impossible to have knowledge independent of funding influence. These participants considered that scientists are ‘like us’ and corruptible by financial rewards, ‘everyone’s got a price’ and ‘you can buy any opinion you want’ (Participant 2c).

There were several ways suggested through which an experimental finding may be influenced by a funding sponsor. Participant 5b suggested that funding for research is provided with a particular outcome in mind, and that as a result the scientist would feel “pressure on facts to be interpreted differently”. Participant 5a spoke of this pressure possibly leading to selectiveness regarding which data is taken into account. Three participants considered that funding ‘pressure’ might result in ‘spin’ being placed on the experimental results. By this they meant that in the reporting of results particular emphases or omissions favourable to the sponsors (such as mobile phone companies) might be made. Participant 5a felt quite strongly about funding influence and argued that the influence of a private funding sponsor ‘will affect every step from just the beginning question of what is being asked of them right through to the final result’.

Participant 6d, along with several other participants, linked the interpretation of results to the obtaining of future research grants, noting that scientists are now more reliant on private funding than in earlier periods. Here the scientists were seen as sometimes being in control of the process, favouring particular lines of research or points of view and using the funding to promote these over others. Participant 3d saw the favoured scientific ideology as directing the interpretation of experimental results. Many participants also noted that the pressure from sponsors occurs because there is a lot of money at stake from the continuing sale of mobile phones which would be under threat if a danger to the health of users was demonstrated.

Role of media

Participants in five out of seven groups and in eight individual interviews raised the role of media in producing the disagreement between the scientists. This was often spoken about in a passionate tone, suggesting a high level of distrust, particularly towards commercial television channels. Talk about the media concerned the possible omission of information, misinformation (inaccurate reporting of facts) or the deliberate manipulation of content for the media's own purposes. These comments were usually in general terms and were primarily describing the purposes or motivations of the media, rather than commenting on the particular news report presented in the focus group. Talk did not refer to the scientists who were interviewed or their possible role in the construction of the news item.

When talking about the aims of the media, participant 6a, for example, observed that it's the media's job "to make a story", and that as a result "you've got to take what they say with a grain of salt". He did not elaborate on how this affects the presentation of scientific research or how it might produce the disagreement between scientists. Other media aims were referred to by other participants. In order to attract an audience or "sell newspapers", the media were seen to "try to dramatise everything" (Participant 3a), to use conflict to "add to the excitement" (Participant 4d) or "they might leave something out to make it seem more shocking" (Participant 1c). In other words, as participant 4d observed, they would "create the media sensation, it's what sells the news". These purposes were seen to lead to a variety of effects which could influence the content of news reports, though again no specific link was made with the report they had viewed.

Two participants observed that the original reports are often taken out of context. The potentially distorting influence of what participant 3b called "cut and paste" was generally seen as deliberate. Participant 4b commented:

> They're feeding us what, you know, they want us to hear. (Participant 4b)

Participant 1c went further to suggest that this selectiveness amounted to dishonesty:

> I mean the news lies, they tell you, they tell, like, different information from different angles and stuff and… they might not be telling the whole story. (Participant 1c)

On the other hand participant 6b saw the omission of information in terms of a 'dumbing down' for the general population, and participant 4a noted that the media often deliberately present opposing opinions to demonstrate 'objective' journalism.

The three categories of response outlined above represent social aspects of the construction of scientific knowledge in the public domain. As will be considered further in the discussion, it is of interest that these categories constituted a significant part of these young people's responses to the uncertainty of the science in the news report. There were 10 other categories of response, as shown in Table 1.

Three of these other responses referred to the process of generating empirical data as a possible source of the disagreement, which is not surprising given that the news report did not provide practical details of both the laboratory mice studies, and also referred to two kinds of methods – using laboratory animals and epidemiological data. Further, formal science education and popular representations of science focus strongly on experiments, thus one would expect the experiments themselves to be an immediate target of the participants' explanations about different findings.

The effect of different research questions

Participants in three of the seven focus groups and participants in a small fraction (3/28) of the individual interviews suggested that disagreements between scientists could be attributed to different framings of the research problem/question. In the focus group discussion participant 4b said, “They would have researched on different things” and participant 2d observed:

> The way they worded it was on, increasing cancer like, effects of cancer or something like that. Another test I saw was whether the radiation waves <u>cause</u> cancer, not just increase the risk of cancer, you know it’s one word here or there but, not all these type, studies are really sort of studying the same thing.

The use of different research methods

In three of the seven focus groups and in about half (15/28) of the individual interviews participants referred to scientists using different methods. This category of response was easily the most common empirical explanation offered and is part of a key finding considered further in the discussion. The participants who elaborated this category of response in the individual interviews revealed varying attitudes towards the use of different methods.

Most of these participants considered that if the experiments were identical the results should be identical. For example, in response to my question about how it is possible to have contradictory findings in scientific experiments, Participant 6b replied:

> Just the way they go about it. I mean, did they look at each other's experiments and exactly how they did it, and did they follow it to the step and get the same results? Or

> did they do something different, did they use a different machine – higher emissions or lower emissions?

This view overlooks the role of the interpretation of empirical data, which must relate back to assumptions and theoretical underpinnings and which could produce differing findings from the same procedures or results.

Some participants saw the use of different methods as necessary. Participant 2b, for example, stated that there was a need for different methods, that "you can't really state from a single study", but rather you need to look at different studies "in contrast to each other". Four participants saw the use of different methods in a more negative light. They referred to the idea of a "correct" or "more accurate" experiment, inferring that when an experiment is done "correctly", it will give a correct or reliable result. Thus if the methods are different one is probably incorrect or less correct. For example, Participant 6b observed that, "They came up with a faulty experiment initially."

Flawed methodology

A category of response related to experimental methods was expressed in three groups but not in the individual interviews; this was that the methodology of the research was flawed. For example, referring to the length of time of exposure of the mice to mobile phone radiation, Participant 2a commented that mice exposure for 1 hour a day did not reflect common hours of usage. In two groups participants argued that findings from research involving mice are not transferable to humans. Participant 3c, who is a working scientist, noted that "Mice don't develop tumours in the same way…..they've got a whole, different types of cell types, they're more prone to actually breaking down and ending up causing cancer". He also noted that laboratory mice are often genetically identical, in contrast to the variability of humans. In the second of these two groups a non-scientist, participant 6b, proposed that in the most recent experiment where there was no change in cancer rates the mice "might have been cancer resistant". A few participants noted that mobile phones may have changed over the period of the two studies, for example by providing more protection from radiation.

Human error

Six participants in the interviews spoke about the role of experimental error in producing different findings. This was specified as human ("who is doing it, whether they're very precise or if they reckon this is just about right" – participant 1b) or equipment related ("the machine might have had a fault on a certain day or something and it gave a false reading" – participant 7a). The small mention of error suggests a high degree of confidence in scientists' competence but some awareness of the possibility of error in scientific experiments.

Theoretical differences between scientists

Although almost all of the participants considered that scientists' opinions on the issue influenced the outcomes of their research, only three participants across both group and individual discussions suggested that theoretical differences could result in different findings. This is of particular interest in relation to the atheoretical view of the nature of science this may reflect which will be considered in the discussion.

Participant 7c distinguished theory and opinion, as follows:

Researcher So when you said [in the focus group discussion] "It seems that scientists have got their theory and that's what they base their work on", what did you mean, their opinion about the mobile phone safety or did you mean something else by using that word 'theory'?

7c Yeah I guess theory……I guess most of the time their opinion probably reflects their theory but I mean opinions are just a personal thing whereas a theory I guess is based more on fact so they go in looking for this…looking for a certain fact that they can use as a base to build their research then like the theory of evolution and where he's…how they believe this happened because of this, so therefore eventually as time progresses, it's hard because if you say, "I believe" then it makes it sound as though he's opinionated where research shows that mobile phones will cause cancer or mobile phones won't cause cancer so.

Researcher So you see his theory as being based on some evidence, is that what you mean?

7c Yes that's what I'm trying to say in a round about fashion.

Two participants considered that disagreement could arise from different assumptions being made by different scientists. One of these participants, a practising scientist, referred to different views of what would constitute appropriate levels of significance in a set of experimental results:

> People might disagree about what is significant and what is not significant…so two scientists could possibly interpret the results in two different ways. (Participant 3b)

The second of these two participants, a non-scientist, also referred to varying assumptions. Assumptions underlying an experiment are likely to link closely with theoretical differences. Differing aims or framings of the question were also mentioned:

> It depends what assumptions they start out with about the likely cancer rates or, yeah and it depends how clear cut the aim of the experiment actually is, whether it's just to measure the incidence of tumours in mice as opposed to a controlled group or as opposed to some sort of figure that's been determined by someone else in a previous experiment or cancer rates for mice or things like that…yeah I'm not sure. (Participant 4a)

Some other responses should be mentioned here, although they did not link differing theories to the scientists' disagreement, so were not coded in this category. Participant 3d considered that the differing views of scientists could be described in terms of their different 'normative frameworks' which would affect the interpretations of results and also determine what were acceptable findings to different parties. But these normative frameworks were not linked with scientific theories.

Participant 2a observed that scientists can be influenced by "belief in a theory":

> I think that scientists can be influenced by their beliefs slightly, just as everyone on earth can, you can look at something and, it doesn't have to be religious beliefs but that is the strongest belief system, it could be belief in a theory, a belief in something."

And finally, three other participants (none of them scientists) used the word "hypothesis" in talking about scientists' opinions. However no actual hypothesis was stated and the relationship between an opinion on the broad issue and the hypothesis was not made clear.

Argument is necessary for consensus building

In two focus group discussions there was reference to scientific knowledge as consensual knowledge, socially constructed through critical discussion and debate. In one group this observation was expressed spontaneously by one participant, immediately after viewing the news report, suggesting that it was seen as an explanation of the scientists' disagreement:

> It's what always happens when research gets done and the results get published, in the field of science there's always people, you know, agreeing and disagreeing, there's an equal and opposite reaction so to speak, with absolutely anything. The thing is like, like scientists understand that, and they realise that, that in the end, one thing will sway it but, when the media just releases results willy nilly saying, this is the result of this, <u>but</u> we have this as well, it just makes people who don't understand it more confused. (Participant 6e)

In the second group the reference to science as consensual occurred in response to my question later in the discussion, asking what would constitute 'solid evidence':

> A solid stand from the scientific community. No-one's going to refute the fact that smoking does cause cancer, there's a solid standing in the scientific community saying yes, it does. There's nothing like that with mobile phones so, you've just gotta play it by ear. Over time you can get that certainty through, you know, scientific studies and that and when you get a general consensus. (Participant 2c)

Although only two participants spoke of consensus in the focus group discussions, it is perhaps surprising that more than half of the participants (16/28) in the individual interviews made some reference to the role of consensus building in the construction of scientific knowledge. These participants generally saw disagreement as a 'normal' part of science. For example, participant 1d said, "That's part of being a scientist and having competition and just discussing." and participant 2a remarked, "It's a scientific principle". Participant 6e extended on this to suggest that this was a strength of science, "Scientists are always disagreeing, that's the whole idea, of science building itself to be respectable. If it survives its own internal criticism, of which there is a lot, it'll stand up a lot better to other criticisms."

Approximately half of these young people considered agreement by a majority of scientists to constitute enough certainty to influence their thinking on the issue of mobile phone safety. However only five of the participants volunteered this consensual (socially constructed) view of science as a possible explanation for the scientists' disagreement in the news report. Of the two practising scientists, one referred immediately to scientists' differing perceptual and conceptual frameworks, based on their particular training, and the other addressed experimental methods.

The focus group discussions ranged across all of the above dimensions relating to the scientists' disagreement about the specific research presented, but talk also moved beyond the news report to consider the issue of mobile phone health risks in its wider setting. This talk is represented in the last four response categories in Table 1.

More time needed for further research

The category of response, "More time is needed for further research", is perhaps the most predictable, given the current state of research into mobile phone health risks. It was offered in half of the focus group discussions but by only two participants in the individual interviews. These two participants considered more time to be needed to accumulate data which one person said would enable theory to be developed into facts.

Controlling variables

In four out of seven groups participants talked of the difficulty of establishing a link between mobile phones and health risks in people's lives. In the interviews almost half (11) of the participants spoke of the need to control variables in exploring the effects of mobile phone radiation, pointing out the difficulty of doing this in a real world context. This suggests an understanding of how scientific experiments are usually structured. However most explained this in everyday language, with only three participants using the term 'variable' in their talk, thus their ideas may have been derived more from everyday experience than from familiarity with the procedures of science.

More time needed for symptoms to appear

In this wider ranging discussion there was also talk of the need for a longer period of time for symptoms of health risks to show up amongst people using mobile phones. This was expressed in five of the seven groups and linked with smoking in one group.

More information needed

Given the brevity of the news report it is perhaps surprising that only two participants expressed a desire for more information. However participant 6e was also concerned about his ability to understand more detailed information when he said, "If I went into it in detail I would probably get in over my head anyway. It must be pretty complicated stuff, but yeah, it'd be interesting to know the kind of standards they were using for their experiments."

The incidence of the different categories of response showed that these young people spontaneously offered more social explanations of the scientists' disagreement than those related directly to the conduct of the experiment or other factors. Scientists' opinions on the issue of mobile phone safety, the influence of funding sponsors and the role of the media in presenting the research to the public were the three main kinds of explanation offered. Significantly less attention was paid to the experimental aspects of the science presented in the news report and almost none to theoretical differences between the scientists' positions. Although awareness of the consensual nature of scientific knowledge was demonstrated in the individual interviews the role of argument was not linked with the scientists' disagreement in the news report.

Ideas of certainty

In the individual interviews five participants described reliable knowledge in cumulative terms, seeing a large number of experiments as a key to knowledge which could be relied upon. In spite of their strong focus on scientists' opinions, almost half the participants (13) considered that science would ultimately bring reliable knowledge through experiments. These views are somewhat understandable, given the large number of participants (16) who saw scientific knowledge as consensual, perhaps as a 'sorting out' of scientists' opinions.

Contrasted with this, however, is the significant proportion (about a third) for whom 'certainty' on this issue, or at least knowledge sufficient to affect their mobile phone use, will come through visible symptoms in people they know, rather than through experimental evidence from scientists. This represents a common sense or 'seeing is believing' perspective.

During the individual interviews I asked participants to what extent they saw school science as certain knowledge. Views were fairly evenly divided between seeing school science knowledge as certain and seeing school science as uncertain. Most seemed to view school science knowledge as highly reliable but not impossible to change, thus appreciating the tentative nature of scientific knowledge.

Science concept knowledge

Science concept understanding which could be expected to play a role in this context was considered to be participants' ideas about radiation and its interaction with biological systems. There was little evidence of this understanding in the focus group discussions where only three participants spoke spontaneously about radiation and its possible effects. Links were made with microwave ovens and beliefs were expressed about the potential of microwave radiation to contaminate food. Interference between mobile phones and household electrical appliances was noted as evidence of their invisible effects. One participant (trained as an electrician) referred to the nature of microwave radiation, noting its small wavelength and thus its capacity to pass through and possibly rupture living cells. Another participant stated that radiation is known to affect cell structure but that the effects of different kinds of radiation are not known. A different focus was reflected by one participant who saw the use of mice genetically predisposed to cancer in trials as a problem and articulated some basic ideas about genetics.

Thus in the focus group discussions concept knowledge did not appear to play a significant role in these young people's responses to the scientists' disagreement. To examine whether this knowledge was available to them as a resource on the issue of mobile phone health risks, in the individual interviews I asked them to describe their understanding of radiation.

Although all but three participants said they had learnt about radiation at school, a clear scientific conception of radiation was rarely provided. Apart from two working scientist participants, only one participant (an electrician) spoke confidently about the nature of radiation and offered a clear picture of the interaction of radiation with biological systems. The most limited understanding expressed was the idea of radiation as a substance, like a "green slime", which is "acidy, it would burn stuff if you touched it". (Participant 1c)

Most offered some terms linked with the concept, such as "electromagnetic", "waves", "spectrum" and "frequencies" but these terms were presented tentatively and their ideas about the concept were not coherent and structured in a way that suggested even minimal understanding of the nature of radiation. The commonest response involved the idea of something being "emitted", for example:

> It's being emitted from a substance to you and it's just around, it could be electrical appliances, it could be anything really, just stuff that comes off machines that you're around…an invisible thing. (Participant 1d)

This emission was sometimes related to the decomposition of atoms or, as with the green slime idea mentioned above, the emission was seen in terms of a substance or a gas.

About half the participants spoke of radiation in terms of damaging effects and danger. The most concerned expression was:

> I think of Chernobyl, I think of bomb testing in the Pacific, I think mutation, people born with no arms or…just in general pretty horrific really. I think of a big sign, big yellow and black, just comes right into your head when you think of that. And people in biohazard suits. It's not healthy anyway, I think, not something to look forward to. (Participant 6b)

Many participants who spoke of the dangers of radiation also mentioned beneficial effects such as its medical use in treating cancer.

Sources of knowledge other than school science were quite common. Four participants referred to Chernobyl and two to Hiroshima. Novels, films, comics, cartoons (*The Simpsons*) computer games and television programs were also given as sources of ideas about radiation. Two participants referred to family experiences. Participant 1c was influenced by her mother's participation in a community protest against the siting of a mobile phone tower and Participant 4c considered that her understanding was more connected to her grandmother's illness than to school science.

In the data presented here, varying degrees of understanding were evident but these young people's accounts of the scientific conception of radiation were generally confused and sometimes contradictory. They would appear to be inadequate resources for considering the issue of the potential health risks of mobile phone use.

Incorporated into responses to my questioning were perceptions of the teaching of radiation in school science. The teaching of radiation was generally seen as having little connection with people or real world contexts. Thus the following participants observed:

> It didn't seem to really relate strongly with, it seems more to relate on a really basic level with the actual reaction, the relationships between particles and not, not quite on, a human level or a social level. (Participant 2b)

> We did plants and human bodies. Radiation wasn't in that. (Participant 3a)

Thus these young people lacked basic understanding of the nature of radiation. Such knowledge has the potential to constitute a significant part of their account of scientific knowledge in this context and to illuminate their decision making about possible risks and how to reduce them.

Discussion

The focus of this paper is to examine the views of science expressed by young people who have recently completed their formal schooling when they engage with the uncertain science of a contested issue. In terms of decision making on the issue most of these 28 young people rejected the scientific knowledge of the news report as a useful knowledge resource. This decision making is analysed in a separate paper. Here discussion focuses on the views of science their responses suggested and the role of concept knowledge. I present three principal findings.

Social nature of science

In this context these particular young people offered a wide variety of plausible explanations for the scientists' disagreement. The first *key finding* is that whilst their explanations were predominantly social - focussing on personal opinions, the role of funding and the media - the social processes of discussion and debate *within* the scientific community were not drawn upon. It could be argued that the stimulus of a television news report which included a mobile phone company representative would be likely to focus attention on the social process of funding. However most footage was given to scientists and their research. Focussing on the media is perhaps not surprising, given that, as Jarman and McClune (2010) have reported, science in this setting is not likely to have been part of their school science experience.

Driver et al. (1996) noted, and most science educators would agree, that in most countries school science does not pay much attention to how scientific knowledge is constructed socially, that is, through the sharing of data and discussion and debate about theories, assumptions, methods and findings. They reported that 9-16 year old students generally viewed scientists as working in isolation. Ryder, Leach and Driver (1999) demonstrated how even final year science undergraduates possessed very poor understanding of these processes, considering that it was possible to prove the validity of knowledge claims using data alone, without the involvement of social processes.

On the other hand, adults are exposed through the media to interactions between commercial interests and science. In every focus group participants raised the case of smoking and tobacco companies and scientists ‘changing their minds’ (expressed in a cynical way). Thus these results are not surprising in relation to external social factors. Such responses suggest that these young people possess a *critical* scientific literacy, involving skills which are part of critical language literacy, in which questions are asked about sources of knowledge, such as “Whose interests are being served here?”. In a widely cited paper, Bingle and Gaskell (1994) argued for the importance of these dimensions of scientific knowledge for citizens dealing with socioscientific issues. This has been advocated more recently by Lemke (2002) who argued that “to dismiss interested science as not science at all is to evade the uncomfortable fact that most science today and historically has been tied to some set of interests.”(p. 2). School science rarely engages with this aspect of science. Lemke has argued for a “multimedia science literacy”, which would include analysis of television reports. Likewise this critical dimension is included in Norris and Phillips’ (2002) description of a ‘fundamental’ science literacy and Jarman and McClune’s (2010) ‘media literacy’ for science education.

The focus on social influences also suggests that these young people have largely resisted or outgrown the 'ideology' of school science which, it can be argued, presents scientific knowledge as value-free and objective, and underplays the social dimensions of science (Lemke, 1990, 2001; Cross & Price 1992; Larochelle & Desautels, 1998). A few participants did refer to this ideal when they spoke of the 'objectivity' of scientists but they did this with considerable tentativeness, expressing their hope that this was the case.

This strong adult interest in the social dimensions of science when dealing with socioscientific issues has also been noted in much public understanding of science research. A social perspective on scientific knowledge needs to reflect an up-to-date conception of the nature of science, based on sociology of scientific knowledge (SSK) studies, in which social factors are acknowledged as playing a role in the construction of scientific knowledge. The limited view of social construction expressed here - a common sense view, involving a major role for the testing of scientists' individual opinions on the issue (in turn easily subject to outside influences) - is unbalanced. This perspective suggests an inadequate understanding of the grounds for scientific knowledge – a rigorous empirical testing of hypotheses based on theories or broad conceptual frameworks, constructed socially through argument and debate.

Empirical dimensions

The second *key finding* is that references to empirical processes by these young people reflected a limited view of experiment as a technical, testing procedure which, if carried out correctly would produce a 'correct' result. There was significant description of the need for identical experiments and the absence of a role for differing theories in explaining contested science. Interestingly, one participant who is a practising scientist spoke of the difficulty of replicating experiments. This reflects what sociologists of science have argued, that identical experiments are in fact rarely conducted (Collins, 1975). Yet this is a common tenet of the nature of science in schools, that credibility in scientific research hinges on the repeatability of experimental results.

These two findings suggest that the participants shared a *common sense* view of science. In this view experiment is seen as a way of finding out what happens and comparing it with what one thinks will happen, in other words, with one's personal opinion on the matter – in this case on whether mobile phones can cause cancer in humans. Hipkins, Stockwell, Bolstad and Baker (2002) also reported from adult focus group discussions of mobile phone safety, that people's views of the complexity of science, data collection and interpretation appeared to be based on intuitive common sense, rather than an understanding of how scientific theory and evidence can be interrelated. More specifically, they wrote:

> "What seems to have been captured here are beliefs of the complexities and contingencies of everyday life rather than an understanding of the manner in which different scientific theories may lead to differing investigative approaches to the same question." (p. 25)

As Conant (1951) noted, an essential element of science is a chain of argument linking an experiment to a broad idea and aims and assumptions which are distinct from those of common sense thinking. There was little evidence of this understanding in the data. It could not have been expected that these young people would possess the knowledge to be specific about theoretical models informing the research (such as causal mechanisms involved in the development of cancer in mice, or how these events in mice are related to the likelihood of similar effects in humans). Nor are such aspects likely to be raised in a news media report.

However it is reasonable to expect adults who are scientifically literate to refer to theoretical issues between scientists as a source of disagreement. If talk does not go beyond common sense ideas of testing personal opinions, this can be considered to represent an atheoretical view of science.

This atheoretical perspective can also be viewed in terms of a *folk theory* of scientific inquiry which Windschitl (2004) argued is pervasive in science education, even amongst some teachers who are science graduates. A folk theory is a taken-for-granted theory about the world that is widely shared by most members of a society and which plays an important role in individuals' understandings of the world and their behaviour in it. A folk theory can have many versions. Windschitl suggested that "Every day thousands of science teachers enact their favoured models of scientific investigations and, in doing so, reinforce various dimensions of a folk theory of inquiry (or "doing science)" (p. 483). Further, he argued that folk theories of inquiry are also codified in various community discourses, such as official curriculum documents and textbooks. While a folk theory of inquiry has some facets which are congruent with authentic science inquiry, other facets represent a limited view and, most importantly, several facets misrepresent some of the most fundamental aspects of authentic science. The most problematic shortcoming in a folk theory of scientific inquiry is the absence of theoretical or scientific models in the consideration of the research question or the experimental findings. The views suggested by these young people's responses could be interpreted in this way, as various folk theories describing inquiry as a technical procedure, ignoring the role of conceptual models and their assumptions.

From their closely related study with 16 year old students, Driver et al. (1996) offered another way of characterizing epistemological reasoning about scientific inquiry. They proposed three levels of reasoning, noting that each kind has its place in scientific reasoning. Their research data suggested that young people's ideas about the nature of science may evolve over time from the simplest to the most complex levels of reasoning.

The least sophisticated level is *phenomenon-based reasoning*, in which inquiry is making phenomena happen so that they can be observed to see 'what happens'. From this perspective most of these young people, through their view of science as scientists testing their opinions, of seeing 'what would happen', demonstrated phenomenon-based reasoning. In this view what happens during an experiment leads unproblematically to knowledge – the world is 'read' directly from the results, and science is seen as reading the book of Nature. In philosophical terms it represents a naïve empiricist view of science. A serious consequence of this kind of reasoning, pointed out by Millar and Wynne (1988, cited in Ryder & Leach, 2000, p. 1069) is that "Individuals who expect scientific explanations to emerge directly and unproblematically from data may automatically interpret disagreements among scientists as evidence of incompetence or bias, rather than a possible consequence of the difficulties of data interpretation in a challenging context."

As well as focussing on phenomena some participants appeared to be also engaged in *relation-based reasoning*, the second level of Driver et al.'s (1996) model. At this level the focus of explanation is on what is measurable, and the aim is to find correlational or causal relations between variables. This was evident in some participants' concern with methodological differences (methods and questions) and accuracy, and their remarks about the problem of controlling variables.

The third level, and the most authentic approach to scientific thinking, is *model-based reasoning*, where empirical investigation involves testing or developing a theory or comparing theories. Only two participants here demonstrated this kind of reasoning. Driver et al. (1996) reported similarly that students tended to view data interpretation as a description of the data (phenomenon-based reasoning), or a search for a correlation between two variables (relation-based reasoning) with only a few students emphasising the role of theoretical models in the interpretation of data (model-based reasoning). Ryder & Leach (2000) reported similar findings with upper secondary and university science students' interpretations of experimental data.

Duschl (2000, p. 192) has reported considerable research demonstrating that "the dialectic between data and theory is a missing conversation in most science classrooms". Commenting on how "science is the domain of inquiry that takes us beyond our senses and into the realms of reasons and reasoning, and models and modelling" (2000, p. 191), Duschl also noted that this move from the direct perceptions of our senses is even more pronounced nowadays with the increased use of instrumentation. Although at this time he cited Driver et al's (1996) research demonstrating that "a concomitant shift has not taken place in the kind of science presented to learners in schools" (p. 191), more recently in the UK national curriculum, science educators have engaged with a new focus on "How science works" (See www.qca.org.uk/curriculum).

Both of the common sense perceptions of science described above, namely, a strongly social view and an atheoretical method, are seriously limiting. As noted by Driver et al. (1996), this perspective contains significant gaps in the 'bank' of resources available for accounting for scientific disagreements about natural phenomena and events. This in turn results in less than adequate ways of dealing with the controversy involved in socioscientific issues. The young people in this study were generally dismissive of the value of the news report for their decision making because it did not provide a definitive answer, suggesting that they lacked resources for dealing with the contradictory findings. Further, Ryder and Leach (2000) have suggested that individuals who recognize the *limitations* of scientific investigation, and the *tentative* nature of data interpretation in many contexts, may be more likely to demonstrate realistic expectations of scientific findings concerning data. In so doing they are more likely to engage with scientific research which suggests the possibility of harm from certain behaviours rather than rejecting it outright, as was the case in this research.

As well as proving consistent with Driver et al.'s (1996) research, findings reported here support those of Sadler et al. (2004) with school-aged students (described earlier), with similar categories of explanation for the scientists' disagreement. However Sadler et al. reported acceptance of the contradictoriness of the scientists' views, whereas participants here rejected the science of the news report because of the contestation. This difference could perhaps be accounted for by the different discussion stimuli presented in the two studies, particularly the different topics. Young people could be expected to respond differently to issues with a personal focus such as mobile phone use compared with more global issues such as climate change. As similarly observed by Sadler & Zeidler (2005), the affective dimension is likely in this study to have played a powerful role in participants' decision making. Here their enthusiasm for and dependence on their mobile phones for social networking would be a powerful influence.

Concept knowledge

The *third finding* of this study is that understanding of the concept of radiation and its interaction with biological systems was almost completely absent as a resource for these young people. Their recollections of radiation in school science reflected an abstract, decontextualised idea which had little to do with their own lives and which they did not understand, despite the fact that they are dealing with it on a daily basis whilst using their mobile phones.

Researchers have only just begun to explore the role of concept knowledge in student discussion of and decision making on socioscientific issues. Sadler & Zeidler (2005) have reviewed some early studies (Fleming, 1986a, 1986b; Hogan, 2002; Zohar & Nemet, 2002) and with their own findings from undergraduate students considering genetic issues they concluded that concept knowledge may be a useful resource for reasoning on issues, influencing the quality of argument in some cases, but that other factors such as affective dimensions (particularly on some issues) may be equally or more influential. The participants' lack of concept knowledge reported here is significant in the light of a more recent study by Lewis and Leach (2006) of the role of concept knowledge in the discussion of gene technology by 200 14-16 year old students. Lewis and Leach reported that the capacity of students to engage in reasoned discussion was affected by their ability to recognise key issues, which in turn depended on some understanding of relevant concept knowledge. Lack of understanding of radiation, the different kinds of radiation and their biological effects could thus have affected the capacity of these young people to engage with the issue of mobile phone health risks. On other issues their responses, including the role of concept knowledge, may differ significantly. Another possible consideration here is the need noted by early public understanding of science researchers (Layton et al., 1993; Irwin & Wynne,

1996) for abstract concept knowledge to be re-contextualised in order to be useful in everyday situations.

Implications and further research

The young people in this study demonstrated a 'critical science literacy' in questioning the sources and the presentation of scientific knowledge in a television news report. It is not clear, however, that their understanding of scientific knowledge as tentative knowledge requiring argument and debate about theory and the interpretation of experiments is secure. Although many expressed awareness of science as consensual knowledge, they did not provide evidence of a link between this understanding and the disagreement between scientists in the news report. Their view of scientists in this context as 'just like us' in acting on personal opinions undermined their capacity to engage with the science-in-the-making being presented. It suggests a need for better understanding of the social processes involved in the construction of scientific knowledge, particularly the role of argument.

As new developments in science and technology proceed apace, decision making skills around contemporary science become more urgently needed. This study concerned a small number of young people engaged with one particular topic, but if widespread, this lack of understanding of how science works is a major concern for science educators which requires attention in the light of recent commitments to science education for citizenship, in which decision making is central.

Explicit teaching of the nature of science has been advocated by many researchers (e.g. Driver et al., 1996; Duschl, 2000; Abd-El-Khalick & Lederman, 2000). Findings of this study demonstrate the need for a focus on the social dimensions of the construction of scientific knowledge, alongside its distinction from common sense. Students need to understand the "social, cognitive and epistemic dynamics that make science an objective way of knowing" (Duschl, 2000, p. 187). In terms of the moderate social constructionism of this study 'objectivity' lies within the consensual rather than individual activity of scientists. A major focus of scientists' shared deliberations is the relation between theory and data, often absent from school science, and the break with common sense that this entails. It would seem important to set such teaching in the context of contemporary issues, at least for some of the time, since such issues are highly likely to focus attention on the nature of science itself as its claims are distinguished from those of other stakeholders. This is consistent with a view of science learning in terms of situated cognition theory as proposed by Sadler (2009). From this perspective context determines the kinds of learning that are possible, thus ways to respond to uncertain science are more likely to be an outcome if this is the kind of science that students are dealing with. Another advantage of this is that science concepts are more likely to seem relevant to young people's lives and so more worth understanding than in traditional, decontextualised approaches.

Further research is needed to examine how teaching about the nature of science can inform students' discussion of and decision making on socioscientific issues. Historical case studies of scientific controversies and how these are resolved through the processes of science might be one approach (see Kolstø, 2008). However science from earlier times present challenges to students in terms of the difficulty of unfamiliar conceptual and cultural framings of the issues. Abundant contemporary contexts exist and in accord with situated cognition theory may provide more relevant learning for current students. A new resource for teachers and students in New Zealand (www.sciencelearn.org.nz) develops nature of science understanding in the context of engagement with particular issues.

Additional research is also needed into the role of conceptual knowledge in the discussion of socioscientific issues and into ways to assist teachers to situate this knowledge in classroom discussions. Lewis and Leach (2006) have demonstrated the feasibility of preparing students for these discussions through the presentation of targeted content; research can explore the effectiveness of this further and investigate the kinds of concept knowledge required for considering particular issues. Understanding of radiation is relevant to many issues of public concern, for example, the use of microwave ovens, living near high voltage power lines, nuclear power, medical uses of X-rays, food irradiation and mobile phones and their towers.

In their landmark UK report, *Beyond 2000: Science education for the future*, Millar & Osborne (1998) conceptualised a curriculum for future citizens in which they recommended a major emphasis on understanding the nature of science. This approach has been adopted in the UK national curriculum in the compulsory *Core Science* subject for 14-16 year olds which is based upon contemporary issues involving science. Early research has shown that this kind of science is effective in engaging students but that it brings major challenges to science teachers, particularly in dealing with 'ideas about science' (UYSEG & Nuffield, 2007). Thus research needs also to be focussing on innovative and effective pedagogies which will engage both teachers and students with socioscientific issues as a part of school science, including a central role for the explicit development of nature of science understanding.

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Appendix A

FOCUS GROUP DISCUSSIONS -Main THEMES of talk and associated ISSUES

Role of mobile phones in participants' lives	*Responses to uncertain science (reasons given for the scientists' disagreement)*	*Positioning re health risks of mobile phone use*	*Talk relating to school science*
Contactability	Funding source	Comparative risk	Conceptual knowledge
Convenience	Time for research	Inconclusiveness	Science processes
Dependence	Time for symptoms	Smoking	Nature of science understanding
Cost	Different questions	Fatalism	Relevance
Safety	Different methods	Individual variation	Socioscientific issues
Health effects/cancer risk	Role of media	Belief preference	Level of complexity
Age distinction	Human error	Caution	Certainty of knowledge
Comparative risk	Improved technology	Risk	
Information	Number of variables	Trust in authority	
Cultural influence	Journalistic objectivity	Visible evidence	
Design features	Scientists' opinions	Reassurance of research	
Don't think about health risks	Social nature of science	Credible knowledge	
Fashion	Causality	Dependence on technology	
Flirting	Credibility of source	Sense of identity	
Games	Certainty	Capitalist consumption	
Keeping up with technology	Flawed methodology	Everyday knowledge	
Peer pressure	Trust in experts	Distance from	

problem

The above themes and issues were derived from analysis of the focus group data. They were also used in analysis of the individual interviews but some themes and issues were added:

INDIVIDUAL INTERVIEWS - Additional THEMES and associated ISSUES

Role of experiment	*Microsociological aspects*	*Macrosociological aspects*	*Ideas of certainty*
Time for research	Consensus	Role of media	Certainty as cumulative
Different questions	Scientists' opinions	Funding source	Certainty as consensual
Identical experiments	Role of beliefs	Role of culture	Seeing is believing
Correct experiment	Manipulation of data		Trust in authorities
Cumulative experiments			Need for causality
Controlling variables			
Theory differences			
Proof through experiment			
Experimental error			
Need more information			