Article

Investigating Scientific Literacy: Scientist's Habits of Mind as Evidenced by Their Rationale of Science and Religious Beliefs†

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Science and Scientific Literacy

Science and technology have been incredibly successful in purely technical terms. For instance, international air travel, space flight, and curing of hitherto untreatable medical illnesses all are now routine events. One feature of the incredible (and seemingly ever increasing) advance of science and technology is a sense of unease amongst the general population of science's potential to change our lives, in sometimes unpredictable and alarming ways. Public understanding of science, or scientific literacy, is of increasing concern worldwide according to much recent literature.[1,2] The term *scientific literacy* represents a diversity of views.[3,4] However, a common theme in the scientific literacy literature is that of being *learned* or knowledgeable about some science content, and being able to critique scientific debates. According to Laugksch[2] 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[3]). Some authors argue that the success or otherwise of a science education system can be evaluated by reference to the literacy of the citizens.[5]

It is interesting that many societal scientific debates are characterised by suspicion of scientists and their motives.[6] Thus Reiss[7] (p. 154) suggests that *the topics on which scientists work – and so the subject matter of science itself – to some extent reflect the interest, motivations and aspirations both of the scientists that carry out such work and of those who fund them*. In other words, the current rate of technological change is perceived as being driven by the motives, interests, and values of the science and technology community.[6-8] This may be one reason that scientists are now seen somewhat as *tainted witnesses* with a vested interest, captured by personal interests, or unduly influenced by funding providers such as central government or multinational corporations.[9]

That the science and technology community has such a large impact on technological change would likely be less problematic if the values and culture (and indeed the demographics) of the science community were considered to be reasonably representative of society as whole.[7] However, in general this is not the case. For example, women are underrepresented in higher education science and technology faculty posts and other science-related occupations. In the UK only 12% of science professors are women,[10] and a similar under-representation apparently applies to many ethnic minorities. Thus indigenous peoples are underrepresented in post-compulsory science education and science professions, purportedly as a result of perceived conflicts between indigenous worldviews and the worldviews of so-called *Western science*.[11]

It is hard to overestimate the importance of scientific literacy in the modern era. Carson[1] says (p. 1007) we need to *teach about the physical world, in order to share the achievements of science with our students, and in order to equip students to be good, informed citizens capable of participating in public discourse concerning matters of science*. Important and topical issues relate to matters such as the appropriate use of cloning technologies or genetic modification or engineering.[12] Oftentimes the *right answer* is not obvious for such scientific debates, and the public are faced with trying to decide who is credible. Such debates are hampered by a litany of scientific disasters such as the uncritical use of pesticides like DDT,[13] and medical mishaps such as with thalidomide.[14] Perhaps the most dramatic recent example of public debate in which scientists were discredited is that of the UK government's *scientifically-based* claims that the so-called *mad cow* disease could not cross the food chain from animals to humans.[13] This proved patently incorrect, and made the British pubic very wary about later scientifically-backed claims of GM crops and the like. Carson[1] provides a strong case for the importance of scientific literacy as a focus for science education. He comments (p. 1011) that *science has become far more than an esoteric body of facts about the natural word*.

Scientific Literacy and Religious Beliefs

Scientific literacy impacts upon schooling, and sometimes conflicts surface between scientific and religious viewpoints. Because of the variation in scientific literacy in the broader community, conflicts about scientific matters can impact upon the management of schools, especially in highly religious communities. Thus, with devolution of school management in some countries debates about what should be included in school science curriculum can become quite heated as characterized by creationism vs. evolution debates,[15,16] and the emerging controversy over the inclusion of the *intelligent design* concept.[17] The basis of such debates may lie in view that there is a rather contentious relationship between an individual's religious belief, and scientific knowledge and training.[18-21] This relationship and its consequences in terms of education are often hotly debated by social scientists and science education researchers. For example, the literature is replete with lengthy discussion about the conflict between scientific and creationist views of the origins of humans.[16] These reports have largely focused on the issue of whether cognitive dissonance occurs in areas for which religious beliefs and scientific thinking are potentially in opposition. Furthermore, many of the studies in the science education literature are confined to issues concerned with Christian religions, particularly those described as fundamentalist,

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.[15,22,23] 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 portrayed as sceptics and objective seekers after truth, and are assumed to hold certain viewpoints in religion-science debates, *e.g.* typically, they are assumed to favour of the teaching of evolution and omit creation.[24]

The current investigation adopts a different approach to that of most previous studies on scientific literacy, by attempting to determine how scientists from different faiths judge claims from within science and their own particular religions. In other words, do they exhibit scientific literacy as defined by Laugksch[2] and only accept opinion about contentious matters critically seeking logic and evidence for any particular stance? This is of particular interest given the public perception of scientists as *objective seekers of truth* and the view that science has largely demystified or even disproved religious beliefs.[19,22,25]

Nature of Science and the *Scientific Mind*

An important aspect of scientific literacy is familiarity with the nature of science. To engage in debate about scientific issues necessitates some understanding of the nature of science. Much of the success of science has been attributed to the so-called scientific method,[26] and high standards of evidence for claims and theories. But how does science work? How do scientists obtain good data? What are good data? What are the *rules of the game* in science? Much has been written about the nature of science, and much research into students' understanding of the nature of science has been performed. It seems students often see science as a codified body of knowledge that is essentially unable to be challenged.[27] Much constructivist writings and constructivist-based pedagogies have sought to overcome such notions. Constructivists see scientific knowledge as mentally constructed personally, based on personal experiences and influenced to a greater or lesser degree by the social context in which knowledge construction occurs.[28]

It seems from the literature that students ascribe scientists fairly stereotypical stances and beliefs, much as do the general public in seeing them as objective seekers of truth, inevitably ascribing to experimentalist methods of inquiry in their scientific search.[29] Scientists are, however, humans and like all humans hold views and biases, *e.g.* seeing some things worthy of inquiry and others not.[2] However, like technology,[30] science is increasingly presented in the science education literature as contextualized and value-laden, and to possess a *sociological agenda*.[31] Carson[1] argues (p. 1012) 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*. Guisasola, Almudí and Furió[32] point out that students, in physics at least, are likely to see science as codified knowledge for which textbooks present a very simplified version of the nature of science, one in which science knowledge is seen to be accumulated in (p. 333) *non-problematic, non-historical, 'linear' accumulation*. Likewise, recent work by Dagher and Ford[33] 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.

Gauld[34] in a seminal paper summarizes much research into the scientific mind and scientists' views of the nature of science. This is presented in terms of the *scientific attitude* (attributed to Gauld & Hukins[35]), and *habits of mind*. According to Guald's[36] 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, *e.g*, open-mindedness and scepticism. However, according to Gauld[34] it is the interplay of these habits of mind that results in *the scientific attitude*, in which (p. 110) *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*. According to Zinman,[37] a key feature of evidence claims, is that scientists have (p. 79) *very high internal critical standards*.

Herron[38] comments (p. 105) 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*, pointing to a need for further research in this area. This resonates nicely with Reif's[39] view that to understand science involves more than content knowledge, it also involves (p. 281) understanding of the *requisite thought process* of science.

The literature is replete with commentary and rhetoric about what scientists are purported to think: their epistemological beliefs,[21] their views about the nature of science,[40] conflicts between science and religion,[19,20,34] and superstitious/pseudoscientific beliefs.[5] But according to Coll and Taylor[41] there are few data reported from contextualized and detailed research studies about scientists' views of the nature of science, and conflicts between scientific and everyday thinking.

Objectives of the Inquiry

Previous work within our research group found that many scientists could be considered to hold superstitious or *New Age* beliefs.[41] It became evident during our inquiry that some participants also held religious views that were in conflict with current scientific theories, *e.g.* ostensibly some believed in, or were not prepared to discount the existence of spirits/ghosts. The present study examined the relationship between an individual scientist's religious belief and his/her scientific thinking. Gauld[34] points out that scientists may hold two positions: a rationalist stance, which is that presented in 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 scientists' views of scientific evidence. Specifically, the present

work addressed the following broad question: "*How do scientists judge evidence claims?*" and is investigated using the vehicle of scientific theories and religious views.

Theoretical Underpinnings

The inquiry has been conducted within an interpretivist paradigm with a social-constructivist view of learning.[28] The authors believe that an individual's constructs are influenced by his/her environment and subject to influence by prior knowledge, peers, learning experiences, social interactions, and context.[42] We consider that religious beliefs and scientific thinking are personal in nature and that mental construction of beliefs is a personal cognitive process. However, we feel that previous work has not addressed adequately the sociocultural 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, *e.g.* their views about specific scientific theories like evolution. We recognize 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-constructivism. To develop our approach with a social-constructivist framework, we have drawn on current thinking from sociocultural views of learning. Sociocultural views of learning suggest that past research has not paid adequate attention to the social mediation of mental construction, even in social-constructivist-based studies. Wertsch[43] summarizes (p. 86): *The basic tenet of a sociocultural 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 independently of the sociocultural setting in which individuals and groups function*.

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.[28] This dialogue recognized the social nature of knowledge acquisition and personal beliefs,[44] and so it was conducted on neutral ground in order to reduce the influence of investigator bias.[45] In practical terms this consisted of the interviewers constantly working to ensure undistorted communication took place: words and beliefs that hold an *established* meaning, *e.g.* a specific religious belief or *established* scientific theory, were only ascribed the meaning imparted to them in the conversation of the interviews (see below, terms like *higher power*, *spirit* and *soul*). A purpose designed instrument was used as the basis for interviews. The instrument† contains 18 assertions or propositions that were deemed to consist of potential conflicts between religious beliefs and scientific theories by a panel of experts. Other items were derived from literature reports of pseudoscientific beliefs held by students[46] – a strategy found useful in our study of scientists' superstitious beliefs.[41] The panel of experts consisted of scientists from a range of disciplines (see below) that 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[47] and were participants only in this advisory capacity.

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*. Propositions were chosen to access beliefs purported to come from several religious faiths and denominations: Catholic, Fundamentalist Christian (Christians who believe in the literal interpretation of the Bible), Islam, 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 23 scientists (Table 1) was chosen carefully to obtain several cohorts for the reasons detailed below. Firstly, we sought participants who were raised in a faith, practiced that faith as children and young persons, and who now described themselves as *non-practicing*. 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 acculturated into science and if this, in turn, had impacted upon how they assessed evidence. Secondly, we sought participants who were strong faith-adherents and strongly practicing in their faith (as identified by the participants, *i.e.* they reported that they were currently practicing their faith in terms of religious observance and rituals. Thirdly, the participants for interview were chosen purposively to provide a reasonably even gender balance and a range of scientific disciplines (chemistry, 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 of expertise influenced the relationship between individual's beliefs about superstitions.[41] Fourthly, we sought a variety of religious affiliation/backgrounds. The intention was to see if, for example, a strong Christian was more inclined to *accept* Christian beliefs that were in conflict with scientific theories than they were about say Hinduism or Bahá'í beliefs that were in similar conflict, and vice versa.

Typically, the participants were 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). The participants ranged from recent appointments with little experience to senior academics with departmental and school management responsibilities. The participants

†Available from the authors upon request

Table 1. Demographics of Research Participants.

Pseudonym	Religion	Occupation/ Discipline	Qualification
Gerrad	Church of England	Lecturer in Biology	PhD
William	Presbyterian	Lecturer in Biology	PhD
Bob	Hindu	Lecturer in Physics	PhD
Mary	Catholic	Lecturer in Biology	PhD
Arnie	Methodist	Lecturer in Agroscience	PhD
Susan	Agnostic	Lecturer in Agroscience	PhD
Phil	Agnostic	Lecturer in Agroscience	PhD
Iman	Muslin	PhD student - Agroscience	MSc
Perry	Methodist	Lecturer in Science Education	PhD
Tom	Catholic	Lecturer in Science Education	PhD
Jack	Catholic	Lecturer in Biology	PhD
Allan	Bahá'í	Resource Consent Manager	MSc[a]
Celia	Hindu	Earth Scientist	MPhil
Anne	Hindu	PhD student - MAPE	MSc
Brian	Bahá'í	Pharmacist	BPharm
Lyle	Bahá'í	Marine Biologist/Evolutionary Theory	PhD
Liam	Christian	Chemist	PhD student
Kevin	Christian	Earth Sciences	PhD student
Sandy	Hindu	Biology Teacher	MSc/MEd
Patty	Buddhist	Chemist	MSc
John	Buddhist	Chemist	MSc
Rachel	Buddhist	Physicist	MSc
James	Buddhist	Physicist	MSc

[a]Environmental Science

were asked to complete the instrument in advance of interviews, such that 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 audio-taped and transcribed, transcripts were 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.[48] Portions of transcripts are used to illustrate the process of analysis and interpretation and pseudonyms are used throughout. These have undergone light and minor editing, *e.g.* removal of repeated words, changes of tense, in some case to make them more readable. In accord with an interpretive approach, the research findings reported here cannot be directly generalized to other settings. An alternative, and that applicable here, is the notion of transferability[47] 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.[49]

Research Findings

The findings are summarized in Table 2 and illustrated below. Some of the themes stem from reasons given by the scientist for supporting the instrument propositions, others from reasons for disbelieving them. These differences are detailed under the individual headings that follow.

Personal Experiences

Personal experience emerged as a reason for believing some propositions with, for example, some scientists reporting friends and colleagues being cured of significant illness, *e.g.* 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 God-like 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 which 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 appeared to consider 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 scientist views about superstitions and New Age beliefs,[41] some personal experiences reported in the present work were dramatic and strongly influential. Thus, a strongly-practising Hindu participant 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 com-

Table 2. Summary of Research Findings.

Classification	Basis	Comment
Personal experience/Personal beliefs	The scientists had undergone or knew intimately of some personal experience of the type discussed/The scientists held strong personal beliefs about the topic.	Reports of personal experiences were deemed reliable/Personal beliefs had no foundation other than religious upbringing.
Testimony from other scientists	The scientists rated personal testimony of other scientists as credible.	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.
Potential theoretical basis/Related evidence	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.	Commonly related to scientists' own discipline or area of expertise. Virgin birth was at least technically feasible since non-sexual reproduction in other supposedly sexual species was well established.
Don't know enough	The scientists felt current evidence about the belief was inadequate to either support or dismiss the belief.	Related to vagueness of terms such as 'spirit' and 'soul' and notions of cosmology.

mon Hindu support for destiny matters (item 4: *what happens in a persons 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? Its 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 NZ, 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, apparently Celia 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, you are dealing with spirits, you are 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.

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. Thus, 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 eh 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 em 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.

However, while 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 Bahá'í, 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?*'

As might be expected, although most participants were more accepting of their own religious beliefs, when they conflicted with science this was not universally accepted. For example, Annie 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, no 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 could 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, Annie, 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*'.

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. Alan comments: '*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 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 questioned 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 to credible evidence. Thus Jack 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, who grew up in the West, but had worked in rural Africa for a number of years, recognised 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 too understand that*'. Similar views were expressed by Annie another Hindu: '*Conception was like a gift that was handed to virgin mums, they were born into a normal family*'. However, some strong Christian adherents 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 as amictic cell, i.e. that can give rise to offspring without fertilization, in the ovary in the womb of a woman turn itself into an embryo? It happens in plants all the time*'. Those that discounted this proposition attributed the belief to something deemed 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 reworked original statements, thinking on their feet and seeking alternative explanations. Alan, 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 form 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 occurred particularly 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 Annie (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 prove…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*'.

Implications for Science Teaching and Learning

Some authors have argued that an outcome of good science education is improvement in scientific and technological literacy[2,18-20] and argue that religion and superstition are antiscience.[21] Modern citizens constantly confront scientific and technological issues and science/religious conflicts. Given that scientists are generally seen as (sometimes *tainted*) authority figures with respect to science claims, it is of interest for science educators to understand what beliefs scientists hold, and on what basis, they hold such beliefs. A more liberal approach to science teaching might, as Matthews[21] posits (p. 91), *maintain that science instruction should be more than merely the conveyance of factual knowledge*. Quite so! In other words, science is value-laden as many authors working in the area of the nature of science have long maintained.[50] Others like Ogawa[51] argue that science needs to move beyond the Western view and take cognisance of *indigenous science*.

One feature of scientific literacy is the ability to make credibility judgements of peoples' and 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, in this case with respect to potential conflicts between science and religion. The research findings provide evidence for dissonance for many of these participants, but others have, in contrast, rationalized such dissonance in variety of ways. It is our view that these data point to a more open-minded attitude than is commonly ascribed to scientists. 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 of scientific content, especially in the case of religious beliefs that conflict with science theories. A scientist's research is screened in that if he or she wishes to publish research in a scientific journal 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 study 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, *e.g.* they are not constrained by external curricula, although course offerings may be subject to some peer review and scrutiny, *e.g.* 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 that 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[52] points out that in the school system sometimes this also is 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.

Mahner and Bunge[18] assert (p. 112) that *consistency in one's belief system is hard to come by*. 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 unjustified and somewhat overstating the case.

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