Scientists' Habits of Mind as Evidenced by the Interaction Between their Science Training and Religious Beliefs

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The University of Waikato, New Zealand  University of New England, Australia
RESEARCH REPORT

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The science education literature suggests that the public and students often hold narrow stereotypical views of scientists and science. Here we argue that it is important that students and the public understand the basis on which scientists make scientific claims. The inquiry sought to develop an understanding of the scientific mind, explored through Gauld’s (2005) notion of ‘habits of mind’. The vehicle used to explore these ideas consisted of an inquiry into how scientists rationalise conflicts between scientific theories and religious beliefs which are not in agreement with consensually-accepted scientific theories. Twenty scientists from different scientific disciplines and levels of seniority were interviewed using as a basis an instrument containing a series of religious-based item statements that a panel of scientific and religious experts considered were in agreement with a variety of religious doctrines yet in disagreement with current scientific thinking, or for which there is at present no supporting evidence from a variety of scientific disciplines. These statements acted as an interview protocol and formed the basis for interactive discourse, which was audio-taped, transcribed verbatim and participant-validated. These data provide a window into scientific thinking as practiced by modern scientists, and helps develop a picture of these scientists’ ‘habits of mind’. The findings suggest that these scientists, unlike their stereotype, hold idiosyncratic views of what constitutes good scientific evidence and sound, credible testimony.

Introduction

Science education literature is replete with assertions and claims about scientists’ ways of thinking; the ‘scientific mind’. In this paper we argue that the concept of ‘scientific mind’ can be explored through Gauld’s (2005) notion of ‘habits of mind’; aspects of scientific thinking that result in consequential action in scientific practice and general behaviour. We propose here that understanding the habits of mind of
An understanding of science, its potential, values, beliefs and processes forms part of scientific literacy. Scientific literacy, according to much recent literature, is of increasing concern worldwide (Carson, 1998; Laugksch, 2000). The term ‘scientific literacy’, however, represents a diversity of views (see for example, Miller, 1998, 2004; Roth & Lee, 2002; Symington & Tytler, 2004). A common theme in the literature is that of being able to critique scientific debates. According to Laugksch (2000) a scientifically literate person does not accept opinion about a contentious scientific matter uncritically. Rather, he or she wants to see logic or evidence for any stance taken on the issue (see also Miller, 1998). Some authors argue that the success of a science education system can be evaluated by the literacy of the citizens (Preece & Baxter, 2000; Yates & Chandler, 2000).

Herron (1969) comments that with respect to the understanding of the nature of science presented in the literature ‘we “talk” a much more impressive procedure than we actually do’ (p. 105), pointing to a need for further research in this area. This resonates nicely with Reif’s (1995) view that to understand science involves...
more than content knowledge, it also involves understanding of the ‘requisite thought process’ of science (p. 281).

Public Understanding of Science

Related to scientific literacy is the notion of public understanding of science. There is now an extensive literature on public understanding of science, and indeed some journals are dedicated solely to such topics. One reason for value being placed on public understanding of science is the economic imperative. The Organization for Economic Cooperation and Development (OECD) sees public understanding of science as a factor in economic performance. For example, a low interest or a negative perception of the value of science is seen as an inhibiting factor in uptake of scientific careers, with concomitant negative economic impacts (OECD, 2006). There are substantial differences in public understanding, interest in, and views as to the value of science depending on the particular context. The National Science Foundation (NSF) (NSF, 2001) report that nine out of 10 Americans report interest in new scientific discoveries (especially in medicine), but rather alarmingly, that many identify television as their primary source of scientific information (with recent interest in the Internet as an information base). Such interest, in the case of Americans anyhow, is not necessarily related to actual understanding of science content, with seemingly few Americans aware that humans did not co-exist with dinosaurs, or that antibiotics do not kill viruses. The British public, whilst also interested in medicine, are seemingly suspicious of scientists’ motives, seeing the scientific community as a ‘closed shop’ (Office of Science & Technology, 2000, 2005). The public in Finland—a highly successful country in international scientific achievement tests such as TIMSS and PSIA (see Kjærnsli & Lie, 2002)—are more positive about the value of science and have greater confidence in the scientific community (Finnish Social Science Data Archive, 2004). Other interest has been in how students and the public view scientists themselves. Are scientists ‘normal’, or are they different in important, fundamental, ways to the general public? Such research is concerned with ‘normative beliefs’: how normal (or otherwise) the public view scientists. Dalgety and Coll (2004, 2005) report that, as might be expected, those with an interest in science, or with family background or affiliation with science, do indeed see scientists as similar in many ways to others. But those with little background in science see scientists in fairly stereotypical fashion as very hardworking, highly intelligent, somewhat odd in personal habits, and so on.

Other related work is concerned with the nature, history and philosophy of science (see, for example, Matthews, 1994 and references therein) and how they can affect student understanding of science and the nature of science. For such ideas, authors focus on particular aspects of the nature of science. Broadly such writings are concerned with answers to questions such as: What is science actually like? What methods do scientists use? Are these methods the only—or the best—ways we should use to investigate the world? To answer such questions we need to develop a better understanding of the nature of science and scientific thinking. Bevilacqua and
Giannetto (1998), for example, report on the history of science development from the perspective of European countries, noting that the role that the history of physics plays in physics education has changed in recent years. This suggests that a historical approach to physics education provides a more comprehensive view of the nature of science and how scientific thought can change over time. This is consistent with Brickhouse (1998), who suggests that a feminist perspective on science can go some way to dispel stereotypical visions of science being dominated by old, white males. Brickhouse suggests if we can help students to appreciate the real contributions of female scientists, they will come to appreciate the value of multiple views of science and its endeavours.

The Nature of Science
An important aspect of scientific literacy is familiarity with the nature of science—to engage in debate about scientific issues requires some understanding of the nature of science. Much of the success of science has been attributed to the so-called scientific method (Chalmers, 1999) and high standards of evidence for scientific claims and theories. But how does science ‘work’? How do scientists obtain good data? What is good data? What are the ‘rules of the game’ in science? Much has been written about the nature of science, and research into students’ understanding of the nature of science. It seems students often see science as a codified body of knowledge that is essentially unable to be challenged (for example, Laugksch, 2000).

The literature suggests that students and the general public credit scientists with fairly stereotypical stances and beliefs, seeing them as objective seekers of truth using experimentalist methods of inquiry in their scientific research (Dalgety, Coll & Jones, 2003; Koul 2002, 2003). Scientists are, however, human, and hold biases, for example, as to what is worthwhile investigating (Laugksch, 2000). Carson (1998) argues that science education should not ‘leave students vulnerable to the occasional dogmatism of the scientists, but able to appreciate and yet criticise the enterprise of science’ (p. 1012). Guisasola, Almudi and Furió (2005) point out that students are likely to see science as codified knowledge when textbooks present a very simplified version of the nature of science, one in which science knowledge is seen as a ‘non-problematic, non-historical, “linear” accumulation’ of facts (p. 333). Likewise, recent work by Dagher and Ford (2005) suggests that science biographies written for children provide insights about scientific experiments and procedures used by scientists, but speak little of how scientists make connections between theory and evidence.

The Scientific Mind
Do scientists really think in different ways to non-experts? If so, in what way? Are scientists’ minds trained to operate in certain ways, and might this mean their views and critiques of contentious scientific matters should be given more weight? Gauld (2005) addresses this issue in a seminal paper in which he summarises research into the scientific mind and discusses scientists’ views of the nature of science. This is
presented in terms of the ‘scientific attitude’ (attributed to Gauld & Hukins, 1980), and ‘habits of mind’. According to Gauld’s (2005) analysis habits of mind for scientists can include: open-mindedness, scepticism, rationality, objectivity, mistrust of arguments from authority, suspension of belief, and curiosity. A number of these habits of mind at first sight seem incompatible (for example, open-mindedness and scepticism), and indeed surprising to the public (Reiss, 2003). However, it is the interplay of these habits of mind that results in ‘the scientific attitude’, in which ‘no idea, conclusion, decision or solution is accepted just because a particular person makes a claim but is treated sceptically and critically until its soundness can be judged according to the weight of evidence which is relevant to it’ (Gauld, 1982, p. 110). A key feature of evidence claims, according to Ziman (1968), is that scientists have ‘very high internal critical standards’ (p. 79).

The literature is replete with commentary and rhetoric about what scientists are purported to think: their epistemological beliefs (Matthews, 1996), their views about the nature of science (Matthews, 1998), conflicts between science and religion (for example, Gauld, 2005; Mahner & Bunge, 1996a, 1996b), and superstitious/pseudo-scientific beliefs (Preece & Baxter, 2000; Yates & Chandler, 2000). But according to Coll and Taylor (2004) there are little data reported from contextualised, detailed research studies about scientists’ views of the nature of science, and conflicts between scientific and everyday thinking.

Identity Formation and Cultural Induction into Science

Science is viewed by some authors as a culture with its own processes and values (Coburn & Aikenhead, 1998). Becoming a scientist then involves learning content, scientific process including how to conduct scientific inquiry, and sharing the values of the scientific community (Coburn & Aikenhead, 1998). Lave and Wenger (1991) say this occurs in the form of an apprenticeship, with novice scientists engaging in ‘legitimate peripheral participation’ in science as they learn science. In doing so they are gradually enculturated into science—shifting from views similar to the public towards a closer match with the views and values of practising scientists (see also Coll & Zegwaard 2006; Paku et al., 2002). However, the public, unlike aspiring scientists, experience limited exposure to science during and after schooling (aspiring scientists typically do more science topics at school and in post-school studies), and as a consequence are unlikely to come to such a shared understanding of science and its culture. This begs the question as to how much can we expect a school science curriculum to achieve in terms of helping students generally come to an understanding of the nature of science and its cultural norms; or indeed, if such a thing is feasible or even desirable.¹ Larson (1995) and Latour (1987) suggest that schooling is based on the ability to deal with science topics that are confined to the classroom setting. In other words, even the most able, or highest achieving science students may not in fact become enculturated into science, since they see science as something confined to particular contexts and not part of everyday life (i.e. not seeing science in an all persuasive way as a scientist might view science).
The Public and Private Faces of Science

The above discussion points to a rather simplified view of science as a culture whose values are shared across the scientific community. The literature notes, however, that there is no such simple view of science or the scientific method (Matthews, 1994, 1998), and that even within a specific scientific discipline scientists hold different values, and engage in different scientific means of inquiry (Allchin, 1998). So while scientists may present a common ‘face’ to the public (for example, Carson, 1998; Nestle, 2003)—that is, they often appear to present consensual agreement—they may harbour different views privately. This, according to Carson (1998), may occur because an individual scientist may not wish to ‘break ranks’ or because of pressure from an external body or authority of some sort (Nestle, 2003). This is not to say that scientists do not engage in rigorous, open debate on occasion (as evidenced, for example, in discussion of climate change), but that an individual scientist might feel the need to conform to the norms of his or her discipline, or might seek to hide controversial beliefs or ideas that might attract unpleasant personal criticism. If a personal view or belief is in marked conflict with the norms of a given discipline (rather than an opposing view about a scientific subject) that might subject the individual to ridicule, then a scientist is less likely publicly acknowledge their view (Coll & Taylor, 2004). This latter is an interesting point in terms of public understanding of science and scientific literacy. Is the public face of science and scientists giving the public and our students a true picture of what science and scientists are actually like? We suggest here that it is not.

Scientific Literacy, the Curriculum, and Religious Views

Scientific literacy also impacts upon schooling and curriculum, and this sometimes results in conflicts about what should or should not be included in school science curricula. In recognition of the importance of scientific literacy, and cognisant of a desire to show students how science is related to everyday life, many curricula contain implicit or explicit reference to aspects of the nature of science (Erduran & Scerri, 2002; Matthews, 1998; McComas, 1998; Mellado, 1998; Metz, 1998) and the relationship between science and everyday life as characterised by the Science Technology Society (STS) curriculum and related ideas (Kumar & Berlin, 1998; Mbajorgu & Ali, 2003; Solbes & Vilches, 1997; Thier, 1985; Wallace & Louden, 1998). They also access or take account of students’ prior knowledge of science and scientific conceptions (Duit & Treagust, 1998; Pfundt & Duit, 2005) and take account of students’ worldviews (Chinn & Brewer, 1998; Pfundt & Duit, 2005) or cultures (Cobern & Aikenhead, 1998). In the past, decisions about scientific content were seen as the role of teachers or school principals. But with the devolution of school management in many countries worldwide, debates about what should be included in school science curricula can become heated as parents or care-givers, many of whom now have considerable influence over curriculum decision-making, present their views. If such individuals hold stereotypical or inaccurate views of
science and scientists, then it is not unreasonable to suggest that conflicts may arise about the appropriateness or otherwise of some scientific content in school science curricula (Poole, 1996; Settle, 1996; Woolnough, 1996). Because of the variation in scientific literacy in the broader community, conflicts about scientific matters can thus impact upon the management of schools, especially in highly religious communities (Wren-Lewis, 1996).

As noted above, probably the most well known science curriculum debates are to do with conflicting views as to the origins of humans, namely, creation vs. evolution (see for example, Dagher & BouJaoude, 1997; Gould, 1983, 1991a, 1991b; Kass, 1988). More recently this has resurfaced in an emerging controversy over the inclusion of the so-called ‘intelligent design’ concept in school science curricula (Scott & Branch, 2002). The basis of such debates may be the widely reported view that there is a rather contentious relationship between an individual’s religious belief and perceptions of scientific knowledge and scientists’ views (see, for example, Jackson, Doster, Meadows, & Wood, 1995; Mahner & Bunge, 1996a, 1996b; Matthews, 1996). This relationship and its consequences in terms of education are often hotly debated by social scientists and science education researchers (Milligan, 1996; Tamir & Caridan, 1993).

Interestingly, many of the studies in the science education literature about science and religion are confined to issues concerned with Christian religions, particularly those described as fundamentalist in nature (i.e. in which adherents believe in the literal or near-literal interpretation of the Bible). However, little is known about non-fundamentalist or non-Christian educational contexts (but see Dagher & BouJouade, 1997; Francis & Greer, 1999; Koul, 2003). Remarkably, despite considerable rhetoric in the science education literature about such conflicts, little data about scientists’ views of such matters has been presented. Indeed scientists are typically assumed to hold certain viewpoints in religion-science debates (for example, they are typically assumed to be in favour of teaching evolution and omitting creation, see Fysh & Lucas, 1998a, 1998b).

**Research Purpose and Objectives of the Inquiry**

This inquiry adopts a different approach to that of most previous studies on scientific literacy, and consists of an investigation into a particular aspect of the nature of science and its potential impact on scientific literacy. Our contention here is that the public and many science students hold stereotypical views of science and scientists. We further posit that there are few data on what modern practising scientists think about scientific evidence and evidence claims of science. Such matters we believe are well suited for investigation when they are concerned with topical debates that bring the world of scientists and non-scientists into contact. Our overall argument is that it is important that the public and science students come to understand how scientists make evidence claims. Hence, here we report on an investigation of how scientists from different religious faiths judge evidence claims from within science, and how this interacts with their own particular religious beliefs. This is of particular interest
given the public perception of scientists as ‘objective seekers of truth’, a view of some
that science has largely demystified or even disproved religious beliefs (see Francis &
Greer, 1999, 2001; Mahner & Bunge, 1996a), and the contentious debates about
science and religion in respect of curriculum (Mahner & Bunge, 1996a).

Previous work within our research group found that some scientists could be
considered to hold superstitious or New Age beliefs (Coll & Taylor, 2004). It
became evident during our inquiry that some participants also held religious views
that were in conflict with current scientific theories (for example, they ostensibly
believed in spirits/ghosts). Gauld (2005) points out that scientists may hold two
positions: a rationalist stance which is that presented in the public domain (the
public domain of their community of practice) and the private idiosyncratic views
more accessible by interpretivist, ethnographic educational research approaches.
The issue of scientific literacy in this work is thus explored by investigation of scienc-
ists’ views of scientific evidence. Specifically the present work addressed the follow-
ing broad question, How do scientists judge evidence claims?, which is investigated
using the vehicle of scientific theories and religious views.

Theoretical Underpinnings

This inquiry has been conducted within an interpretivist paradigm with a social-
constructivist view of learning (Good, Wandersee & St Julien, 1993). The authors
believe that an individual’s constructs are influenced by his or her environment and
subject to influence by prior knowledge, peers, learning experiences, social interac-
tions, and context (Tobin, 1993). We accept that religious beliefs and scientific think-
ing are personal in nature and that mental construction of beliefs is a personal cognitive
process; however, we feel that previous work has not adequately addressed the socio-
cultural component of knowledge and belief construction. We wish to develop an
understanding of the religious beliefs and scientific thinking of the participants in this
study (for example, their views about specific scientific theories like evolution). We
recognise that we need to situate our research findings within the context in which the
study was conducted, and hence place emphasis on the social aspect of social-construc-
tivism. To develop our approach within a social-constructivist framework, we have
drawn on current thinking from socio-cultural views of learning. Socio-cultural views
of learning suggest that past research has not paid enough attention to the social medi-
ation of mental construction even in social-constructivist-based studies. Wertsch
(1991) summarises:

The basic tenet of a socio-cultural approach to mind is that human mental functioning
is inherently situated in social interactional, cultural, institutional, and historical
context. Such a tenet contrasts with approaches that assume, implicitly or explicitly,
that it is possible to examine mental processes such as thinking or memory indepen-
dently of the socio-cultural setting in which individuals and groups function. (p. 86).

It is worthwhile to note here that there is a limit as to how well we can actually
access or describe the sociological communities for these individuals, particularly
aspects of their religious communities. As will be seen in the data presented below, we did gain some insights into the culture of science, but less so in respect of religious communities.

**Researchers’ Viewpoints and Backgrounds**

The researchers in this work come from a variety of scientific, educational and religious backgrounds. Given the nature of the present work (i.e. dealing with an emotive and complex topic), it is appropriate for the authors to describe their background in order for the reader to be aware of any potential biases, and to aid in interpretation of our research findings.

One researcher was brought up in a relatively strict Catholic background. He was and still is a ‘practising Catholic’ in that he attends Sunday observances and other Catholic obligations regularly. He is a scientist with a doctorate in chemistry and record of publishing on organometallic chemistry. He also is a science education researcher with a second doctorate and publishing record in science education. Metaphysically he ascribes to constructivist views and acknowledges the social nature of research. A second researcher is from a church-going Protestant Christian background. He is still a tentative believer but no longer attends church on a regular basis. He has a doctorate in science education and comes from a science background, having completed undergraduate and postgraduate degrees in biology. Like the above researcher he ascribes to constructivist views and acknowledges the social nature of research. A third researcher was raised as an atheist and was converted to the Bahá’í Faith at high school as a result of extensive intellectual discussions with another Bahá’í. He is a scientist/engineer with a PhD in materials and process engineering, and an undergraduate degree in the biological sciences. He is a social-constructivist in epistemology but subscribes to a scientific-objectivist methodology for his science/engineering research. He is broadly in agreement with an interpretive-based research approaches to science education research in that he recognises the importance of subjective views in both learning and research in education.

**Methodology**

The methodology derived from the social-constructivist-based theoretical framework described above comprised an approach in which individual constructions were elicited by interactive dialogue between the researchers and the participants (Good, Wandersee & St. Julien, 1994). This dialogue recognised the social nature of knowledge acquisition and personal beliefs (Lave, 1991) and thus was conducted on neutral ground to reduce the influence of investigator bias (Johnson & Gott, 1996). In practical terms, this consisted of the interviewers constantly working to ensure undistorted communication took place: words and beliefs that hold an ‘established’ meaning (for example, a specific religious belief or ‘established’ scientific theory) were only ascribed the meaning imparted to them in the context of the interviews (see below, terms such as ‘higher power’, ‘spirit’ and ‘soul’). A purpose-designed
instrument was used as the basis for interviews. The instrument contains 18 assertions or propositions. The items were derived from literature reports of pseudoscientific beliefs held by students (for example, Wilson, 2002), a strategy found useful in our study of scientists’ beliefs about common superstitions (Coll & Taylor, 2004).

These propositions were examined by two cohorts of people. First was a panel of experts with a strong science background who agreed that the item statements consisted of ideas that were potentially in conflict with current scientific theories (Appendix). This panel of experts consisted of scientists across a range of disciplines who examined each item statement and asserted that it was in conflict with current scientific thinking in that discipline. These individuals had no contractual interest in the study (Guba & Lincoln, 1989) and were not participants (other than in this advisory capacity). Second, the researchers themselves, coming from a variety of religious backgrounds examined the statements to confirm they were consistent with a particular religious affiliation. These also were confirmed by examination of religious writings and documents produced by religious authorities (for example, encyclicals from the Catholic Church). The researchers additionally sought input from a panel that consisted of individuals representing each of the religions that formed the focus of this work. This panel confirmed that the statements were consistent with their particular religious affiliation.

Sample items included: ‘People can be cured of serious ill health by petition to a higher spiritual power’; ‘The age of the earth is no more than 10,000 years old’; ‘After death the soul/spirit of a person returns in a subsequent life form’; and ‘Human conception can occur by spiritual not physical means’. Participants were asked to respond to a four-point scale ranging from ‘I believe that this is almost certainly true’ to ‘I believe that this is almost certainly untrue’ with two in-between responses qualified by replacing ‘almost certainly’ with ‘quite likely’. Some of these statements are fairly definitive in nature and might have been modified or qualified in some way (for example, item 9 might have read ‘Some evil behaviour in the world occurs as a result of powerful evil spiritual forces’). There were two reasons this was not done. First, we wanted to have the items as similar in nature as possible. If we moderated item 9 in the manner suggested above but not other items, it might have subtly suggested to the respondents that belief or agreement with that item should be more tentative in nature than others. Second, we deliberately wanted to stimulate debate in the interviews, and our thinking here was this might be facilitated by statements that were slightly provocative in nature.

The selection of possible responses provided was intended to ensure items were not overly provocative. In a similar way, item 14 may appear to ask two questions (i.e. a respondent might think inanimate things have no soul/spirit, but that animals do). To present this item in terms only of ‘inanimate things’ might again send a subtle message that inanimate things could not be thought to possess a soul/spirit on logical grounds (i.e. the terms if juxtaposed would appear contradictory in nature, at least linguistically speaking). The research design employed thus sought to allow respondents to commit to a proposition, but allowed the researchers to tease out fine distinctions of this nature.

Propositions were chosen to access beliefs purported to come from several religious faiths and denominations: Catholic, fundamentalist Christian (namely, Christians
who believe in the literal or near literal interpretation of the Bible); Sunni Muslim, Judaism, Buddhism, Hinduism, and Bahá’í (based on religious writings and informal interviews with ministers and faith adherents for each of the above named religions).

The sample of 20 scientists was carefully chosen to obtain several cohorts for several reasons. First, we sought participants who were raised in a faith, practised that faith as children and young adults, and who now described themselves as ‘non-practising’. The intention was to see if these individuals drifted away from their beliefs and religious practices for no particular reason, or if this occurred because they encountered conflict between religious beliefs as they became enculturated into science—and if this in turn had impacted upon how they assessed evidence.

Second, we sought participants who were strong faith-adherents and strongly practising in their faith (as identified by the participants—i.e. they reported in the first part of the interview that they were currently practising their faith in terms of religious observance and participation in religious rituals).

Third, the interview participants were chosen purposively to provide a reasonably even gender balance and a range of scientific disciplines (chemistry, the earth and biological sciences, physics, etc.). The intention was to see if gender or scientific discipline influenced the relationship between religious beliefs and scientific thinking—since discipline or expertise appeared to influence the relationship between individual’s beliefs about superstitions (Coll & Taylor, 2004).

Fourth, we sought a variety of religious affiliation/backgrounds, to see if, for example, a strong Christian was more inclined to ‘accept’ Christian beliefs that were in conflict with scientific theories than say Hinduism or Bahá’í beliefs that were in similar conflict, and vice versa.

The participants were typically educated to the doctoral level or were engaged in doctoral level study (almost exclusively in science) and employed as faculty in their disciplines (mostly full-time but in some cases part-time academics studying a PhD part-time). The participants ranged from recent appointments with little experience to senior academics with departmental and school management responsibilities. They were first asked to complete the instrument in advance of interviews and the interviews addressed their responses along with other topics not presented in the instrument that arose during discourse. The interviewers strove to ascertain the basis on which the scientists had arrived at their views about the propositions contained in the instrument and any other beliefs or views respondents introduced during the interviews.

All interviews were audiotaped, transcribed fully, and participant-validated (i.e. transcriptions were sent to participants for comment and alteration). The transcripts were subsequently examined for statements about the scientists’ views in an iterative process based on a phenomenographic approach allowing pools of meaning, and subsequent categories of description, to arise from the data (Marton & Booth, 1997). Portions of transcripts are presented below to illustrate the process of analysis and interpretation, and pseudonyms are used throughout this report of the research. Some of these transcript segments have undergone minor editing (for
example, removal of repeated words, changes of tense) to make them more readable.

In accord with an interpretive approach, the research findings reported here are not directly generalisable to other settings. An alternative notion, applicable here, is the notion of transferability (Guba & Lincoln, 1989) in which the reader evaluates the significance of the findings in his or her own educational context. The provision of descriptive findings (see below), the so-called ‘thick description’ is intended to facilitate this process (Merrian, 1988; Peshkin, 1993).

**Research Findings**

The research findings that emerged from these data are summarised in Table 2 and here we provide a description of some of these findings. Some of these themes were reasons given by the scientist for supporting the instrument propositions while others were reasons for disbelieving them; these differences are detailed under individual headings. The themes discerned included: Personal experience/Personal beliefs;

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<td>Presbyterian</td>
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<td>Resource consent manager</td>
<td>MSc Environmental Science</td>
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<td>Buddhist</td>
<td>Physicist</td>
<td>MSc</td>
</tr>
</tbody>
</table>
Table 2. Summary of research findings

<table>
<thead>
<tr>
<th>Classification</th>
<th>Basis</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal experience/Personal beliefs</td>
<td>The scientists had undergone or knew intimately of some personal experience of the type discussed/ The scientists held strong personal beliefs about the topic</td>
<td>Reports of personal experiences were deemed reliable/ Personal beliefs had no foundation other than religious upbringing.</td>
</tr>
<tr>
<td>Testimony from other scientists</td>
<td>The scientists rated personal testimony of other scientists as credible.</td>
<td>This did not necessarily take the form of direct testimony but included the fact that another scientific discipline existed and inquiry was presumed to be reliable.</td>
</tr>
<tr>
<td>Potential theoretical basis/Related evidence</td>
<td>The scientists perceived a potential theoretical basis to the belief/The scientists held domain specific knowledge which they felt was relevant and supportive of the belief.</td>
<td>Commonly related to scientists’ own discipline or area of expertise. E.g. virgin birth was at least technically feasible since non-sexual reproduction in other supposedly sexual species was well established.</td>
</tr>
<tr>
<td>Do not know enough</td>
<td>The scientists felt current evidence about the belief was inadequate to either support or dismiss the belief.</td>
<td>Related to vagueness of terms such as ‘spirit’ and ‘soul’ and notions of cosmology.</td>
</tr>
</tbody>
</table>

Testimony from other scientists; Potential theoretical basis/Related evidence; and that We do not know enough. We then examined the findings in terms of habits of mind. Specifically here we looked to see what we could infer from the findings about scientists habits of mind. Habits of mind identified were: rationality, scepticism, open-mindedness, and mistrust of arguments from authority. Finally the findings were re-examined for evidence of how these habits of mind influenced personal actions, including scientific practice within the particular profession. Themes identified here were the influence of habits of mind on: personal day-to-day actions; interpretation of data from their own or others work; actions as teachers of science and that they would not engage in particular scientific research work or activity.

Personal Experiences

Personal experience emerged as a reason for believing some propositions with, for example, some scientists reporting personal experiences and reports of friends and colleagues being cured of significant illness (for example, cancer) by ‘petition to a higher power’. This was in some cases seen as resulting from what Bob called ‘the mere act of petition’, and in other cases from the actual intervention of a higher power as seen in Phil’s comment that ‘I know that in the intervention of God, there is clear evidence in healing’. Those who opposed godlike interventions generally felt that the notion of mind over matter was overriding as seen in Steve’s comment that ‘pointing the bone, that sort of thing in [Australian] Aboriginal or African culture, if you believe you’ve done something wrong, it could be because a higher power intervened, or it could be because of a belief that was self-fulfilling’.
Personal experiences reported included Bob’s experience of physical encounter with a native bird species that he considered as potential evidence for item 13 (‘some animals have a special spiritual status’) and Jim’s personal links and affinity with things Russian, which he saw as potential evidence for having lived a past life: ‘One of the other things is that my birthday is on the day of the Russian Revolution’.

As was seen in our study of scientists’ views about superstitions and New Age beliefs (Coll & Taylor, 2004), some personal experiences reported in the present work were dramatic and strongly influential. This is illustrated in the case of a strongly-practising Hindu participant, who talked of a dramatic personal experience involving ‘spirits’. Celia said:

I totally believe in it [i.e., ‘the spirit or soul of a person lives on after death’] because I have had certain experiences. When my grandfather died I was a little girl at the time. My mother was looking after him at the hospital and he said wanted to see me…. My mum took holidays for me from the school and I went with my mother to visit him in hospital and he died at the hospital—but the second it really happened that spirit got into me and maybe three or four months later everyday at 12 o’clock afternoon midday I used to get fits. They thought it was fits but it wasn’t. It was the spirit in me.

Similar reasoning was used by Celia to explain the common Hindu support for destiny matters (as probed in item 4, ‘what happens in a person’s life is set at the beginning of their life’) which she interpreted as being astrologically-related:

What happens in a person’s life except at the beginning of life? It’s more like fate isn’t it?…. The planetary positions and all that…. Even now everyone [i.e. in India] decides when you get married, or where you go. We were seven students and he [a pundit-astrologer] said you should be married at 29 and you’ll be very rich and be owning a car at that time. I never believed it at that time, but definitely next time. I brought a car here [i.e., in New Zealand] and I think back to him, and I said, you know what he was correct…. There should be some sort of power, control, over your fate—that’s what I believe.

The converse also was true in that lack of, or non-fulfilling personal experiences were deemed to be evidence against some propositions. To illustrate, Celia apparently did not accept that ‘a person can be affected in their personal life by petition to a higher spiritual power’ (item 5, Appendix) as the result of failed petition: ‘I was once thinking that if I pray to God I get good marks, it never happens, I have to study to get good marks. So I slowly understand that it doesn’t happen’.

Participants who believed that evil spiritual forces caused evil behaviour tended to point to their experience of human behaviour to explain this: ‘Well, I’ve just seen the evidence… I see it as spiritual evil, in that power corrupts and absolute power corrupts absolutely. There are so many people who have brought untold misery to themselves and the world and to others and they are still doing it’.

Personal Beliefs

Personal beliefs based in religion, with no supporting ‘evidence’ or indeed any need for evidence was used as a basis for acceptance of some of the propositions in the
item statements used in the interviews. Jack, a biologist, was firmly of the belief that the soul or spirit of a person continues to exist after death. This was grounded in a dualist material and supernatural view of reality:

> It’s pretty apparent to me that reality comprises both the material and the non-material…the natural and the supernatural and they are different spheres altogether…you see I’m quite happy with the existence of the supernatural and the recognition that the material world is completely different from that…one is material and other is non-material…and when you are dealing with the non-material…dealing with the human soul, your dealing with spirits, your dealing with God, angels, the devil all those sorts of things…no there has never been a conflict there…I can clearly see that science is a way of knowing which relates specifically to the material…it just that it takes a little time for the truth from one sphere to merge seamlessly with the truth of the other.

However, while Jack claimed no evidence or personal experience to support his belief in the non-material/supernatural concept, his view of material concepts was strongly grounded in scientific evidence. For example, when asked why he believed that the world was more than 10,000 years old he responded: ‘It is simply the accumulated scientific evidence from geology, palaeontology, physics, chemistry…. I think the scientific evidence is overwhelming in this’. Furthermore, he was also a strong believer in evolution based on the current scientific evidence:

> There doesn’t seem to be any satisfactory substitute as an explanation for the diversity of the world’s living things and I know… I’m acquainted with a number of other alternative theories that have arisen in the past and evolution explains things in a purely natural way and although there are some outstanding details, ‘t’s to be crossed and ‘i’s to be dotted, the paradigm is pretty well constructed I think.

Conversely, Ahmad, a Sunni Muslim, said that if science could prove something he would accept it:

> But whatever science may say, if it proves something, then everybody agrees, and everybody can repeat and get the same answer, that’s fine, I believe, I accept it… I agree with science if it has a strong base, strong evidence.

However, Ahmad, was adamant that evolution was baseless, and it seems what he considers as evidence for evolution (in this case) is not adequate when compared with evidence from God:

> The exam, I did not answer that question, because it is totally against humanity, it hurts me. One thing is always more important than anything else, and that is my faith.

When probed further regarding evidence for ‘Adam and Eve’, Ahmad stated:

> I have the strongest evidence that a person can have, which is God’s statement. God said He created you from Adam and Eve. What is stronger than the evidence of God? Nothing!

Whilst individuals were often prepared to accept aspects of their own particular faiths ‘on trust’, they were often sceptical about the beliefs held by adherents of other faiths. Alan, a Baha’i, was rather dismissive of Hindu-based beliefs in reincarnation and the special status of some animals: ‘I guess the evidence for reincarnation
is flawed in that there’s not much point to the exercise.... Why come back as a cow as a punishment?’

Interestingly, in some instances, although participants were more accepting of their own religious beliefs, when they conflicted with science this was not universally accepted. For example, Anne was brought up and remained a practicing Hindu. However, when probed about reincarnation (item 3) she commented: ‘In Hinduism there is a thing called reincarnation.... When people ask if I believe in reincarnation, not I don’t, but I believe the soul lives on’.

**Testimony**

A number of the scientists felt that whilst they themselves were not sure of the details of the evidence against some of the propositions, negative testimony from other scientists meant such propositions should not be taken seriously. This was most typically the case for the age of the earth proposition with, for example, Keith, a biologist, commenting that ‘the scientific evidence of fossils and dinosaurs and all that sort of stuff, the age of the stars’ and Jane, another biologist, saying, ‘You would have to throw out so many theories to believe that one’. This occurred irrespective of religious faiths with, for example, Anne, a Hindu, commenting, ‘I know a little bit about carbon dating and I know it is definitely older than 10,000 years because I believe in the carbon dating technique and the research that has been done in terms of prehistoric creatures and the evolution of man’. When asked why she believed in carbon dating she replied ‘because the half life of carbon-13 decays and produces isotopes of carbon, it has been scientifically proven, that decay kills off [sic] carbon’. Similarly, Mahmoud, a Sunni Muslim, felt that:

> Only God knows exactly when the world started, but from some of the evidences we have today, we can see that there are probably some animals that lived [were in existence] for longer than 10,000 years.

This he felt was believable because as he saw it:

> from what is described in religion God has created [some creatures] before mankind came to the surface, God has other creations that existed before then, so the world has probably been in existence for many, many more years than that.

Other participants pointed to things such as near death experiences for which in their minds there were now sufficient reports to support the religious propositions presented in items 2 and 3 (Appendix). Alan commented: ‘Our consciousness is not affected by sleep or injury to the person’s brain or whatever. There have been far too many cases of people remembering to dismiss... there are studies currently being conducted into near death experiences to the point where enough scientists are taking them seriously to warrant belief’.

One scientist, an earth scientist and fundamentalist Christian, ostensibly did think that the Earth was less than 10,000 years old. This he reasoned was a matter of data interpretation: ‘There is fossil and dating evidence, facts that suggests the Earth is millions of years old, these are facts... but you can interpret this in other ways’. When
probed further, he talked about a theory to do with changes in the speed of light which ostensibly meant that radio-chemical dating experiments were unreliable: ‘The speed of light is constant, but it may not always have been constant... this would affect the reliability of the carbon-dating data’.

However, for other scientists, the testimony of non-scientists could be considered as credible evidence. For example, Jack, a catholic, had no personal experience of ‘petition to a higher spiritual power’ impacting on his own life, but he believed that prayers could be answered based largely upon the experiences of others. ‘I know from friends, many of them Protestants, that they believe and that they have experienced the answer to prayers and I wouldn’t deny the reality of their experience.’

One participant, Arnie, who grew up in the West but who had worked in rural Africa for a number of years, commented on the strong cultural influence in evaluating testimony:

In the village I lived in, in Botswana we had one of the most powerful witchdoctors...and the stories people would tell about things he was capable of doing...you’d hear from a range of people including university educated people that I worked with in the school, they would tell stories...and you’ve got no basis for dismissing them, you’re not really being very objective if you dismiss it purely because you bring your own beliefs to the situation and there are some really quite strange things.

Implicit in this statement is also the sense that university education adds to the credibility of testimony.

Theoretical Basis to Beliefs

Again similar themes emerged from the religion and science study. To illustrate, for most of these scientists human conception by spiritual rather than physical means was deemed impossible. Celia, a Hindu, said: ‘It’s ridiculous, it will never happen. I totally believe it is due to physical means, because I am not a Christian I have never tried to understand that’. Similar views were expressed by Anne, another Hindu: ‘Conception was like a gift that was handed to virgin mums, they were born into a normal family’. However, some strong Christians and one Sunni Muslim used their discipline-specific scientific knowledge to propose reasons as to why this might be possible. For example, human conception was seen as at least technically feasible since non-sexual reproduction in other species was well established as seen in Bill’s comment: ‘It’s a possibility that if we have an all-loving God who constructed these processes in the first place using the natural things anyway, why can’t you have an amictic cell [i.e. which can give rise to offspring without fertilisation] in the ovary in the womb of a woman turn itself into an embryo? It happens in plants all the time’. Likewise Mahmoud supported his belief with what he considered to be suitable evidence: ‘I believe that an angel blew the spirit into the womb of his [Jesus’] mum and she conceived without any father involved. But you know that in the animal world, some animals can conceive without the opposite sex... I may have some examples that I compiled some time ago’. Those who discounted this proposition attributed the belief to something deemed to be socially-acceptable at the time with,
for example, Keith commenting ‘that way she [i.e. the mother of Christ] can’t have been soiled in any way, something that has a basis in belief and trying to fit into a particular framework’.

It was noteworthy that some scientists re-worked original statements, ‘thinking on their feet’ and seeking alternative explanations. Alan above was dismissive of Hindu beliefs in reincarnation but upon probing he looked for alternative explanations that might be seen or interpreted as ‘evidence’ at least consistent with such beliefs. He said of reincarnation: ‘the fact that genetic material is passed from one person to another as generations proceed, one after another, that is “reincarnation” so to speak’.

We Don’t Know Enough

The notion that we simply don’t know enough about many ‘spiritual things’ meant that some of the participants in the study likewise felt that ‘we need to keep an open mind’. This particularly occurred in relation to things such as spirits and souls living on after physical death and cosmological notions of pre-determinism and order in the universe or its creatures. Mary indicated that she thought that order in the universe was almost certainly due to a higher spiritual power: ‘You’re looking at some structure, let’s say a fly or a spider. Now what are the chances the probability that something like that can construct itself?’ This was universal across the religious denominations with Anne (a Hindu) commenting that the reason she was prepared to believe the notion that after death a spirit could continue to exist was because ‘I think that there is a lot yet to be discovered, there’s a lot yet unknown that we don’t know about and it could be proven…. Even if science has not proved it now, who know what might happen in the next 1000 years?’ She held similar views about people being cured by petition to a higher power: ‘People diagnosed with cancer found other ways and means not in terms of cures like alterative medicines, but in terms of believing, having faith and praying or taking up religion that they have been healed’, although she went on to comment that this was likely due to ‘a belief that they can destroy it if people believe in something it gives them the ability to fight something better’.

Habits of Mind: Scientific thinking, religious beliefs, personal action and scientific practice

The research findings reported here provide a picture of these scientists’ habits of mind. These habits of mind appeared to be a consequence of both religious beliefs and scientific training. It is of course likely that the formation of these habits of mind also was influenced by other factors such as upbringing and environmental-cultural influences. However, the data here suggest religious beliefs and scientific training together exert a potent influence in the formation of scientists’ habits of mind. The most significant outcome for this interesting mixture of scientists is variation in habits of mind: for some religious beliefs appear to override their scientific training and the norms of their profession; for others religious beliefs are paramount; and, for
some religious beliefs and scientific thinking are compartmentalised to avoid cognitive dissonance.

What also is of interest is what influence these beliefs or thinking have on the scientists’ actions and scientific practice. Examination of the data allows for a framework of their thinking to be developed. Here four main themes emerge.

First, the scientists engaged in some personal day-to-day actions not particularly related to their scientific work practice, but influenced by either their religious beliefs, or their scientific thinking separately. For example, with respect to religious beliefs, some scientists engaged in prayer or petition to a higher power when faced with illness of a spouse, relative or close friend. Jack, for example, said, ‘In my experience the answer to prayers is quite dramatic’. Those who did petition did not necessarily believe a higher power would intervene in some beneficent manner, but believed in the power of petition; that is, ‘the act of petition itself is either of comfort or becomes a self-fulfilling prophecy’. This, it seems depended on the event. So, for something you might have substantial control over such as good exam results, Liam thought were ‘more a result of your own actions’, but for more complex multi-dimensional things like human illness petition was worth considering: ‘It’s possible to be cured, doesn’t always happen, but yes I think it’s quite possible’. Likewise, Anne, a practicing Hindu, believed that an astrologer-pundit must be consulted ‘when deciding when to get married or where you go’. These types of action are of course similar to actions any religious person, scientist or otherwise, might engage in; but the influence of habits of mind shows through since such action was not indulged in by those who disbelieved in particular religious propositions, for example, the efficacy of petition to a higher power on scientific grounds. For other cases the religious ritual or activity was rationalised with scientific evidence, as noted by Arnie who commented, ‘Certainly I think there is a lot of scientific evidence for mind over matter’. To further illustrate action resulting from habits of mind, consider Anne, who reported being told to ‘put my head in a certain position when sleeping’, which upon analysis she felt might be because ‘with the sun’s direction, sun and the moons position that it’s better not to put your head there because it, the rays upset the head…. What they believed originally could have been true and scientific’.

Similar rationale was presented around the topic of global warming. So whilst religion might encourage us ‘not to waste the worlds resources’, bad human environmental management might then be a result of ‘evil spiritual forces’ which ‘are around … meaning we are then burning too much fossil fuel’. Hence, we might act by means of petition to a higher power—or not—to cure illness depending on the dominance of science or religion; make life or career choices based on religious beliefs; and, modify our physical environment or environmental management practices because both religion and science encourage this. Habits of mind evident here, we suggest, might be rationality and scepticism.

Second, the scientists’ interpretation of data from their own or others’ work was strongly influenced by their religious beliefs, their scientific training or a combination of the two. The main manifestation of this was a strong desire to be open minded about data interpretation, with clear evidence that a scientist should ‘keep
an open mind’—not only about conflicting issues; but that such a habit of mind was the very essence of scientific thinking. This notion was encapsulated in Arnie’s comments:

The things you start to learn in science, you are starting to put together a more sophisticated picture of the world and when certain things no longer fit very well, and so you start to think, well start to question … and then think … who knows, the world is a mysterious place and so I don’t want to rule out, rule out some possibilities.

This was more than a general observation or ‘feeling’: some of the scientists commented specifically on how this type of thinking influenced their own scientific research endeavours. Two examples illustrate how this intersection of ideas can be manifest; in scientific discourse with colleagues, or in personal mental engagement with scientifically-accepted theories from their own scientific discipline. In the first, Kevin, an earth scientist, was talking about evolution. When responding to the question ‘On what basis do you believe the earth’s created by a higher spiritual power?’, he replied:

Of late, I’ve challenged that certainly from a scientists’ perspective, having to look at evolution, for example, in greater detail, the age of the earth, it makes me think in the past there was more water, there was more genetic information…. I think we were genetically more diversified in the past and we’ve lost it and ultimately we must’ve been more diverse in order as a life which means we started off more complete that we are now which really points to creation.

In the second example, William was talking about human conception and started by saying that ‘this is a whole area of uncertainty’ with such thinking reflected in a debate with a research colleague about plant breeding:

You see, that’s one of the things I was arguing with Peter [a pseudonym] about, just when you came here now, breeding systems in grasses…. We are thinking of our own breeding system… when we are talking about plants…. It’s very comfortable to treat plants the same as us, boy meets girl, pollen tries to do what? … It doesn’t work that way…. If you get sematic cells in a plant ovary producing embryos and a seed…. It’s a possibility that if we have an all-loving God who constructed those process in the first place using the natural things anyway, why can’t you have a sematic cell in the ovary of a woman turn itself into an embryo?

Hence, scientists need to be open to alternative interpretations even if these are outside mainstream science, including major theoretical paradigms like evolution, or seemingly unchallengeable things like human conception. Habits of mind evident here we suggest might be open-mindedness, rationality and mistrust of arguments from authority.

Third, many of the participants were faculty researcher-teachers and actions as teachers of science were influenced by religious beliefs and scientific training or a combination thereof. Jack noted that his belief in ‘order in the universe exists as a result of the influence of a higher spiritual power’ was manifest in aspects of science content: ‘In the properties of the elements, there is order there and you can understand that order if you are a chemist’. In the context of a complex multi-faceted teaching environment, many noted that a teacher of (tertiary-level) science needed to be cognisant of students’ and others religious beliefs when conflicts might occur
and strive to present science in a scientific, yet culturally sensitive manner. Phil notes: ‘Look, I am just one person from my particular culture and this is what I believe. That doesn’t necessarily mean it’s right, and it’s convenient for our culture you know’. William noted:

I remember once when I was in Utah, was teaching the ecology course and I was giving the students some questions to do … this was before the days of computers … I got the secretary who was a Mormon to … and one of the questions was something, like you know human population being too high … she had a problem with that, and I said “What’s the problem with that?”, and she said, “The good Lord taught us to populate the earth”.

Hence, teachers of tertiary level science need to be aware of the potential religious diversity in their classes and teach in a manner that is respectful of personal religious views whilst maintaining scientific integrity. Habits of mind evident here we suggest might be open-mindedness.

Fourth, in a few instances the scientists indicated that they would not engage in particular scientific research work or activity that might be accepted or endorsed by some from their community. The most common example of this was the biologists, who encountered issues such as human cloning or genetic modification; their objections expressed here were seemingly a result of cognitive dissonance between their religious beliefs and scientific training. Some could separate these: Jack said, ‘Once you accept the idea of supernatural and natural spheres, it doesn’t trouble me at all’, but others such as Mary said, ‘I’ve got quite a problem with in vitro fertilisation… particularly in terms of the spare embryos. I abhor that term because each one of those is an individual, a human’. She went on say, ‘Cloning animals doesn’t really concern me that much. I’d have a problem with human cloning… we are meddling too much: it’s not something I would do’. The converse also happened, with some scientists encountering conflict between scientific ideas and religious beliefs of others effectively imposed their scientific thinking on others. Allan, an environmental scientist working with indigenous peoples in Australia, encountered a religious rite that required the slaughter of an endangered animal, a turtle, which offended his scientific instincts to preserve the species: ‘They were going to have a feast… so they brought two sea turtles… in the end I had to go and buy them, so they could have the money to buy a pig instead’. Habits of mind evident here we suggest might be rationality.

Discussion and Implications for Science Teaching and Learning

In the present work it seems with a few exceptions (Jack and Arnie) most of the scientists’ views expressed in relation to religion were not in fact personal beliefs unsupported by data (at least in the interviews) or rationalised in any coherent fashion. In contrast they drew quite strongly on scientific arguments when dismissing items or views they disagreed with. This may be an artefact of the methodology employed, in that we put specific propositions to participants and then sought their views. Such an approach may not have accessed some religious beliefs of respondents that they may not have been able to rationalise. However, when they wanted to dismiss some item
statements, they felt they needed to provide convincing reasons, and did so, even with item statements outside their field, by drawing upon ideas outside their own discipline, evidence of them in some instances accepting the ‘authority of science’.

Mahner and Bunge (1996a) assert that ‘consistency in one’s belief system is hard to come by’ (p. 112). This seems to be borne out in the present work. However, their addendum that this is ‘particularly so in the midst of a society where religion wields a formidable cultural and political power’, seems to us to be harder to justify. Certainly there is evidence that some of these scientists allowed their religious beliefs to override scientific evidence. Equally however, some of the scientists accommodated religious beliefs and scientific evidence in the face of apparent dissonance. In some cases they held the scientific view at the expense of the religious dogma; in other cases it seems they saw no need to resolve this conflict; perhaps then the material and spiritual worlds need not agree.

Some authors have argued that an outcome of good science education is improvement in scientific and technological literacy (Laugksch, 2000; Mahner & Bunge, 1996a, 1996b) and others argue that religion and superstition are anti-science (see, Matthews, 1996, and references therein). Modern citizens constantly confront scientific and technological issues and, in particular, science/religious conflicts are common nowadays. Given that scientists are generally seen as (sometimes ‘tainted’) authority figures with respect to science claims, it is of interest for science educators and the public to understand what beliefs scientists hold, and on what basis, they hold such beliefs. A more liberal approach to science teaching might, as Matthews (1996) suggests, ‘maintain that science instruction should be more than merely the conveyance of factual knowledge’ (p. 91). Quite so. In other words, science is value-laden as many authors working in the area of the nature of science have long maintained (see, for example, Sutching, 1994). Others like Ogawa (2002) argue that science needs to move beyond the ‘Western view of science’ and take cognisance of ‘indigenous science’. The findings here suggest that scientists are not necessarily highly dogmatic and do take into account many factors when forming their views of good evidence including testimony, personal beliefs and experiences, and a healthily opened-minded attitude when they perceive a paucity of scientific knowledge exists.

An important feature of scientific literacy is the ability to make credibility judgements of people’s and particularly scientists’ testimony. Scientific literacy is important in modern society as people encounter debates and issues of a scientific and technological nature, including science curriculum matters. This study provides a window into some scientists’ thinking and shows how they make judgements about evidence and evidence claims. As noted above, it is our position that these research findings point to a more open-minded attitude than is commonly ascribed to scientists, accorded their stereotype presented in the literature (Mahner & Bunge, 1996a), or held by students and the public (Dalgety, Coll & Jones, 2003). This suggests that scientists are not automatically dismissive of non-scientific beliefs—including religious beliefs—and points to a human dimension of scientific thinking.

A second issue is the impact, if any, of scientists’ beliefs on their teaching or engagement with scientific content that conflicts with science theories. A scientist’s
research is ‘screened’ in that if he or she wishes to publish research in scientific journals, peer-review likely screens out views that are widely disparate from those held consensually by the particular community, such as chemists, earth scientists and so on (insofar as there is consensual agreement). The fact that many of the scientists in the present work held beliefs that were in direct conflict with ‘normal science’ is not necessarily of concern in this context. Tertiary level teachers arguably have more autonomy over specific course content (in that, for example, they are not constrained by external curricula) although course offerings may be subject to some peer review and scrutiny (for example, accreditation programmes exist for many professions, and course structure and content in tertiary level science are often externally moderated, especially at advanced levels). But what of, say, an earth scientist or biologist who is required to teach current scientific theories that conflict with their personal religious beliefs? Several such individuals were identified in this work. There are several possible explanations or responses to such an issue. First, many religious beliefs (spirits, destiny, special status of animals, etc.) are topics unlikely to arise during teaching. McGeorge (1992) points out that in the school system contentious scientific content also can be avoided when the topic evolution is not expressly presented in curriculum documents. Second, such individuals might seek to avoid occupations, including tertiary level teaching that results in such encounters.

Notes

1. Snively (1990) notes viewing science teaching as enculturation into science has negative connotations of assimilation—with a corresponding judgement that science is superior to other knowledge such as that of indigenous or first nation peoples.

2. An interesting example of this concerns a rather short-lived debate over the structure of DNA. In the late 1970s, two scientists proposed an alternative model for the structure of DNA (Rodley & Reanney, 1977). This challenge to the successful and well established Watson–Crick model was highly controversial and acrimonious. Interestingly, it was well known that the Watson–Crick model possessed limitations—for example, the rapid unzipping of the DNA chain seemed inconsistent with the double-helix model (Crick & Klug, 1975; Rodley & Reanney, 1977). However, the remarkable success of the Watson–Crick model meant that many were highly uncomfortable about any challenge to its correctness.

References


Appendix

Please indicate the answer you think MOST CLOSELY REPRESENTS your opinion about the following statements.

For example, if you think that people are NEVER cured by petition to a higher spiritual power, you would provide the following response:

<table>
<thead>
<tr>
<th>Statement</th>
<th>I believe that this is</th>
<th>I believe that this is</th>
<th>I believe that this is</th>
<th>I believe that this is</th>
</tr>
</thead>
<tbody>
<tr>
<td>People can be cured of serious ill health by petition to a higher spiritual power</td>
<td>almost certainly true</td>
<td>quite likely to be true</td>
<td>quite likely to be untrue</td>
<td>almost certainly untrue</td>
</tr>
<tr>
<td>The age of the earth is no more than 10,000 years old</td>
<td>almost certainly true</td>
<td>quite likely to be true</td>
<td>quite likely to be untrue</td>
<td>almost certainly untrue</td>
</tr>
<tr>
<td>After death the soul/spirit of a person continues to exist</td>
<td>almost certainly true</td>
<td>quite likely to be true</td>
<td>quite likely to be untrue</td>
<td>almost certainly untrue</td>
</tr>
<tr>
<td>After death the soul/spirit of a person returns in a subsequent life form</td>
<td>almost certainly true</td>
<td>quite likely to be true</td>
<td>quite likely to be untrue</td>
<td>almost certainly untrue</td>
</tr>
<tr>
<td>What happens in a person’s life is set at the beginning of their life</td>
<td>almost certainly true</td>
<td>quite likely to be true</td>
<td>quite likely to be untrue</td>
<td>almost certainly untrue</td>
</tr>
<tr>
<td>A person can affect what happens in their life by petition to a higher spiritual power</td>
<td>almost certainly true</td>
<td>quite likely to be true</td>
<td>quite likely to be untrue</td>
<td>almost certainly untrue</td>
</tr>
<tr>
<td>Human conception can occur by spiritual and not physical means</td>
<td>almost certainly true</td>
<td>quite likely to be true</td>
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7 People can be cured of serious ill health by petition to a higher spiritual power

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8 Order in the universe exists as a result of the influence of a higher spiritual power

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9 Evil behaviour in the world occurs as a result of powerful evil spiritual forces

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10 Inspiration for arts, sciences and crafts is a consequence of spiritual forces

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11 The lives and activities of all living things are influenced by spiritual forces

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12 There are benevolent spiritual forces that assist or protect people in their daily lives

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13 Some particular animals have special spiritual status

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14 All living and inanimate things have a soul/spirit associated with them

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<td>People who behave well are rewarded in an afterlife</td>
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<td>Humans are distinguished from other animals as a result of having a soul/spirit</td>
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