A New Vision for Science Education: 
Spirituality, Contemplation and 
Transformation

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I chose to carry out this research as a Melbourne College of Divinity thesis rather than a Faculty of Education thesis because I am writing as a committed Christian. My faith commitment led me to undertake this research for science educators for the purpose of improving science education and the common good of society. The thesis has been enhanced by peer critique for the following conference presentations and publications as supported by Monash University.

Conference paper presentation

Publications
Refereed conference papers


Book Chapter

Article
ABSTRACT

Despite the enthusiasm of most young Australians for the latest hi-tech products (digital cameras, mobile phones and mp3 players) many are not choosing to study science in senior school years. As a consequence the number of science graduates continues to decline, which threatens to hinder Australia’s advancement in science related fields.

Informed by socio-cultural-historical theory, the argument developed in this thesis is that science education, when inclusive of spirituality, can challenge students’ stereotypical views of scientists and science. When spirituality is purposefully weaved into the science curriculum, students develop a better understanding of both the nature of science and how scientists do their work. In addition to hands-on science investigations, contemplation can help students connect with the science they are expected to learn.

A narrative of Nobel Prize winner geneticist Barbara McClintock shows students that creativity can stem from a spiritual connection with the organisms being investigated. McClintock viewed the maize plants she studied as her friends rather than mere objects. She understood that reason and experiment, although important, are insufficient for a scientist to articulate the laws of nature. McClintock’s contemplative connectedness with the experimental plants, together with her unique relationship to the natural world, offers a different, broader perspective of scientific endeavour.

A new vision for science education is put forward, one that enables students to appropriate such a scientist’s way of working. This vision for a transformative science education would involve students in new ways of participating in science that take into account the relational world of nature. Implementing this vision, that incorporates science and spirituality, would involve students in hands-on and meditative activities, both in the classroom and in the natural
world. When students are provided with opportunities to reflect on the way McClintock worked as a scientist, their prior stereotypical views of scientists and science are challenged, and they begin to see themselves as fledgling scientists. Scientists who incorporate spirituality in their work can be inspirational and diverse role models for students. By making such narratives readily available to students in learning environments that foster contemplative connectedness, students may be more interested in science, and in turn choose to travel the pathway that leads to science careers and more scientific breakthroughs for the good of society.
ACKNOWLEDGEMENTS

I wish to thank my supervisor, Dr Maryanne Confoy for her support and encouragement throughout my theological studies. Our discussions about this research were always motivating and uplifting, giving me the confidence and determination to pursue this challenging topic. Her expertise provided direction for my research and her thoughtful feedback on drafts of chapters was very much appreciated.

DECLARATION

This thesis contains no material that has been accepted for the award of any other degree or diploma in any educational institution and, to the best of my knowledge and belief, it contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

Name: Beverley Lois Jane

Signed

Date 16/03/2009
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Spirituality has everything to do with education – it should be the leaven that vitalizes the whole enterprise. (Groome, 1998:322)

CHAPTER 1 INTRODUCTION

1.1 Context and background to the research

The motivation for this exploration of how science and spirituality might be linked in order to improve science education stems from my passion for science and the realisation that something vital is missing from current practice in science classrooms. In this thesis I identify that missing component as ‘spirituality’ because many students perceive the science they are expected to learn at school as being irrelevant to their everyday lives. This apparent disconnectedness persists despite two decades of science education research on students’ alternative conceptions and conceptual change. My experience as a science educator at the primary, secondary and tertiary levels has led me to conclude that science curriculum designers ignore the students’ inner life when they design curriculum materials. Therefore the spiritual dimension is omitted from the curriculum documents that drive current teaching practice.

This first chapter begins by identifying the problem and contains the research questions that were addressed as I explored the notion of linking spirituality and science in the education process. I describe the theoretical framework - socio-cultural-historical theory - that underpinned both the research approach and the definition of spirituality in this thesis. I discuss spirituality as presented in popular culture prior to including definitions of spirituality located in the research literature. Both the research approach and the thesis structure follow Thomas Groome’s movements of shared praxis, explicated in the latter part of the chapter.
1.2 Identifying the problem

In the first chapter of this interdisciplinary thesis I raise a significant problem that Australia as a country faces. Namely, that for many years, the science that young Australians have encountered during their compulsory school years has not motivated them to pursue careers in scientific fields. Consequently, Australia has an alarming shortage of science and engineering graduates that threatens to hinder the country’s progress in innovation and scientific development.

According to the most recent statistics there has been an increase in student applications for entry into science and engineering university courses for 2008, with this interest being due to lucrative careers in the resource industry and the highly performing hi-tech economy. However the dean of science at the Queensland University of Technology, Margaret Britz is concerned that these statistics mask a continuing alarming decline in the general sciences (Healy, Rowbotham & Rout, 2008). I contribute this decline to two factors: ‘stereotypical images of scientists’ frequently portrayed by the media, and the ‘nature of science’ taught in schools. Both these factors influence young Australians to steer away from studying science beyond the compulsory school years.

In relation to the first factor, in popular culture several stereotypical representations of scientists have been identified that depict scientists in negative terms. Most students in the middle years of schooling hold these stereotypical views of scientists. In contrast these same students eagerly embrace the latest technological products, such as mobile phones, computers, iPods and digital cameras. As ‘being connected’ is very important for teenagers, mobile phones are rapidly becoming essential accessories for communication with their friends anywhere and at anytime. Such a mismatch between strong interest in high tech products and low interest in science careers needs to be addressed at the school level and in science classrooms in particular.
challenge for teachers of science is to provide experiences for students that debunk these stereotypical images of scientists.

I explore the problem of student disinterest in science at school by focusing on the missing component in science education that is spirituality. My proposal is that when spirituality is included in the science curriculum students gain a better understanding of how non-stereotypical scientists work, which in turn challenges the stereotypical views of scientists that many students hold. I argue for a science curriculum that blends spirituality and science that in turn enables students to learn about the nature of science and the way scientists carry out their scientific work. When teachers provide science activities that are both active (hands-on) and contemplative (meditative) in supportive, safe and challenging learning environments, students naturally build connections between school learning and their everyday lives.

1.3 Stereotypical representations of scientists in sci-fi films
In their everyday lives most students engage with recreational technologies, such as electronic games, and also enjoy watching the latest sci-fi films. For example, the popularity of the Star Wars films has permeated to numerous Lego sets and games.

Science fiction (sci-fi) can be defined as “works that take a more or less scientific world-view; narratives in which events are depicted on the assumption that they are explicable within the world of physical nature as investigated by science” (Blackford, Ikin & McMullen, 1999:xii). The sci-fi film genre frequently portrays scientists as obsessive in nature and addicted to their scientific work. A good example is the classic film Frankenstein that is based on a story of the same name that was written by nineteen-year-old Mary Shelley during a house party at Lake Geneva, Switzerland in 1818. This story was in response to Lord Byron’s challenge to the group to write a ghost story. Interesting theories abound for why Shelley wrote Frankenstein. One popular
theory is that the experiments carried out by Erasmus Darwin (Charles Darwin’s grandfather, 1731-1803) gave Shelley the idea for her story. Erasmus “Darwin subjected many of his medical patients to electrical shocks in hopes of understanding the universal life force he was so certain existed” (Herrick, 2003:121). At first Shelley was slow to get started on her story, but a nightmare motivated her to write the novel about Dr Victor Frankenstein who aimed to create a living human being, but instead created a monster.

Young Frankenstein became obsessed with the possibilities of modern science. He was so consumed with the knowledge of how to animate a human being that he disregarded the morality of his creation or even its’ aesthetics. His total absorption in the detail of creating each section meant that he overlooked the total effect. The scientist was so desperate to make a human being (out of parts taken from dead bodies in the morgue) that he did not anticipate how his creation might behave in the real world. Once created the monster threatened the very being of its inventor. The scientist became the hunted and the haunted as a result of his failure to set any boundaries in relation to his scientific work.

The characteristics of a scientist that are portrayed in this story are Frankenstein’s obsessive character, demanding ambition and ‘out of control’ behaviour that he later realised had made him ill.

… my work drew near to a close; and now every day showed me more plainly how well I had succeeded. But my enthusiasm was checked by my anxiety, and I appeared rather like one doomed by slavery to toil in the mines, or any other unwholesome trade, rather than an artist occupied by his favourite employment. Every night I was oppressed by a slow fever, and I became nervous to a most painful degree; the fall of a leaf startled me, and I shunned my fellow-creatures as if I had been guilty of a crime. Sometimes I grew alarmed at the wreck I had become; the energy of my purpose alone sustained me: my labours would soon end, and I believed that exercise and amusement would then drive away incipient disease; and I promised myself both of these when my creation should be complete. (Shelley, 1968:43)
Frankenstein was a brilliant, yet eccentric, preoccupied scientist, who begins with noble, humanitarian ideals but becomes so obsessed with his project that he loses sight of the negative consequences. The Frankenstein story challenges past and present scientific theories by highlighting their ethical complexity. Recent experimentation with genetic engineering makes the implicit warnings decidedly modern.

Another example of a sci-fi film is *A.I.: Artificial Intelligence* that is set in the future when natural resources are limited and nearly everything is engineered or artificial. There are numerous robots to help humans meet their needs. Scientific knowledge generates the latest invention, which is a prototype boy or ‘mecha’ whose capacity to love is irreversible. A couple accepts the mecha as a substitute for their cryonically frozen and terminally ill son. The robot boy is programmed to love, and is activated when his new mother reads a special code to him. There are complications when the new mother cannot return his love, and the mecha, knowing he is not human, craves to be a ‘real’ boy. Unexpectedly the real son recovers and the robot boy is cast aside, his fate uncertain.

In this film scientists have not made the world neat and tidy in *A.I.* The opposite is the case, with the mechas being neglected, particularly when they are in need of repair. The film raises many questions about scientists as manipulators of robots. Rosaleen Love (2001) aptly describes the robots’ situation in the futuristic film where artificial intelligence has become part of everyday life.

Imagining the future for robots is an activity that directs attention to alternative futures, and questions present assumptions about robots, i.e. that humans control robots, where robots are neither free subjects, nor agents of their own destiny, nor intelligent like humans. (Love, 2001:583)

Although the film *A.I.* currently appears far-fetched, Hans Moravec a roboticist contends that by 2050 scientists will have devised robots with brains that rival
human intelligence.

In the comic adventure film *Flubber*, viewers watch a scientist who is so involved with his new invention that he forgets to attend his own wedding. He invents a revolutionary green coloured compound that he names *Flubber* because it can fly and has similar characteristics to rubber. While most viewers enjoy the gravity-defying visual effects in the film, the focus is on an absent-minded scientist who becomes obsessed with his chemical experiments. Such a naïve concept of a scientist is encouraged by the film *Flubber*, and is perpetuated by popular science fiction films that also portray scientists as being out of touch with reality and living in their own worlds. In these films scientists are frequently depicted alone in basement laboratories, working all night making bubbly, explosive solutions by mixing chemicals in complex scientific equipment. These stereotypical images of a scientist are commonly seen in children’s drawings.

A literature review of studies of images of scientists in science fiction films reveals several features. Firstly the image of the scientist is generally a negative one. Scientists are usually portrayed as mad or so dedicated to their work that they are completely insensitive to their colleagues and families. Secondly, the nature of science portrayed does not reflect the way science progresses. The slow and painstaking investigations in which scientific knowledge is gradually built up are rarely shown. Instead the ‘gee whiz’ syndrome is present.

Haynes (1994) identified six stereotypical representations of scientists in Western literature that are also evident in science fiction films.

- **Alchemist**: Scientist who appears obsessed or maniacal (e.g. the genetic engineering biologist; Victor Frankenstein in *Frankenstein*)
- **Stupid virtuoso**: Scientist out of touch with the real world. Can be sinister or comic (e.g. the absent-minded professor in *Flubber*)
• **Heroic adventurer:** Scientist in the physical or intellectual world. Emerges at times of scientific optimism.

• **Helpless scientist:** Scientist who has lost control over his discovery or the direction of its implementation. (E.g. Victor Frankenstein)

• **Idealist:** Scientist who is acceptable, sometimes holding out the possibility of a scientifically sustained utopia, but is in conflict with a technology-based system that fails to provide for individual human values. (E.g. scientist in the film *AI*)

## 1.4 Research questions

The following research questions were addressed:

1. Does spirituality have a role in science education, one that might challenge students’ stereotypical views of scientists and science?

2. How can spirituality and science be connected in the education process?

3. What might be the benefits of this integration for science educators and scientists?

4. What is the transforming potential of such an integrative science education?

## 1.5 Theoretical framework: socio-cultural-historical perspective

The theoretical framework that informed this research is socio-cultural-historical theory, which is a new perspective for science education research that has for the past 25 years been driven by constructivism. Constructivism is the view of learning whereby learners actively generate meaning from experience. This view has dominated how research in science education has been framed, data analysed, and findings used to inform curriculum, policy and pedagogy in the science education community. Socio-cultural-historical theory offers a different theoretical orientation, one that enables new ways of thinking about research and possibilities in science education.
According to socio-cultural-historical theory development is viewed as a social and cultural process. Individuals develop through participation in the cultural activities of their communities (Rogoff, 2003). From this perspective, learning is not viewed as being individualistic, but is part of development that occurs through participation with others in activities that are mediated by cultural tools. Therefore learning involves interpersonal as well as community and contextual factors.

Consistent with socio-cultural-historical theory I define spirituality as “an individual desire (personal plane) for connectedness with others (interpersonal plane) and with a transcendental dimension that is greater than human beings. The transpersonal aspect of spirituality affects society (community plane) which may (or may not) be associated with organized religion” (Jane, 2007b:7).

Socio-cultural-historical theory derives from the work of Lev Vygotsky and his colleagues. Issues in education can be explored using the Vygotskian concepts:

- Mediated action;
- Intramental and intermental functioning; and
- Everyday and scientific thinking.

1.5.1 Mediated action

Vygotsky (1997) theorised that higher mental actions are mediated within activities by tools, artefacts and cultural inventions (such as writing, schemes, diagrams, maps, drawings and all sorts of conventional signs). Other tools recognised in socio-cultural-historical discourse include paintbrushes, computers, calendars and symbol systems (John-Steiner & Mahn, 1996). Vygotsky considered speech to be the most important tool (Wertsch, 1990). These tools and signs are social in origin and are used initially to communicate with others, and later to mediate interaction with self (Moll, 1992). Most of these tools bring a cultural history with them. By learning to manipulate these artefacts and the practices in which they are used, people integrate the
experiences of their society. Säljö (1998:55) articulates “…the world is pre-interpreted for us by previous generations, and we draw on the experiences that others have made for us”. Vygotsky theorised that tool-based “mediation is first intermental and then becomes intramental as children learn to regulate the mediational cultural tools with their own social and mental activity” (Lantolf, 2003:350).

1.5.2 Intramental and intermental functioning

According to Vygotsky thinking progresses through intermental functioning to intramental functioning. This means that thinking first occurs on the social plane (between people engaged in joint socio-cultural activity), and then later on the individual plane (within the child). Hedegaard (2001) describes this internalisation in the following way.

In Vygotsky’s theory, learning is a social process that takes place between people. He conceptualized learning as internalisation of social interactions in which communication is central. Learning takes place in social interaction in a specific context, which comes internalised by a person. By internalisation, Vygotsky did not mean copying but transforming the external interaction to a new form of interaction that guides the child’s actions. Internalisation does not directly mirror the external social relations; it is a transformed reflection. (Hedegaard, 2001:16-17)

The concept of internalisation has been used in several theoretical approaches to describe how shared thinking (or intermental functioning) results in changes in the thinking of the individual (intramental functioning). However, Rogoff (1998) is critical of the concept of internalisation because it implies a ‘boundary’ between the individual mind and the external social world. Such a boundary differentiates the ‘social add-on’ or ‘social influences’ approach from socio-cultural-historical theory. From the socio-cultural-historical perspective, learning and development are creative processes that occur through a changing participation in activities, not via internalisation across a boundary. Rogoff’s transformation of participation recognizes that individuals continually develop
and change using the understanding gained through participation in shared
eendeavours in socio-cultural activities. “In the process of participation,
individuals change, and their later involvement in similar events may reflect
these changes” (Rogoff, 1998:689).

1.5.3  Everyday and scientific thinking
Vygotsky emphasised that children acquire concepts via a process that is
mediated by speech. Through a series of experiments he demonstrated that
children gain important concepts inside school (scientific concepts) as well as
outside (everyday concepts), and that they are related (Panofsky, John-Steiner
& Blackwell, 1990). Vygotsky used the term scientific (academic or scholarly)
concepts when he referred to ideas explicitly introduced by adults in school,
and sometimes by parents (van der Veer & Valsiner, 1993). Scientific concepts
form a logical system in a particular discipline, are generalisable, removed from
material experience, and exist within a hierarchical network of related concepts.
Scientific concepts contrast with spontaneous or everyday concepts that
develop within children’s daily lives due to their interaction with adults, peers
and the non-social environment. Although Vygotsky identified two distinct
types of concepts they are also interdependent. Ordinarily, the development of
scientific concepts in school depends on a previously developed set of word
meanings that stem from the child’s everyday experiences, and this
spontaneously acquired knowledge mediates the learning of the new scientific
concepts (Panofsky, John-Steiner & Blackwell, 1990). For example, children
will not readily understand scientific concepts such as technical systems unless
they have the everyday concepts of things such as switches and levers. In turn,
when children learn scientific concepts, these change their understanding of
switches and levers.

According to Vygotsky (1987) scientific and everyday concepts have strengths
and weaknesses. The scientific concept (such as technical systems) is
“embedded in a whole, connected, conceptual structure that supposedly reflects
the true nature of the subject one is talking about” (van der Veer, 1998:91). Scientific concepts have been explicitly taught, so children can consider their relationship with other concepts. However, a potential weakness of these scientific concepts is that they may be beyond the children’s personal experience, and therefore lack meaning and relevance, and are easily forgotten (van der Veer, 1998). In contrast, the strength of everyday concepts is that they have emerged out of personal experience, instead of memorisation, so they are less likely to be forgotten. However they are only applicable within specific contexts or activities (van der Veer, 1998).

1.5.4 Rogoff’s research tool
Everyday concepts are embedded in children’s life experiences and natural conversational contexts. Therefore it is important for researchers and teachers to attend to the activities children participate in at home and in the community, and to the significant relationships, artefacts, meanings, actions and histories within those contexts and activities. A useful research tool is Barbara Rogoff’s (1998) three foci of analysis, where the personal, interpersonal and community issues surrounding any activity can be examined. This tool enables the foregrounding of individuals or groups of children (and/or adults) to see how they are being transformed as they participate in everyday activities (personal focus of analysis). It also enables the consideration of factors such as shared understandings and the important interpersonal relationships that are structuring and supporting these understandings (interpersonal focus of analysis).

Additionally, particular community constructions of science and the value that is placed on science within that community can be highlighted, as well as specific cultural tools or artefacts that are available, and the history these tools and the social players themselves bring with them to the activity (community focus of analysis). While one of these foci is brought to the forefront, the others remain in the background while still being part of the analysis. Through the use
of this tool, the multiple pathways to learning within the community can be highlighted (Rogoff, 2003).

1.6 Moving towards a socio-cultural-historical approach to learning science

As mentioned above, for more than two decades constructivism has been the view of learning supported by science education researchers who have focused on the individual learner acquiring knowledge or concepts, and therefore a conceptual change approach to teaching science. A socio-cultural-historical perspective challenges the notion of conceptual change (Lemke, 2001). In recent years some researchers in psychology and education have embraced socio-cultural-historical theory of development as a framework for their research. One study showed that when socio-cultural-historical theory was first introduced in an early childhood setting teachers required extensive time to adjust as they moved from an individualistic approach to a socio-cultural-historical approach (Fleer & Richardson, 2003).

From a socio-cultural-historical perspective Rogoff’s (1995) three planes of participation, the personal, interpersonal and community, are applicable to any activity, including science activity. These different planes are like lenses that enable the focus to be on individuals, or groups of people as they participate in socio-cultural activities such as science. Focussing on the ‘personal plane of participation’ allows the researcher to concentrate on the role of the individual and identify how that individual might change through involvement in a particular activity. By focussing on the ‘interpersonal plane of participation’ the researcher can identify how individuals communicate with one another as they engage in shared endeavours. When focussing on the ‘community plane of participation’ the researcher finds out how people use cultural tools as they participate with others in culturally organized activities. These activities are often determined by institutional practices with inherent cultural values.
In this thesis the application of Rogoff’s lenses allowed me to direct attention to how an individual scientist participated in scientific activities. The interpersonal lens enabled me to focus on the relationships that support or structure shared understanding. When I changed my focus, the interactions were analysed without prioritising any particular plane, nor isolating it from the other planes. “Fore grounding one plane of focus still involves the participation of the backgrounded planes of focus” (Rogoff 1995:140). These planes of socio-cultural participation are inseparable, yet mutual, and show an individual’s participation or involvement in a cultural context. “Using personal, interpersonal and community/institutional planes of analysis involves focusing on one plane, but still using background information from the other planes, as if with different lenses” (Rogoff, 1998:688).

When applying the community lens, it is revealed that the scientific community must accept an individual scientist’s work before it can be given recognition. Publication in high profile journals requires peer review and acceptance of the ideas as being rigorously tested. The individual scientist must effectively communicate his/her ideas to peers. Failure to do so may result in any recognition being delayed for many years, as was the case with scientist Barbara McClintock (refer to Chapter 4). I chose McClintock as a key figure for exploring science and spirituality because she was a non-stereotypical scientist whose way of working included a contemplative dimension.

1.7 Definitions of spirituality in the literature

Spirituality is a way of knowing with a transcendental dimension and is secular and non creedal. Secular spirituality refers to an unchurched or nonreligious context. Transcendence does not refer to an infinite, absolute Being, but signifies something that extends beyond ourselves and can invoke a sense of awe and wonder and moves us toward an open-ended future state.
Any attempt to define spirituality is somewhat problematic given that the term has a range of meanings with no single, identifiable entity. In the research literature, some researchers define spirituality in terms of a need for connectedness, and two examples follow. “Spirituality is a desire for connectedness, which often expresses itself as an emotional relationship with an invisible sacred presence” (Tacey, 2000:17). Spirituality is the human quest for connectedness with something that can be trusted more than our own egos (Palmer, 1998). A definition put forward by theologian Ruwan Palapathwala (2005) includes the notion of transcendence. “Spirituality is our transcendental awareness about the ‘more’ in us which seeks progression in and through our quest for our ‘where from’ and ‘where to’” (p. 2). Philosopher and physicist Ronald Anderson takes a universal approach, drawing from the writings of A. N. Whitehead.

Spirituality is forming a vision that which stands beyond, behind, and within the passing flux of immediate things; something which is real, to be explored by a close attention to our immediate world, and yet waiting to be realized; something which is a remote possibility, and yet the greatest of present realities of our life; something which gives meaning to all that passes and yet forever eludes full apprehension; something whose possession is the ultimate good, and yet as that beyond our life demands an ongoing quest; something which embeds us in relationships with others, and yet at times will require a journey in solitude; a vision that makes us participants in the unfolding of the universe, yet ever mindful of and haunted by the horizon beyond that unfolding, a vision requiring the exercise of mind, heart, and body, a vision replete with consequences of action. (Anderson, [http://www2.bc.edu/~anderso/sr/spirituality.html](http://www2.bc.edu/~anderso/sr/spirituality.html))

On a personal level, Sandra Schneiders (1994) understands spirituality in terms of integrating all one’s aspects of life in the context of ultimate concerns, which leaves adequate room for the passive dimension of the spiritual life. “Spirituality is the experience of conscious involvement in the project of life-integration through self-transcendence toward the ultimate one perceives” (p. 39). This definition shows spirituality to be far reaching and encompasses a
person’s relationships to all of creation, to the self and to others, to society and nature, to work and leisure.

Drane (2005) tried to clarify the spiritual spectrum by documenting how spirituality is described in popular culture. He examined three popular books: *The Executive Mystic* (Dolnick, 1998), *Spirituality for Dummies* (Janis, 2000) and *The Complete Idiot’s Guide to Spirituality* (Ely, 2002) to obtain snapshots of spirituality and generate the categories shown in Table 1.1.

Table 1.1 Representatives of the spiritual spectrum (Drane, 2005:60)

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<th>Lifestyle</th>
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<th>Enthusiasm</th>
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<td>Values</td>
<td>Commitment</td>
<td>Experimentation</td>
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<tr>
<td>Community</td>
<td>Structure</td>
<td>Freedom</td>
</tr>
<tr>
<td>Belonging</td>
<td>Authority</td>
<td>Experience</td>
</tr>
<tr>
<td>Morality</td>
<td>Traditional faiths</td>
<td>Mystery</td>
</tr>
<tr>
<td>(Idiot’s Guide)</td>
<td>(Dummies)</td>
<td>(Executive Mystic)</td>
</tr>
</tbody>
</table>

The Lifestyle category includes people who have turned away from external or objective roles, duties and obligations, and live according to their own subjective experience. At the opposite end of the spectrum, the Enthusiasm category includes people who are enthusiastic about direct experience of the transcendent. In the middle, the Discipline category includes people committed to structured spiritual expression, or faithful disciplined practice, such as traditional religion, and keeping healthy by intentional physical activity.

In this thesis, I define spirituality from a socio-cultural-historical perspective, incorporating Rogoff’s three planes of transformation. “Spirituality is an individual desire (personal plane) for connectedness with others (interpersonal plane) and with a transcendental dimension that is greater than human beings. The transpersonal aspect of spirituality affects society (community plane) which may (or may not) be associated with organized religion” (Jane, 2007b:7).
1.8  Research approach and thesis structure

Thomas Groome’s (1980) movements of shared praxis (devised in the context of Christian religious education) formed an appropriate research approach to explore relations between spirituality and science. Groome’s approach consists of five main movements: present action, critical reflection, dialogue, story and the vision that arises from the story. Because story is often an integral part of the vision, the two can be considered together. Each of these movements is explicated below.

1.8.1  Movement 1: Present action

In a praxis way of knowing, ‘present action’ takes account of what is happening in the present moment, the ways people express themselves and their whole engagement in the world. In this movement ‘present’ means the consequences of the past, things now present, and the present as shaper of the future. Groome’s idea of Present Action:

Includes what we are doing physically, emotionally, intellectually, and spiritually as we live on personal, interpersonal, and social levels. … The present is the historical self and society that are reflected upon, since our present action is the consequence of our past and the shaper of our future. By reflecting on present action, we can uncover the ‘pasts’ that have brought us to such action, and raise to consciousness the ‘futures’ in that action by becoming aware of its likely or intended consequences. (Groome, 1980:184-185)

1.8.2  Movement 2: Critical reflection

In the second movement present action becomes the primary object of reflection that takes the form of self-reflection. In a ‘praxis way of knowing’ the rational and the affective are fused, which means that critical reflection involves the head and the heart. Critical reflection is dialectical critique that has both rational and affective factors. This movement - critical reflection on present action - requires three levels of reflection - reason, memory and imagination. Although inseparable, it is useful to consider each level.
**Critical reason to evaluate the present**

This first level of reflection begins by attempting to reveal the obvious in the present. The obvious often goes unnoticed because it is inevitable or taken for granted. The process of delving deeper reveals the underlying assumptions on which present action is based facilitating a critique of the ideology that maintains it.

**Critical memory to uncover the past in the present**

The process of remembering brings the personal and the social sources of the present action to the fore. A critically remembered past informs current and future choices. For most people, remembering is looking backward, but in this level it is also looking outward to the wider world. Reason and critical memory enable us to name our present action and what we know from our engagement in the world.

**Creative imagination to envision the future in the present**

Imagination that focuses on the future is the third level in the process of critical reflection. Imagination is necessary to ensure that we do not keep repeating or duplicating the past. Creative imagination not only provides intentionality to the future, but also offers hope in connectedness.

1.8.3 **Movement 3: Dialogue between narratives**

In Groome’s view of shared praxis, dialogue and critical reflection on present action involve authentic telling or disclosure, combined with listening that leads to discovery. Therefore dialogue is a subject-to-subject encounter that involves both telling and listening. For Groome (1998) dialogue begins with one’s self, and “at bedrock it is a conversation with our own biographies, with our own stories and visions” (p. 189).

1.8.4 **Movements 4 and 5: Story and Vision**

Story and Vision can be considered together because they are not separate, but are aspects of the same reality. To maintain the unity between theory and praxis, the story is critically appropriated and encountered in the midst of present praxis. In the pedagogical context of this research, the metaphor ‘story’
refers to the narratives of scientists that describe the way they view the world and their unique ways of working. The vision is the hope for the future, for a science education that is authentic for students and fosters connectedness.

Drawing attention to the process of education rather than content, and believing that spiritual growth is a lifelong journey, Groome takes a secular and non-creedal view of spirituality and argues that all educators are able to engage learners as spiritual beings. He proposed that even in educational contexts where explicit religious education is disallowed, wise educators should place a spiritual vision at the foundation of their teaching. He was convinced that “spirituality has everything to do with education – it should be the leaven that vitalizes the whole enterprise” (Groome, 1998:322).

1.9 Thesis overview
Spirituality is a way of knowing, that is secular and non creedal. On the community plane, spirituality is not widely accepted as a secular school responsibility. However, there are educational psychologists who argue that spirituality is a secular concern and “is symbolized by a search deep within and rising above our physical realities” (Vialle, Lysaght & Verenikina, 2005:213).

I take this notion one step further and argue that the spiritual dimension is integral to the discipline of education. Yet currently this dimension is missing in science education. In this thesis, structured according to Groome’s shared praxis approach, reflections on the narrative of scientist McClintock facilitate a vision for a more authentic science education that fosters a sense of connectedness that is so important for students. The focus of the next chapter (the first movement) is present action.
CHAPTER 2 PRESENT ACTION IN SCIENCE EDUCATION

2.1 Introduction
In this chapter, I have used Groome’s (1980) first movement of shared praxis approach, by starting with a description of current happenings in science education, whilst also taking into account the consequences of the past that precipitated the stereotypical images of scientists that most students hold.

The recent political push for values to be explicitly taught in Australian schools led to a national values study that specified a list of values for schools. Soon after this national study, a set of values was mandated for Victorian government schools. In this chapter a critique of these mandated values precedes an examination of the values unique to science education itself.

Also in this chapter, I discuss recent research into students’ spiritual wellbeing, because it relates to how students engage with the natural and designed world. I close the chapter by considering how the past and present might shape future science curricula, particularly if the spiritual wellbeing of students is valued and given high priority.

2.2 Studies of students’ perceptions of scientists
The first report on research that explored students’ perceptions of scientists occurred in 1957 (Mead & Matrax). Almost three decades later the characteristics of stereotypical images of scientists depicted in students’ drawings were reported (Schibeci & Sorensen, 1983). Since then the ‘Draw-A-Scientist’ Test (DAST) (Chambers, 1983) has been a useful tool for extensive research into students’ views about scientists. Data collection involves students’ drawings that are coded according to the following DAST indicators of a stereotypical image of a scientist (Chambers, 1983; Purbrick, 1997).
- Laboratory coat
- Spectacles (glasses)
- Facial hair (beard, moustache, very long sideburns)
- Laboratory equipment (bubbly solutions, scientific instruments)
- Books and filing cabinets
- Technological products of science
- Captions (formulae, eureka!)

A further development was the ‘Draw-A-Scientist Test Checklist’ (DAST-C) that was a reliable and efficient format for analysing students’ drawings of scientists (Finson, Beaver & Cramond, 1995). This checklist provides quantifiable scores for drawings that facilitate comparative data analysis. In a study undertaken in Indianapolis, the DAST-C was used to analyse more than 1,500 K-8 students’ drawings (Barman, 1999). Results showed that most scientists were depicted as white males, which supported the previous studies carried out by Chambers (1983), Fort and Varney (1989), Finson et al. (1995), and Huber and Barton (1995).

More recent research shows that these stereotypical images of scientists influence how students perceive science, and that negative images can affect the choice of careers by minorities in general, and females in particular (Finson, 2003). Females are less inclined to become scientists when the images they see are of destructive males. Adding complexity to the issue is that in some Indigenous Australian groups there is no word for science, so views of scientists come from images supplied by Western media.

Although the DAST has proven to be a useful research tool to probe students’ images of scientists, there are other procedures, such as interviews and ‘Interviews-About-Instances’ (White & Gunstone, 1992) generate spontaneous responses that can then be probed (Schibeci, 2006). In a recent study we investigated how students think about science, and scientists by collecting data
in the form of children’s drawings, followed by their explanations for why they had drawn such images (Jane & Gipps, 2007). In our qualitative study we did not use the DAST to analyse the children’s drawings of scientists, preferring to listen to the children as they talked about their drawings. This research approach gave us the advantages of spontaneity. In future research using mixed methods, DAST could be employed in addition to children’s explanations of their drawings.

2.3 Study of children’s stereotypical drawings of scientists

Rogoff (2003) put forward three analytical lenses for foregrounding and backgrounding different aspects of a child’s socio-cultural learning. In our study (Jane & Gipps, 2006; Fleer & Jane, 2007) we used Rogoff’s theoretical drivers to frame the analysis of the data we collected from four composite Prep-1-2 classes (children aged six and seven years) and four composite 5-6 classes (children aged ten and eleven years). To each classroom of 20-25 children and their teacher we assigned four pre-service teachers who were in their second year of a Bachelor of Primary Education or Bachelor of Early Childhood Education degree. All classes were in the same government school that was situated on the Mornington Peninsula, southeast of Melbourne, Victoria, Australia, and attracted children from middle class Caucasian families.

2.3.1 Data collection

During the semester, the pre-service teachers taught science on a weekly basis planning a range of activities including practical experiments, making things, worksheets, on-line and book search of the literature, reading stories, discussions, games and excursions to the playground. The format of the study included an initial workshop whereby the pre-service teachers were introduced to the literature about the ‘draw a scientist’ studies. In this way the student teachers were prepared for, and knew the purpose of, the ‘draw a scientist’ strategy to explore children’s ideas about scientists. At the commencement of teaching their small group the pre-service teachers asked the children to ‘draw a
group of scientists’ and then talk about their drawings. The children’s drawings and comments became the data for analysis.

2.3.2 Data analysis

Most children’s drawings showed the stereotypical ‘scientist’, wearing a white lab coat, working alone in a laboratory, experimenting with beakers and test tubes. Scientists were depicted as looking weird and even mad. The boy who created Figure 2.1 said “Crazy hair, he has crazy hair and a scientist wears a white coat, lots of buttons ... and glasses, they always have glasses. They make potions.”

![Figure 2.1](image)

Figure 2.1 Drawing of a ‘mad’ scientist

Some children, like Mea, drew scientists as bad.

Mea: “Scientists knock down walls with a big hammer. They make people drink potions. They are bad people and they where (sic) tall boots.”

Some drawings portrayed scientists as dangerous to know, such as the one Chloe drew.

Chloe: “They make stuff like potions. They turned a man into a lama and then he needed another potion to turn him back into a person. I saw it on The Emperor’s New Groove!”
The majority of children thought scientists were mostly males, but some, such as Nicola, drew females. Although the scientist in Figure 2.2 is female, other characteristics are consistent with the stereotypical image of a scientist.

![Image of Nicola’s drawing of a scientist working alone in a laboratory](image)

**Figure 2.2** Nicola’s drawing of a scientist working alone in a laboratory

Some children think scientists have useful skills, as Billie’s drawing (Figure 2.3) shows. He said “The scientists have made the money really big. Scientists make potions and stuff. This is the potion that the scientist spilt and turned it black. This is the factory where scientists work”.

![Image of Drawing of a group of scientists](image)

**Figure 2.3** Drawing of a group of scientists
Some scientists look reasonably normal, as shown in Figure 2.4.

![Figure 2.4](image.png)

*Figure 2.4* Drawing of a scientist

The comments shown in Figure 2.5 are by Years 5 and 6 students and show more developed ideas. One drawing showed a group of male scientists (Figure 2.6), while another depicted all females (Figure 2.7).

![Figure 2.5](image.png)

*Figure 2.5* Year 5/6 children’s comments about scientists
Figure 2.6  Lachlan’s drawing of a group of scientists

Figure 2.6 shows the typical portrayal of a scientist by children; that is they are wearing lab coats, work on computers, have funny hair and are male.

Figure 2.7  The drawing shows a group of female scientists
At the end of the semester of hands-on science activities with the preservice teachers, some children realised that they themselves were rudimentary scientists “We are scientists because: We worked as a group! We explored! We made theories! We researched! We discovered! We had fun!”

These comments indicate that these children value working in groups, researching, exploring, discovering and theorising, which incorporate cognitive and affective dimensions and reveal positive attitudes towards science. Their comments contrasted vividly with their original drawings of stereotypical scientists that they could not relate to.

2.3.3 Interpretation of study findings
The children’s experiences of small group investigations that led them to discover scientific concepts transformed their views about science and scientists. These findings are consistent with Vygotsky’s theoretical work in which he stressed that learning first occurs through intermental functioning in the social context (between children and adults) and later leads to intramental functioning (child’s understanding). The shared thinking in the small group situation builds on the child’s everyday concepts resulting in changes in the individual child’s thinking. The science activities were socio-cultural in nature and involved cultural tools that enabled transformation through participation. The activities chosen by the students also had to relate to the curriculum as set out in Curriculum and Standards Framework II (VCAA, 2000). In the following section I critique values in curricula for Australian schools and the new Victorian curriculum that replaced C&SFII.

2.4 Values in curricula for Australian schools
In this section the political push to influence the teaching of values in Australian government schools is outlined, followed by a critique of the values
in the intended science curriculum. But first what is meant by the term values? “Values are the priorities individuals and societies attach to certain beliefs, experiences, and objects, in deciding how they shall live and what they shall treasure” (Hill, 1997:3 cited in Hildebrand, 2007:51).

It was in 2004 that the then Prime Minister John Howard tried to justify the current popularity of private schools by blaming the teaching in government schools for the trend. He declared that because Australian government schools were ‘values free’, parents were choosing to educate their children in the private school system where values were explicitly taught. This declaration has led to ongoing public debate about values in the curriculum (Gunstone, Corrigan & Dillon, 2007).

Consequently, articles appeared in newspapers that focussed on the topic of values in school curricula (Green, 2004; Lovat, 2004; Maiden, 2004; Singer, 2005; Clark, 2006). The political push for curricula with a strong values component was evident when the Education Minister at that time, Brendan Nelson commissioned The Values Education Study (2003). The study findings of twelve cases in Australian schools identified the following nine important values for education.

• Tolerance and understanding
• Respect
• Responsibility
• Social justice
• Excellence
• Care
• Inclusion and trust
• Honesty
• Freedom and being ethical
The political move to include values in the Victorian curriculum was met with some opposition, and generated strong debate over what values should be taught, and the process of deciding whose values would be chosen. Additional values to those proposed by the national study included “love of learning, spirituality, risk-taking, independence, self-esteem, self-discipline and persistence” (Green, 2004:3). Towards the end of 2004, the then Minister for Education and Training Lyn Kosky mandated the following five values for all Victorian government schools:

- Learning for all
- Pursuit of excellence
- Engagement and effort
- Respect for evidence
- Openness of mind; being willing to consider a range of different views.

These mandated values for the state of Victoria fall short of those identified in the national *Values Education Study* by omitting tolerance, understanding, respect, social justice and freedom.

In Chapter 1, I described a socio-cultural-historical perspective on learning that diverges from viewing learning merely as a process that occurs for the solitary individual. From a socio-cultural-historical perspective, the list of values for Victorian schools is inadequate, because it merely focuses on the individual student, neglecting that individuals are part of local and global communities. The mandated values are restricted to the intra-personal lens that foregrounds the individual student’s participation, learning and expertise. However, school is also about the many relationships individuals form with other students. Peers play important roles in shaping an individual student’s participation in the group, and the process of group learning is also influenced by cultural practices (places and things). Furthermore the list of values set for Victorian schools fails
to pay attention to the cultural/historical lens that is useful in describing these cultural practices.

The communal context also influences the values being promoted according to Rogoff’s *transformation of participation* developmental theory. Learning is not an individual action, but occurs between all members of a learning community. However, while this is generally the case, sometimes there are exceptions, such as the gifted or non-gifted child. One example, considered in detail in Chapter 4, is scientist McClintock who made her discoveries in the field of genetics when working in isolation most of the time. Even as a child McClintock valued time alone. However her mother could not understand why her daughter frequently just ‘sat quietly by herself’.

In the contested ground surrounding values in education, the question that needs to be asked is: Whose voices are being heard? In a communal context, a survey of Australian grandparents identified that they consider values education an important issue. The results of the survey were presented in the *Grandparents Speak* report that called for the following set of values:

- Tolerance and good manners towards all people
- A sense of self-value enabling the taking responsibility for their own actions
- Honesty, trustworthiness and responsibility to the community

(The Grandparent, 2005:6)

It is evident from the above set of values, that the mandated values for the Victorian curriculum seem less relevant than the ones the grandparents deem necessary for a healthy and happy future.

### 2.5 The Victorian Essential Learning Standards

One aim of the latest curriculum for Prep to Year 10 the *Victorian Essential Learning Standards* (VELS) (VCAA, 2006) is to foster values in addition to
conceptual knowledge and skills associated with each domain. The values specified in the curriculum document are those mandated as discussed above. VELS offers increased flexibility that encourages schools to take an interdisciplinary approach to topics with an emphasis on creativity, thinking and communicating. The VELS document cuts across traditional discipline areas and no longer recognises the Key Learning Areas. There are three core and interrelated strands: Physical, Personal and Social Learning; Discipline-based Learning (where Science is positioned); and Inter-disciplinary Learning. The Science domain consists of two dimensions: Science knowledge and understanding and Science at work.

In Chapter 1 section 1.8, I described present action as taking account of the ways people express themselves, and their whole engagement in the world, physically, emotionally, intellectually, and spiritually. An early draft of VELS had a spiritual dimension that was omitted from the final version. De Souza (2004:5) explains: “The word ‘spiritual’ because of its previous association with religion and religious traditions in the Western world often provokes distrust and even hostility within secular education contexts.” Unfortunately, while other Western countries have debated the importance of a spiritual dimension in education, most Australian curriculum advisors and designers continue to ignore it. Despite its centrality in our lives, spirituality is possibly the main thing lacking in public schooling (Noddings, 1992).

2.6 Studies of spiritual wellbeing and curriculum development
In contrast to the Victorian curriculum, New Zealand’s Health and Physical Education curriculum acknowledges the significance of spiritual wellbeing, defining it as “the values and beliefs that determine the way people live, the search for meaning and purpose to life, and personal identity and self-awareness. For some individuals and communities, spiritual wellbeing is linked to a particular religion; for others it is not” (Ministry of Education, 1999). Such recognition of life’s spiritual dimension allows teachers and researchers to
research the meaning of spirituality, and how children’s spirituality in particular, can be fostered in the classroom.

One study aimed to find out how teachers in New Zealand secular schools perceive the word ‘spiritual’. Fraser and Grootenboer (2003) interviewed nine teachers about their lived experiences, and knowing that there is a range of meanings for spirituality, used a grounded theory approach whereby the categories emerged from real life experiences. ¹ All except one of the subjects were women, with four Maori, one English, one Eurasian and three Pakeha. In terms of religious beliefs, six were Christian, and three agnostics. Research findings indicate that for these teachers spirituality refers to the transcendence of physical boundaries, connection to others, and a way of ‘being’. They perceived every classroom as being spiritual, whether it is acknowledged or not. ² Furthermore, the study found that although the spirituality curriculum is not formally planned, teachers enhance the spiritual dimension of classrooms through numerous strategies. Strategies include being non-judgmental, exhibiting non-self-conscious actions, power sharing, including deeply meaningful activities and events that provide a sense of awe, wonder and flow (in science, social studies and the arts), taking leaps of faith or courage, including powerful literature, facing adversity/tragedy, taking responsibility, and including the support of ancestors.

Another example is the international Steiner schools that foster children’s spirituality by organising subjects to interweave so they are connected. These strategies include non-judgmental actions, power sharing, deeply meaningful activities and events that provide a sense of awe, wonder and flow, taking leaps of faith or courage, powerful literature, facing adversity/tragedy, taking responsibility, and including the support of ancestors.

¹ I think this approach was helpful because it focussed on concrete experiences rather than the participants’ perceptions of the word spiritual. Such an approach also allowed for the recognition of different lifestyles, including indigenous ways of being in the world. One limitation was that the sample of participants was small.

² This is a naïve view, and based on my own experience is certainly not the case. The researchers have ignored what occurs in other classrooms and not taken into account classrooms where connectedness is not fostered and children are always expected to work individually.
interconnections enable children to learn from the experience that ‘every part is part of a whole’, rather than in fragmentary ways or from abstract concepts. Steiner education emerged from the spiritual-scientific research of Austrian scientist Rudolf Steiner (1861-1925), and aims to educate the whole child (head, heart and hands). This objective stems from his philosophy that humans are spirit, soul and body (Barnes, 1991). Through what he called ‘Spiritual Science’ (a way of understanding the nature of the world, of finding the spirit within matter, and humans taking a conscious responsibility for the world), Steiner envisaged “a responsible, caring balance of spiritual insight and common sense – of technical know-how and love” (Trenoweth, 1987:94).

In Steiner education there is coherence between the personal and the communal. Children learn in a communal context, to develop their individual potential. All members of a learning community “contribute inseparable aspects whose combinations create a landscape – shapes, degrees, textures – of community membership” (Lave & Wenger, 1991:35).

Myers (1997) recognised the spiritual dimension to child development as well as the physical, cognitive, emotional and social aspects. He made transparent the difficulties researchers experience when trying to find ways to understand and name spiritual life in the secular world. “This severely limits our ability to address issues related to the ‘whole child’ – even as we claim that this is what we do” (Myers, 1997:xi). Moreover “it is in the realm of personal knowledge that all other areas of knowledge become integrated, and it is within this realm that we can further examine “spirit” and the related term “spirituality” (Myers, 1997:22).

Some Australian researchers are beginning to explore spiritual wellbeing and development. In South Australia there are two discussion papers that address the issues and implications of including the spiritual wellbeing dimension in the overall Wellbeing framework. The papers report on an inquiry that sought
feedback from teachers and leaders concerning the concept of including the spiritual/values/beliefs dimension in the draft *Wellbeing is Central to Learning* Working Paper (DECS, 2005). In addition, final year pre-service teachers were invited to complete an informal survey about their views concerning the spiritual dimension. Analysis of the 50 responses led to the conclusion that including the spiritual dimension in education is challenging and complex, “but it can be implemented along a continuum and continue to be a work in progress” (Burrows, 2006:16).

In the United Kingdom, Annie Woods (2007) suggests ‘elemental play with natural objects’ is a way to support children’s spiritual wellbeing and development.

I believe that playing with and exploring the elements has a cultural, spiritual and genetic footprint, furthermore, that natural elements – earth, wind, water and fire hold a fundamental fascination for very young children right up to adulthood as we try and recreate or master their power and potential. (Woods, 2007:8)

2.7 **Nature of science and values in science education**

Currently, in addition to values, standards in Australian schools are a key issue and there continues to be controversy about the science being taught in schools. As a result of the federal government commissioning an analysis of science education in schools, Goodrum and Rennie (2006) found that the content-driven courses failed to engage many students because the science curriculum was disconnected to their interests and priorities (Leung, 2007).

To learn science effectively, students need to clearly understand the nature of science. Trevor Anderson (2005) contends that science education has tended to ignore philosophy of science that can inform students about the nature of science. He argues: “a good understanding of the nature of science can
significantly enhance the practice of science and the development of various
cognitive skills that are crucial for the doing of good science” (p. 144). Table 2.1 is a summary of the main features that characterise the nature of scientific knowledge.

Table 2.1  Factors characterising the nature of scientific knowledge  
(Anderson, 2005:144, modified from Lederman, 1992)

<table>
<thead>
<tr>
<th>Science knowledge</th>
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<tbody>
<tr>
<td>1. Is indefinite in nature (never absolute or certain)</td>
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<tr>
<td>2. Is dynamic and ever changing</td>
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<tr>
<td>3. Is tentative (subject to revision)</td>
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<tr>
<td>4. Is temporary (Likely to eventually change)</td>
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<tr>
<td>5. Is dependent on the consensus view of the community of scientists</td>
</tr>
<tr>
<td>6. Has ‘grey’ areas which may, or may not become generally accepted by the community of scientists</td>
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<tr>
<td>7. Is partially subjective in terms of conceptual understanding and interpretation of results</td>
</tr>
<tr>
<td>8. Is a product of the cognitive, practical and technical skills used to obtain results</td>
</tr>
<tr>
<td>9. Is a product of human imagination and creativity</td>
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<tr>
<td>10. Is a product of how scientists visualize phenomena</td>
</tr>
<tr>
<td>11. Is a product of human endeavour. Enterprise affected by conceptual knowledge, social fabric, power structures, politics, socio-economic factors, philosophy, worldviews, culture, ethics and religion</td>
</tr>
<tr>
<td>12. Is dependent on the use of good, valid and reliable scientific methods</td>
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<tr>
<td>13. Is affected by the limitations of the methods and techniques used to obtain the results</td>
</tr>
<tr>
<td>14. Involves both observation and inference</td>
</tr>
<tr>
<td>15. Includes theories which are inferred explanations for observable phenomena</td>
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<tr>
<td>16. Includes laws which describe relationships between observable phenomena</td>
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<tr>
<td>17. Has a history and progresses by building on old models of the natural world, not replacing them</td>
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Geoff Masters (a leading education consultant) recognises the need for multidisciplinary science curricula that are based on applications of science to everyday issues (Ferrari, 2007). This view is consistent with the essence of this thesis in which I argue for a more permeable membrane between science and spirituality so that science education may be more authentic and meaningful for students.

The following values of science are identified, based on the nature of science as a human activity carried out in a particular socio-cultural context. In school, students might conceive and practice the following values of science:

- Consideration of consequences – decision based on the assessment of the effects emanating from an action or set of actions.
- Longing to know and understand – a conviction that knowledge is desirable, and the effort for acquiring it is worthwhile.
- Demand for verification – search for supporting evidence to verify the validity and accuracy of a statement.
- Questioning – a belief that all things, including authoritarian statements and ‘self-evident’ truths are open to question; questions often lead to further understanding.
- Respect for logic – consideration of influences that emerge from cause-effect relationships.
- Search for data and their meanings – the acquisition and processing of data and information form the basis of understanding. Some of them may be useful in the immediate context, while others might be at a later stage. (UNESCO, 2001:14)

Hildebrand and Tytler (2004) advocated the following list of values and attributes, as well as ‘habits of mind’ that should be taught through the science curriculum.
Values

Through learning science students will come to value:

• Honesty – valuing truthfulness; trusting themselves; trusting people who, and processes that, can be relied upon to provide consistent and trustworthy evidence.

• Ethical behaviour – valuing fairness, equity and justness; exhibiting and respecting behaviour that is open, moral and consistent with science’s expectations for transparency of processes.

• Scepticism – valuing a questioning and doubting attitude that expects evidence for claims.

• Objectivity, logic and rationality – valuing the goal of trying to be independent of personal prejudices, and systematic and logical in thinking through ideas; recognising that all human thought has subjective elements – and that this can be a strength in particular contexts.

• Diversity – valuing a variety of perspectives and accepting that they each have useful contributions to make to science, technology, society and their interactions.

• Community – valuing the input of people into building our constructed and social worlds, and in creating scientific ideas and valuing working collaboratively in, and with, communities.

• Authenticity – valuing validity, genuineness, and the appropriateness of information in particular contexts.

• Verifiability – valuing processes and dispositions that expect data and evidence to be verifiable.

• Reliability – valuing the reproducibility of evidence and expecting procedures to be available to do this.

• Interdependence – valuing the interdependence of ourselves, and our social, physical and constructed worlds; and respecting the ways we shape our environment and it shapes us.
Attitudes and habits of mind

- Curiosity – wondering how things work; possessing an orientation to inquiry, to speculation, to chasing ideas and testing them against evidence, both formally and informally.
- Creativity – a lateral thinking and generative frame of mind that is able to draw on a wide spectrum of ideas and bring them together in innovative ways.
- Interest – seeing science as an enjoyable way of knowing, a means of investigating the wondrous world we live in.
- Persistence – preparedness to persevere in the face of difficulties and problems; a determination to continue seeking evidence and arguments before making decisions.
- Precision – being accurate and aware of the limitations in the accuracy of arguments, evidence, measurements and calculations.
- Care and sensitivity – being sensitive to the needs of ourselves, others and our shared environment; and taking deliberate steps to care for those needs.
- Open-mindedness – willing to listen to and explore new ideas; an evaluating perspective on information; a preparedness to look at situations and problems from a range of perspectives.
- Responsibility - accepting responsibility and being accountable for the personal decisions that we make and the consequences of those decisions; taking risks and managing them responsibly. (Hildebrand & Tytler, 2004:29-30)

A critique of this extensive list of values and habits of mind shows that it focuses on the individual. Such a predominance of the intrapersonal is not surprising given that the authors, Hildebrand and Tytler favour the constructivist paradigm. When the values are sorted using Rogoff’s (2003) lenses, the imbalance is clearly apparent (Refer to Table 2.2) and a spiritual dimension has been overlooked.
Table 2.2  A socio-cultural analysis of the values and habits of mind being taught through the science curriculum

<table>
<thead>
<tr>
<th>Rogoff’s focus of analysis</th>
<th>Focus of attention</th>
<th>Values and habits of mind</th>
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</thead>
<tbody>
<tr>
<td>Intrapersonal lens</td>
<td>Concentrates on the individual and what he/she may think</td>
<td>Honesty, Ethical behaviour, Scepticism, Objectivity, logic and rationality, Authenticity, Verifiability and reliability, Curiosity and creativity, Interest, Persistence, Precision, Responsibility</td>
</tr>
<tr>
<td>Interpersonal lens</td>
<td>Includes the social relations among people, as they appropriate concepts and make meaning of them through their interactions</td>
<td>Honesty, Ethical behaviour, Diversity, Interdependence, Care and sensitivity, Open mindedness</td>
</tr>
<tr>
<td>Community/cultural lens</td>
<td>Draws attention to the cultural and contextual factors that could be operating within the community of practice</td>
<td>Diversity, Community, Interdependence</td>
</tr>
</tbody>
</table>

However, having identified these values, ensuring that they are built into the science curriculum is altogether another matter (Hildebrand, 2007). While values are taught implicitly through the science curriculum, they should be made explicit, if not there will be consequences. In his study Clarkeburn (2002) found that students who were successful in secondary science and studying
tertiary science, still had poor understandings of ethical or moral issues in the science they studied. Importantly, one reason for these findings is that the science curriculum is based on constructivism, with a strong emphasis on the individual generating meaning from experience. Such an emphasis is restrictive, making it difficult for students to adequately understand ethical issues if they are not given opportunities to consider the communal and cultural context.

A new approach to science education, one that is inclusive of spirituality, requires a pedagogy that is respectful of the values of students, their families and communities, and appreciates the spiritual dimension of human experience. When teachers of science acknowledge a spiritual dimension, the individual is valued in the communal context, and learning can be enhanced, because spiritual knowledge:

- Emphasises the connectedness of all things (interpersonal and community);
- Integrates heart, mind and soul to give meaning and purpose (intrapersonal);
- Enables ethical and compassionate decision-making (intrapersonal and community); and
- Promotes student initiative and self-reflexive thought (intrapersonal).

To be successful this new approach will need to be part of pre-service teachers’ science education courses, and the formation of teachers should include ethical and moral values.

The values put forward by UNESCO (1991) were generated in the worldwide context and are expressed in terms of an individual doing science. They appear to be essential and universal, and when combined with the values associated with spiritual knowledge, form a well balanced set, even though the periphery of culture changes (Refer to Table 2.3).
Table 2.3  A socio-cultural analysis of the values that should be taught through the science curriculum

<table>
<thead>
<tr>
<th>Rogoff’s focus of analysis</th>
<th>Focus of attention</th>
<th>Values as demonstrated by students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intrapersonal lens</td>
<td>Concentrates on the individual and what he/she may think</td>
<td>Considering consequences Longing to know and understand Demanding verification Questioning Respecting logic Searching for data and their meanings Initiative and self-reflexive thought Ethical and compassionate decision making</td>
</tr>
<tr>
<td>Interpersonal lens</td>
<td>Includes the social relations among people, as they appropriate concepts and make meaning of them through their interactions</td>
<td>Considering consequences Connectedness of all things</td>
</tr>
<tr>
<td>Community/cultural lens</td>
<td>Draws attention to the cultural and contextual factors that could be operating within the community of practice</td>
<td>Considering consequences Connectedness of all things Ethical and compassionate decision making</td>
</tr>
</tbody>
</table>

From a socio-cultural-historical perspective the current practice of including social action (intermental functioning) in school science is often limited to involving students in environmental activities aimed at preventing environmental degradation, such as recycling campaigns, pollution studies and the re-vegetation of the local grounds (Blades, 2000).
Controversial issues (such as abortion, cloning, euthanasia, genetically modified foods) are justified in science education because the process of considering such issues helps “the development in students of four main approaches to thinking: ethical, civic and social, sociology of knowledge and psychology of learning” (Van Rooy, 2004:199). In the ethical approach, students become aware of the influence of values on people and society (the community plane). Van Rooy who investigated controversial issues in the context of school science, strongly advocates including these issues in science education because learning about them promotes students’ personal, intellectual, emotional and social growth. Unfortunately she neglects the effects such authentic learning experiences might have on students’ spiritual growth.

Even though Michael Reiss (2007) contends “school science needs more education for social justice, socio-political action and criticality,” he is also sympathetic towards Jenkin’s conservative view. Jenkins queried whether science teachers were able to tackle such issues, given their specialised discipline training.

The central task of a compulsory school science education for all is surely to introduce students to the key features of how scientists understand the material world. It is not to train students to think like scientists, save when they are addressing scientific problems, nor is it primarily to engage them in socio-political issues that have a scientific dimension. Such engagement is better undertaken by (or in conjunction with) others whose training and expertise fits them to handle ethical, moral and political controversy, and might be better accommodated within lessons or activities devoted to citizenship or personal and social education. More fundamentally, such engagement again exposes and challenges the limitations of a subject-based curriculum. (Jenkins, 2004:175, cited in Reiss, 2007:25)

Unfortunately Jenkins based his argument on a ‘deficit model’, that teachers of science lack the ability to effectively handle such dilemmas. He fails to appreciate that some teachers feel confident to cross the discipline boundaries
and also engage in professional learning in more than one curriculum area. In professional development programs Aikenhead (1996) encourages teachers to be cultural brokers and cross the discipline borders. Teachers who have participated in these programs say they are more confident to teach in this way.

In contrast to Jenkins, I argue for a shift to a ‘pro-active model’ that includes in teacher education courses opportunities for students to enhance their own spiritual wellbeing, which in turn fosters their capabilities to deal with the complexities surrounding moral and ethical issues. Furthermore an interdisciplinary approach, whereby links are made across subject domains, can provide teachers of science with an understanding of different ways of knowing that lead to harmony rather than discord. In this way teachers of science may gain the confidence and expertise to engage students in socio-political issues that have a scientific dimension. In professional development programs Aikenhead (1996) encourages teachers to be cultural brokers and cross the discipline borders. Many of these teachers, after participating in professional development are confident to teach in this way.

2.8 Summary
In this chapter I followed Groome’s (1980) first movement of shared praxis, to raise the problem of students’ perceptions of scientists as stereotypical images. A literature search of studies of children’s stereotypical views of scientists was critiqued. Importantly the chapter contains the findings of a recent study of children’s drawings of a group of scientists. Data analysis showed the impact of shared interactions on the transformation of children’s self-understanding as a result of the personal-communal dialectic. The ‘aha’ moment was evident when some children said: “We are scientists”. The small group teaching fostered children’s intermental functioning through their participation in a community of learners. These shared interactions nurtured the personal (intramental functioning) and the communal, each nourishing the other, but not at the expense of the other.
A discussion of the debate on values in education led to a critique of the Victorian curriculum. This thesis offers a means of improving education by fostering connectedness in science curricula that in turn might encourage more young people to be interested in science. In the next chapter, the second movement of Groome’s praxis approach, Parker Palmer’s notion of contemplation-in-action provides a way forward towards developing courageous teachers of science who are willing to accept the challenge of fostering an environment of connectedness for students.
CHAPTER 3  CRITICAL REFLECTION AND DIALOGUE

3.1  Introduction and chapter overview
In this chapter I have critiqued present action in science education research to uncover the pathway already travelled, and to raise awareness of future consequences (intended or otherwise) of that action. This critical reflection occurred on several levels and took account of rational and affective factors, and involved reason, memory and imagination. The first level revealed the obvious in the present that often goes unnoticed because it is taken for granted. The second level involved delving deeper into present action to expose the underlying assumptions on which it is based. Third level reflection required me to imagine new ways forward for the science education community. At this level I examined research in science education from a socio-cultural-historical perspective, and a ‘community of learners’ orientation in particular. In the latter part of the chapter that follows Groome’s third movement, I dialogue with the narrative by Parker Palmer focusing on his paradoxical model for teaching and learning that helps create an educational environment that fosters connectedness.

3.2  Critique of present action in science education research
3.2.1  First and second levels: Research from a constructivist perspective
For two decades constructivism has been accepted as the major theoretical driver in science education research. In most of these research studies the researchers probed individual children’s views about particular science topics (Driver, et al., 1985; Gunstone, 2000). Researchers sought ways to change the so-called naïve or alternative conceptions that children hold by devising various constructivist-based teaching and learning models. In the science education research literature that these studies generated, researchers argued that while everyday concepts (alternative views) are important they obstruct some children from learning scientific concepts in school (Osborne & Freyberg, 1985). When
these research studies were first reported the findings were innovative and considered useful for changing science teaching and learning in schools (Gunstone & White, 2000). However, that change has not necessarily occurred as Tytler (2007) identified when he called for re-imagining science education to engage students in science.

When the cultural dimensions of science learning are considered it becomes obvious that they have generally been framed from a Western science perspective (Aikenhead, 1996). This is not surprising given that the research literature at the time was written in the main by researchers from developed countries. Cross-cultural studies (e.g. Mei-Hung Chiu & Jing-Wen Lin, 2005) have also concentrated on how children from different cultures think about particular science topics, which mirrors the research frameworks developed in the 1980s.

The crisis in school science, that in the near future may hinder Australia’s progress in science and technology because of dwindling numbers of science and engineering graduates, was identified in Chapter 1. In 2006, in response to this issue, the Australian Council for Educational Research (ACER) organized a conference and invited local and international speakers to attend and offer possible solutions to the crisis. They suggested ways to instigate change in the purposes and practice of science in schools. Based on the input given by participants a review was recently published (Tytler, 2007). In his conference paper Peter Fensham identified that students should feel interested in science when they leave school. For this to happen there needs to be “an emphasis on the methods of science and the nature of science as it works in the world. Thus the purposes of school science need to be re-imagined, and broadened. The content needs to be more open and flexible” (Tytler, 2007:15).

In the process of remembering, personal and the social sources of present action are brought to the fore. Therefore a critically remembered past informs both
current and future choices. At the second level of reflection, remembering is looking backward as well as outward to the wider world. When aggregated, reason and critical memory enable the naming of present action by taking account of the knowledge gained from engagement in the world.

3.2.2 Third level: Research from a socio-cultural-historical perspective

An important aspect of remembering is connected with and informed by the research of Vygotsky (1987) that has been the catalyst for understanding today’s social, cultural and historical contexts. Socio-cultural-historical theory highlights those contexts that shape social relations, community values, and past practices. Therefore in order to understand an individual’s thinking, researchers must appreciate the cultural-historical context surrounding the individual.

Some science education researchers have realised the potential of Vygotsky’s (1997) work for framing their studies. They have adopted a socio-cultural-historical perspective to their research and focus on embedded practices within communities and homes. Recent studies of children in the early years have generated an understanding of the contexts that shape science learning in the years prior to attending school (French, 2004; Gelman & Brenneman, 2004; Eshach & Fried, 2005; Jane & Robbins, 2004; Hannust & Kikas, 2007). Carrying out these studies requires a prolonged time in the research context so researchers can map the movement of children’s thinking. In her doctoral study Robbins (2005) describes how children’s thinking twists and turns as they explore or discuss concepts.

Most Western heritage communities still organise schooling by giving priority to the individual, yet cultural-historical research shows that learning occurs in the participation framework in communities. From a situated learning perspective, schools can inadvertently foster disconnectedness, between dis-embedded Western concepts and concepts that naturally arise within a community of practice (Lave & Wenger, 1991).
When researchers frame their research from a socio-cultural-historical perspective, and examine the social engagements and context in which conceptual learning occurs, they obtain a multi-layered view. “All members of a learning community contribute inseparable aspects whose combinations create a landscape – shapes, degrees, textures – of community membership” (Lave & Wenger, 1991:35). By documenting the changing participation of members of a particular community of practice, researchers can determine how “communities of practice are engaged in the generative process of producing their own future” (Lave & Wenger, 1991:57). Initially learners are on the periphery of practice, but gradually they become fully participating community members. Over time, young children, embedded in the social fabric of the family, move from being peripheral to becoming full members of that community.

In considering learning as part of social practice, we have focussed our attention on the structure of social practice rather than privileging the structure of pedagogy as the source of learning. Learning understood as legitimate peripheral participation is not necessarily or directly dependent on pedagogical goals or official agenda, even in situation in which these goals appear to be a central factor (e.g., classroom instruction, tutoring). We have insisted that exposure to resources for learning is not restricted to a teaching curriculum and that instructional assistance is not construed as purely interpersonal phenomenon; rather we have argued that learning must be understood with respect to a practice as a whole, with its multiplicity of relations – both within the community and with the world at large. (Lave & Wenger, 1991:113-114)

Most individuals belong to several communities of practice at any one time (such as neighbourhood communities, workplaces, educational institutions) in which they develop their “own practices, routines, rituals, artefacts, symbols, conventions, stories, and histories” (Wenger, 1998:6). Representations include: “language, tools, documents, images, symbols, well-defined roles, specified criteria codified procedures, regulations, and contracts that various practices make explicit for a variety of purposes” (Wenger, 1998:47). Because these artefacts and processes that frame communities of practice can go unnoticed,
students benefit when teachers attend to these artefacts/processes, in order to develop a community of learners in the classroom.

People move through rather than to understanding, and participatory appropriation occurs when “individuals transform their understanding of and responsibility for activities through their own participation” (Rogoff, 1995:150). This notion contrasts with the traditional perspective of viewing the process as one of “internalization in which something static is taken across a boundary from the external to the internal” (Rogoff, 1995:151). Often in the past, when children’s learning was considered, important historical and contextual factors were disregarded. Moreover, the teaching and learning context, in which children must apply their new ‘knowledge’, has generally been overlooked.

A more comprehensive understanding of the processes of conceptual change can be gained by focusing on a ‘group of learners’, their social engagement, and the contextual factors operating. This is the case because concept formation is held within a community of practice and enacted through social engagement. Research in science education from a socio-cultural-historical perspective shifts the focus from the individual child, to the ‘group of children’ or the community of learners.

3.3 Imagined communities of learners

Direct involvement with community practices (engagement) is one way in which individuals can belong to a community. Another important source of community that is not immediately tangible is imagination- “a process of expanding oneself by transcending our time and space and creating new images of the world and ourselves” (Wenger, 1998:176). Imagined communities (so called by Anderson, 1991) are groups of people, not readily accessible, with whom individuals connect through the power of imagination. Imagined communities can affirm what has not yet happened in the future, and can motivate what learners do in the present. "The notion of imagined communities
enables us to relate to learners’ visions of the future to their prevailing actions and identities” (Kanno & Norton, 2003: 248).

So that the past is not merely duplicated, imagination or ‘outside the box’ thinking is essential. Potentially, imagination can develop in a similar way to language, and depends on the brain’s maturity, interpersonal factors and environmental factors (Neville, 2005). Skilful imagination “like language, significantly affects the child’s ability to learn, to develop peer and adult relationships, to pursue goals” (p. 94). Unfortunately, people who only rely on what they have learned in the past, from their parents and teachers, are at a disadvantage (Osho, 1999). Creative imagination and flexibility are required for the future, and being open to new ideas (receptivity) is a way to access imagination. 3 Creative imagination gives intention to the future, offers hope in connectedness, and is an important element of critical reflection on present action, because it helps ensure that the past is not just repeated.

Separation into subject boxes still predominates in schools, with only some fostering connectedness through holistic education (e.g. Steiner education). Attempts to merge traditional subject areas in secondary and tertiary institutions have generally been resisted. One exception is the curriculum area Studies of Societies and Environments (SOSE) that fosters integration of geography, history, social studies and environmental education. In Victoria this subject area was criticised (see Taylor, 2007), then abandoned by VELS, and displaced by Humanities. The report The Future of Schooling in Australia (launched in April

3 The first step is receptivity, because in receptivity ego cannot exist - it can exist only in conflict. And when you are receptive, suddenly your faculty of imagination becomes tremendously powerful. The poets, the painters, the dancers, and the musicians - they absorb the universe in deep receptivity, and then they pour whatsoever they have absorbed into their imagination. (Osho, 1999:66)
2007 by the then Victorian Premier Steve Bracks) made the controversial school subject SOSE obsolete.

In respect to the subject Science, objectivity can inhibit the imagination and contradict the way some scientists make their discoveries. ‘Doing science’ involves engagement, an encounter with the object(s) being investigated. Therefore science is a ‘relational way of knowing’ whereby the scientist forms a partnership with the other. This knowledge is always communal, and the relational aspect of knowing is “animated by a desire to come into deeper community with what we know” (Palmer, 1998:54).

This relational way of knowing … is a way of knowing that can help us reclaim the capacity for connectedness on which good teaching depends (p. 56)… Knowledge is how we make community with the unavailable other, with realities that would elude us without the connective tissue of knowledge. Knowing is a human way to seek relationship and, in the process, to have encounters and exchanges that will inevitably alter us. (Palmer, 1998:54)

A teacher’s understanding of how students come to know shapes pedagogy. Effective teachers are able to “weave” connections between themselves, their subjects and students. Good teachers “join self and subject and students in the fabric of life” and deliberately avoid the ‘objective’ mode of knowing that still dominates education (Palmer, 1998:11). Science teachers in particular are encouraged to imagine subjective ways to teach that create connections for learners.

Objectivism portrays truth as something we can achieve only by disconnecting ourselves, physically, emotionally, from the thing we want to know….if we get too close to it, the impure contents of our subjective lives will contaminate that thing and our knowledge of it. (Palmer, 1998:51)

It is not uncommon to hear proponents of objectivism claim that subjectivity gets in the way, as opinions and bias distort knowledge. To avoid knowledge
becoming contaminated in this way, objectivists distance themselves from what they are studying by treating what is to be known as lifeless objects so they cannot threaten or transform them. In contrast, subjectivity encourages relationships between objects and the knowledge seeker. Objectivity can inhibit the imagination and does not accurately describe the way some scientists work.

For objectivism, any way of knowing that requires subjective involvement between the knower and the known is regarded as primitive, unreliable, and even dangerous. The intuitive is derided as irrational, true feeling is dismissed as sentimental, the imagination is seen as chaotic and unruly, and storytelling is labelled as personal and pointless. … It fails to give a faithful account of how knowing actually happens, even at the heart of science itself. No scientist knows the world merely by holding it at arm’s length. Science requires an engagement with the world, a live encounter between the knower and the known. That encounter has moments of distance, but it would not be an encounter without moments of intimacy as well.” (Palmer, 1998:52, 54)

3.4 Creating an educational environment that fosters connectedness

In the past, educators often taught science by breaking a topic down into simpler parts. In addition, facts were kept separate from feelings. This process of dislocating theory from practice generally results in theories with little relevance to everyday life, and practice that is not informed by understanding. When theory and practice are disconnected, educators do most of the talking and very little listening, while students are to listen without much talking. Teachers need “to walk quietly, to remain observant, to practice listening and to keep exploring” (Livsey & Palmer, 1999:5).

Palmer, who is passionate about paying attention to the inner life of teachers, recommends teachers embrace opposites and appreciate paradoxes. Teaching that actively accepts paradox and the tensions of opposites, facilitates positive outcomes for students’ learning. Effective teachers can consciously link thinking and feeling by implementing a paradoxical model of teaching and learning. Such a model involves:
• Teaching that comes from identity, not technique;
• Intellect working in concert with feeling;
• Teaching at the crossroads of the personal and the public; and
• An equal and opposite need for both community and solitude. (Palmer, 1998:63)

Palmer (1998) identifies that teachers who encourage paradoxical tensions in the learning space enable students to learn at a deeper level because the space:

• Is bounded and open;
• Is hospitable and “charged”;
• Invites both individual and group voices;
• Honours students’ “little” stories and the “big” stories of science;
• Supports solitude surrounded with resources of community; and
• Welcomes both silence and speech.

These features are consistent with the educational environment advocated in a shared praxis approach. In shared praxis students feel welcome and comfortable when in emotional and physical environments that offer warmth, openness and hospitality. An ‘emotional environment’ is hospitable when there is trust, and students know their contributions are valued. When such an atmosphere exists in the classroom, students offer their ideas. Furthermore, a trusting environment encourages authentic dialogue, critical reflection, and supports risk taking. It is the educator’s responsibility to create an emotionally safe environment. “By creating a model of dialogue, trust and hospitality, the educator has a crucial role in creating such an environment in the group” (Groome, 1980:226).

Educators must also attend to the ‘physical environment’ to make it comfortable. As well as checking that the room is large enough to hold the number of students in the group, educators can create a ‘soft’ environment with appropriate seating, lighting, floor coverings, furnishings and colour scheme. In
a praxis approach, group size should not exceed 12, because all members must have opportunities to speak. Large groups are divided into groups of four for sharing reflections, followed by time for small group feedback to the large group.

When the teaching and learning space is the science classroom, ‘boundaries’ are necessary to keep students focussed on the task at hand. The questions, text or activities the teacher plans should be clear and compelling for students. Boundaries keep students on track during the journey towards their destination. An ‘open’ learning space means students are free to travel different paths together until they reach their destination (which may be different from the destination the teacher intended). To keep students from getting lost in the open space it must be safe and trustworthy. A metaphor for this journey is ‘expedition’ which requires “places of rest, places to find nourishment, even places to seek shelter when one feels overexposed” (Palmer, 1998:75). At the same time a “charged” atmosphere precipitates learning at a deep level, and is generated when the teacher provides relevant topics that students are not to evade or trivialize. Furthermore the space should encourage students to find their authentic voice and speak their mind.

While listening to the collective voice of the group, students should be open to group influence on their own ideas and beliefs. Sufficient time is allowed for individuals to tell their stories of personal experience “in which the students’ inner teacher is at work” (Palmer, 1998:76). When these stories are framed with big stories of science (such as biographies of noteworthy scientists) meaning is added to the personal stories. “We must help students learn to listen to the big stories with the same respect we accord individuals when they tell us the tales of their lives” (p. 7). Students can learn from the biography of noteworthy geneticist McClintock, who was open about her feelings for the organisms she researched. She viewed the corn plants she studied as subjects not objects. “By emphasizing the spiritual aspects of her work, teachers can encourage students
to engage in science in a more subject-to-subject way” (Jane & Gipps, 2006). McClintock found that periods of meditation facilitated her scientific discoveries. Accordingly individuals should experience quiet time in the learning space that invites silence as well as student talk. Silence in an atmosphere of trust can be productive for student learning. When students experience silent time within an authentic community of learners, they learn at a deep level.

3.5 Reflection/action in a communal context

Previously I acknowledged that people in all parts of the world benefit significantly from scientific discoveries and technological products that make life easier (Jane, 2001, 2003). However, many individuals are beginning to question the effects materialism is having, such as doubting the value of economy-driven societies led by politicians whose policies neglect the spiritual needs of human beings. Individuals seeking connectedness and purpose in their lives are part of the current spiritual awakening.

Spirituality, as broadly defined earlier, is concerned with the belief in something larger than ourselves. From a socio-cultural-historical perspective, and using Rogoff’s (1998) three planes of participation in communities, I define spirituality as follows.

Spirituality is an individual desire (personal plane) for connectedness with others (interpersonal plane) and with a transcendent dimension that is greater than human beings. The transpersonal dimension of spirituality affects society (community or institutional plane), which may (or may not) be associated with organized religion. (Jane, 2006:4)

People in the Lifestyle category of the spiritual spectrum (Drane, 2005, described in Section 1.7) tend to value the inward search (which is the personal plane) and engage in meditative techniques to balance their fast paced, active lifestyles. Historically, in the early centuries, in ascetic communities,
contemplation was valued more than action. In the second half of the 20th century, in a monastic setting, Thomas Merton (1972) participated in practices that included silence, solitude and contemplation. King (2001:54) recognised that in the new edition of an old book *New Seeds of Contemplation*, “Merton places contemplation squarely in the context of ordinary life and appeals directly to experience”. Merton defined contemplation as

The highest expression of man’s intellectual and spiritual life. It is that life itself, fully awake, fully active, fully aware that it is alive. It is spiritual wonder. It is spontaneous awe at the sacredness of life, of being. It is gratitude for life, for awareness and for being. It is a vivid realization of the fact that life and being in us proceed from an invisible, transcendent and infinitely abundant Source.” (Merton, 1992:1)

Even though Merton’s writings were produced in a closed community, his ideas were influential in the outside world. Today, throughout the world there is a renewed search for the contemplative in order to cope with the stresses of an active life. Ideally contemplation should be held together with action, because “people called to active life need to nurture a spirituality that does not fear the vitalities of action” (Palmer, 1990:8). ‘Active life’ is the pathway to aliveness that is relational and communal and includes responding to other people’s needs as well as our own. The paradoxical partner of the active life is the life of contemplation. ‘Contemplation-in-action’ is a whole-minded approach that combines L-Directed reason with R-Directed spirit.

Because very few things human beings do are governed exclusively by one hemisphere or the other, I’ve chosen the terms ‘L-Directed’ and ‘R-Directed’ instead of the more convenient ‘left-brain thinking’ and ‘right-brain thinking’. *L-Directed Thinking* is a form of thinking and attitude to life that is characteristic of the left hemisphere of the brain – sequential, literal, functional, textual, and analytic. Ascendant in the Information Age, exemplified by computer programmers, prized by
hard headed organizations, and emphasized in schools, this approach is directed by left-brain attributes, toward left-brain results. *R-Directed Thinking* is a form of thinking and attitude to life that is characteristic of the right hemisphere of the brain – simultaneous, metaphorical, aesthetic, contextual, and synthetic. Underemphasized in the Information Age, exemplified by creators and caregivers, shortchanged by organizations, and neglected in schools, this approach is directed by right brain attributes, toward right brain results” (Prince, 2005:26)

There is a growing quantity of scientific evidence that positions the capacity for spirituality in the brain’s right hemisphere. An emphasis on left hemisphere brain functioning generated the current dominant Information Age with Information and Communications Technologies impacting in a major way on people’s lives and work. When Pink (2005) imagines the future he predicts a shift to the Conceptual Age that emphasises the right hemisphere brain qualities of inventiveness, empathy and meaning. Such a shift prioritises ‘post-materialist’ values and ‘meaning’ becomes central to people’s lives. “We are social creatures of meaning, who crave a sense of coherence and purpose” (Quartz cited in Pink, 2005:213). In the future, professional success and personal fulfilment will depend on individuals using both hemispheres of their brain.

Results of an audit involving interviews with 100 executives about spirituality found most defined spirituality, not as religion, but as “the basic desire to find purpose and meaning in one’s life” (Pink, 2005:215). The study revealed that when spirituality is allowed into the workplace it helps organizations achieve their goals.

3.6  **Spirituality braided with science education**

Quality science education in the future will require an integration of shared praxis with reflection/action in a communal context. Through contemplation-in-action, that integrates both hemispheres of the brain, students are able to learn at a deep level. Since spirituality has a locus in the brain’s right hemisphere,
and schools emphasise left-brain thinking, spirituality in science education can foster whole brain learning.

Contemplative experiences such as mindful walking and meditation (Fleer & Jane, 2007) followed by hands-on scientific investigations can encourage a sense of connectedness for students. When they share personal stories in a teaching and learning space that is both open and bounded, and these are framed by stories of scientists and their work, science education becomes relevant and meaningful and understood as a way of being in the world.

3.7 Summary
In this chapter about science education research I have uncovered the pathways already travelled, and revealed the obvious in the present and the underlying assumptions. Imagination, which is inhibited by objectivity, is necessary if past practices are not to be duplicated. ‘Doing science’ is subjective, requires engagement and an encounter with that which is to be known. Paradoxical tensions in the teaching and learning space can encourage deep level science learning through an environment that encourages connectedness. Spirituality, which fosters connectedness, is often integral to the scientific enterprise, and a move towards a spiritual way of being can enhance science education.

In the next chapter, Groome’s fourth movement, I critically engage with the narrative of scientist McClintock and reveal the role contemplative awareness played in her scientific discoveries that significantly advanced the field of genetics.
CHAPTER 4  NARRATIVE OF SCIENTIST BARBARA McCLINTOCK

4.1  Introduction

In the previous chapter I critically reflected on science education and identified concerns associated with present practice. Through imagined communities, I suggested new ways forward that included valuing subjectivity, and designing learning environments that encourage students to make connections with new knowledge. I proposed that when spirituality, which fosters connectedness, is integral to the scientific enterprise, science education has significance for students as human beings. In this chapter, the notion of incorporating spirituality in science is further explored through the unconventional, yet important narrative of non-stereotypical scientist McClintock.

Following Groome’s (1980) third movement, the focus of this chapter is ‘story’. Narrative is the research tool used to describe the story of McClintock’s early childhood, the family interactions that influenced her personality, details of interpersonal relationships as a researcher, and the scientific communities’ responses to her scientific discoveries and radical theories.

Consistent with socio-cultural-historical theory - the theoretical framework of this thesis – I used the ‘personal lens’ to generate a description of McClintock as an individual. The narrative tells the story of her distinguishing characteristics, and begins with the family’s historical background that significantly influenced the development of her personal traits.

Applying the ‘interpersonal lens’ I focused attention on the complex, mother-daughter relationship that shaped McClintock’s personality. This lens facilitated my examination of the interactions between her and colleagues that occurred at several of the institutions where she undertook her scientific work. The
narrative also identifies McClintock’s preferred way of working and unique approach to integrating cytology and genetics (cytogenetic).

The ‘community lens’ shifted my focus to the scientific communities at the time, revealing how their members reacted to her radical discoveries, and the recognition she finally gained for her scientific breakthroughs. I conclude the chapter with a brief chronology of McClintock’s life.

In the main, the particular narrative presented here, arose from my reflections on reading Evelyn Fox Keller’s (1983) biography of McClintock’s life and work as a scientist. This text of McClintock’s story is validated, wherever possible, by her own words given in interview responses, when she talked about her personal characteristics, explained the genesis of her boundary pushing theories, and revealed the scientific communities’ reactions to these ‘ahead of her time’ theories. First I explain how narrative relates to story in the next section.

4.2 Narrative in relation to story

The terms ‘narrative’ and ‘story’ can be defined in the following way.

Story is a powerful way to communicate ideas through a sequence of events that can be told in various ways, depending on the storyteller. When the same story is told in different ways, different versions called texts are generated. These texts constitute multi-layered ‘narratives’ consisting of the sequences of events (the stories), the versions of the stories (the texts) and the “way in which these events are presented” (the fabulas). (Bal, cited in Berger, 1997:34)
Narratives - stories that take place at a particular time - are powerful catalysts for deeper understanding. For example, personal stories can be vehicles for passing on cultural traditions, as Neville explains.

A great deal of what we know we know as story. Our basic assumptions – the things we take so completely for granted that we never reflect on them – are embedded in the story of who we are and where we come from. … We inherited it from our parents, our family, our religious tradition, and, more widely, from our culture. … Our cultural narrative is expressed in lots of different ways in the stories we tell our children. (Neville, 2005: 95)

Story can promote understanding by placing ‘what is to be known’ in context which often generates an emotional response.

Stories can provide context enriched by emotion, a deeper understanding of how we fit in and why that matters. The Conceptual Age can remind us what has always been true but rarely been acted upon – that we must listen to each other’s stories and that we are each the authors of our own lives. (Pink, 2005:113)

Narratives can be very engaging and therefore are effective. For example, Parker Palmer (1990) used narratives from the Taoist; Jewish and Christian religious traditions to show that spiritual life can facilitate a deeper engagement with the world, and does not require abandoning it, as in the monastic life. In Parker’s narratives, the nature of ‘active’ life is highlighted, but in addition, he pays attention to its paradoxical partner, the ‘contemplative’ life, emphasising the need for both, and advocating ‘contemplation-in-action’.

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4 Berger (1997:67) defines Story as the various events that occur in a narrative. The story is not identical to the text; a given story can be told in several different texts. For example, in films, many stories have been told several times; there are two versions of King Kong and three of A Star is Born, not to mention re-workings of the same stories made under different titles. The basic stories are the same (or very similar), but they are told somewhat differently each time, using different actors, emphasizing different themes, and so on.
Another example of the effective use of narrative is Pamela Bone’s (2004) text of Australian cartoonist, Michael Leunig’s story. Bone found out about his childhood and early adulthood through interviews, and she included snippets of these in the narrative. Leunig talked about growing up in Melbourne’s western suburbs, saying that he always valued solitude, even while he was leading an active social life.

There were a lot of children around, the street was a place you could be at night, there was a great sense of security, of community, a reliability. Life wasn’t too dramatically changing. There was solitude, space, and time to think. It was not an overcrowded childhood. I do recall people saying, Oh, Michael’s a dreamer, he’s in a world of his own, but this was not seen to be a problem. I was allowed to be in my world alone, in the sandpit making sand cities for ants. But I was social too. I think I could be with me or with someone else pretty well. (Leunig cited in Bone, 2004:136)

The things he valued which were so strongly cemented in childhood, are evident in his adult life. He chose a country lifestyle for his family, had his children home educated, and went without television. This narrative provides insight into how people are shaped and transformed by their childhood experiences. Leunig explains:

In the country now I feel echoes of what my childhood was like. Modern life is so passive and at the same time so overstimulated. What I had was space, and freedom and time to be alone and even bored at times. Creativity can grow out of being bored, and coming past that boredom. Cross your fingers, that’s what you try to do for your children. In the acorn is the oak. What you have to do is let it grow. (Leunig in Bone, 2004:136)

It is therefore important to consider what McClintock valued in her early years, and how her childhood experiences influenced the way she carried out her adult work as a scientist. In the next section her family background is described, and its effect on her personality development is highlighted.
4.3 McClintock’s childhood and capacity for full absorption

McClintock (1902-1992) was a scientist who had a significant impact on scientific knowledge in the field of genetics. She was born in Hartford, Connecticut, USA, and named Eleanor McClintock. Her mother Sara was high-spirited, resourceful, and inherited her grandfather’s love of adventure and independent-mindedness that drove him to captain his own ship at 19 years of age (Keller, 1983). Sara was an amateur painter and poet, as well as accomplished pianist. Her father, Reverend Benjamin Handy, being a righteous, stern man was very protective of his daughter and disapproved of all her suitors. He even called her future husband, Thomas Henry McClintock a foreigner because his parents were Celtic immigrants from the British Isles. However, Thomas was a determined young man who persisted until he married Sara just before graduating from Boston University Medical School in 1898.

Dr McClintock and his wife had four children quite close together: Marjorie (1898), Mignon (1900), Eleanor McClintock (1902) and Malcolm Rider (1903). When Eleanor was four months old, her strong fortitude and unique temperament led her parents to decide that the name Eleanor did not suit her character because it was too delicate and feminine. From then on they called her by her second name, McClintock, because it was more masculine.

McClintock recognised her ‘capacity to be alone’ originated when she was a baby: “My mother used to put a pillow on the floor and give me one toy and just leave me there. She said I didn’t cry, didn’t call for anything” (McClintock cited in Keller, 1983:20). Throughout her life, there was constant tension between McClintock and her mother, which led to the little girl growing up solitary and independently. In part this was due to Sara having to raise four small children on her own, while her husband concentrated on his fledgling medical practice. To make matters worse, Sara also taught piano in order to make ends meet. Consequently, as stress relief she periodically sent her daughter for lengthy stays to paternal relatives in Massachusetts. McClintock,
instead of resenting being sent away relished those times, “I enjoyed myself immensely and was absolutely not homesick” (McClintock cited in Keller, 1983:20).

When McClintock was six years old, her family moved to a semirural part of Brooklyn, New York. She recalls, “I remember getting up early in the morning and walking with the dog. I used to love to be alone, just walking along the beach”. Her favourite past time was sitting alone, just “thinking about things”. Right from childhood she had the capacity to be intensely absorbed. “I loved information. I loved to know things” (McClintock cited in Keller, 1983:26). She experienced an alternative form of connectedness, and her inner world was being developed. The influence her family background had on her characteristics is described below.

The portrait that emerges from McClintock’s recollections so far gives us only glimpses of the characteristics that would be so important in defining her as a scientist. As a child McClintock had a striking capacity for autonomy, self-determination, and total absorption. But what was truly exceptional was the extent to which she maintained her childlike capacity for absorption throughout her adult life. (Keller, 1983:36)

The capacity for absorption in the task at hand relates to my definition of spirituality because this characteristic of an individual facilitates connections to that which is being studied. McClintock was not distracted by gender concerns or materialism. In contrast to most girls, McClintock disregarded her appearance and talked about wanting to be free of her body, “I think it had to do with the body being a nuisance. What was going on, what I saw, what I was thinking about, and what I enjoyed seeing and hearing was so much more important” (McClintock cited in Keller, 1983:36). Fortunately, her mother valued self-determination, so McClintock was not pressured to conform to social expectations. Her parents knew she was different from her siblings, and so did she. At high school McClintock understood “that I just had to make these
adjustments to the fact that I was a girl doing the kinds of things that girls were not supposed to do. … I would take the consequences for the sake of an activity that I knew would give me great pleasure. Whatever the consequences, *I had to go in that direction*” (McClintock cited in Keller, 1983:28). This statement is an expression of her spiritual development on the personal plane, which is consistent with my definition of spirituality.

Despite her mother’s initial objections, McClintock was determined to go to college and study science. Cornell University was an ideal choice, because at that time it was one of only two universities that actively supported female students in science courses. She endured initial enrolment difficulties, due to a lack of paperwork, which was somehow overcome. McClintock remained positive and persevered until she was accepted into a zoology course in 1919. “I was doing now what I really wanted to do, and I never lost that joy all the way through college” (McClintock cited in Keller, 1983:31). McClintock’s connectedness to the sciences she studied is evident.

### 4.4 Becoming a scientist and interactions with colleagues

In contrast to her solitary childhood, first year at college was very social, with McClintock being elected president of the women’s freshman class. Her single-mindedness made her determined to remain independent, so she refused to conform to fashion in dress or hairstyle. Relations with men were short lived, because she had no need of intimacy and was content being single.

These attachments wouldn’t have lasted. I knew [with] any man I met, nothing could have lasted. I was just not adjusted, never had been, to being closely associated with anybody, even members of my family…. There was not that strong necessity for a personal attachment to anybody. I just didn’t feel like it. And I could never understand marriage. I really do not even now…. I never went through the experience of requiring it. (McClintock cited in Keller, 1983:34)
McClintock’s career came about while she was following her passion. She recalls, “I remember I was doing what I wanted to do, and there was absolutely no thought of a career. I was just having a marvellous time” (McClintock cited in Keller, 1983:34). With no thought of a career, or any professional aspirations, the subject matter was always foremost in her mind. “I was just so interested in what I was doing I could hardly wait to get up in the morning and get at it. One of my friends, a geneticist, said I was a child, because only children can’t wait to get up in the morning to get at what they want to do” (McClintock cited in Keller, 1983:70).

Howard Green from Harvard Medical School, described her as a “prototype non-careerist”. McClintock had interests in various vocations such as meteorology (all are part of the natural universe), and while working in Missouri she spent numerous hours at the local weather bureau (Green cited in Peterson, 2004:1). With no mentors or role models, she succeeded in becoming a professional research scientist who held a unique worldview.

Every scientist comes to his subject with a worldview that is uniquely his own – a worldview reflected in his relations to people as well as to his subject. Each brings a distinct set of interests – interests stamped by his or her own personality. (Keller, 1983:49-50)

On completion of her undergraduate degree McClintock remembers, “I knew I just had to go on”. She became a graduate student in the botany department, majoring in cytology with a minor in genetics and zoology, because women were not allowed to major in genetics at Cornell. Her thesis supervisor, cytology professor Lester Sharp, fully supported her endeavours in a way that suited her style of working. She said, “He just left me free to do anything I wanted to do, just completely free”. Green recalled McClintock’s motto about graduate students, “Let them sink or swim”. She did not believe in coddling them (Green cited in Peterson, 2004:1).
At that time, geneticists studied *Drosophila*, that reproduced rapidly, or *Maize*, whose lifecycle was much longer. Studies of the tiny fly, *Drosophila*, had identified individual chromosomes, but being so small their fine structure eluded scientists. McClintock chose to work with *Maize*, despite the time required for successive generations. Inheritance studies of *Maize* were very time consuming, and restricted to two per year. McClintock soon established herself as the foremost investigator in cytogenetics with the publication of a series of exceptional papers about her detailed cytogenetic analysis of *Maize*.

After gaining her PhD, McClintock continued at Cornell, integrating the two forms of genetic research by combining the breeders’ work with results of the scientists studying chromosomes. She also devised new staining techniques that enabled her to see more detail in *Maize* chromosomes than was possible in *Drosophila* chromosomes. Her superior findings generated friction between her and the geneticists who could not comprehend what she was trying to do. Thomas Kuhn (1962) recognised the issue she faced. In *The Structure of Scientific Revolutions* Kuhn’s argued that science progresses in periodic paradigm shifts rather than as a linear accumulation of knowledge. When a finding does not fit the prevailing paradigm, the scientific community views the incongruence as the mistake of the researcher rather than the paradigm being called into question. The lack of understanding of McClintock’s discoveries by the geneticists is consistent with Kuhn’s central argument that it is impossible to comprehend one paradigm through the conceptual framework of an opposing paradigm.

McClintock’s ground breaking cytological work enabled new questions, which she explored with Marcus Rhoades and George Beadle, two young graduate students who came to Cornell to work with leading *Maize* breeder, Professor Rollins Emerson. She recalls, “We were a group all of us highly motivated, and we used to have our own seminars from which we’d exclude the professor – just us and a few others.” (McClintock cited in Keller, 1983:48). McClintock
became highly influential in this small group that studied *Maize* cytogenetics, the genetic study of corn at the cellular level.

Many scientists misunderstood her work, and her impatience with the slowness of others meant that the situation deteriorated. These two factors resulted in McClintock experiencing communication problems with other geneticists. Fortunately, Rhoades, who recognised her genius, chose to mediate for her. In an interview he acknowledges McClintock as the real inspiration of their small collaborative group.

One thing that’s to my credit – that I recognized from the start that she was so good, that she was much better than I was, and I didn’t resent it at all. I gave her full credit for it. Because – hell – it was so damn obvious: she was something special (Rhoades cited in Keller, 1983:50)

On the other hand, Beadle was not personally close to McClintock. He respected and recognised her unique cytological expertise. Not surprisingly their relationship became strained and he was offended when McClintock interpreted his data before he did.

Another significant person in McClintock’s working life was Harriet Creighton who arrived at Cornell as a young graduate student. McClintock was welcoming, quick to take on a mentoring role, and unselfishly gave Harriet an important investigation to begin with. In 1931, they published a seminal paper on genetic crossing-over in *Maize* that provided evidence of the chromosomal basis of genetics.

McClintock was first and foremost a research scientist, and she struggled to obtain a position that did not involve teaching. She was happy with a laboratory and an opportunity to do her research. When at Cornell on a fellowship (primarily to work with Emerson), Lewis Stadler became McClintock’s close friend and colleague. Five years later, he invited her to the University of
Missouri to participate in his new research involving mutagenic effects of X rays. In 1936, with a Rockefeller Foundation grant, Stadler persuaded the University to take her on as assistant professor so they could be collaborative colleagues.

McCIntock stood up for her acceptance as an equal among equals, and demanded her right to be evaluated against the same standards as men. Unfortunately her colleagues perceived that this action arose from the “chip on her shoulder” attitude, and they reacted by not wanting to work with her. “Visible evidence of her difference was an essential part of her self-definition” (Keller, 1983:85), and she was committed to pursuing whatever gave her the most pleasure. Her free-speaking and forthright manner of speech also caused her colleagues some concern. She criticised scientists who could not achieve her high standards, including Stadler, an excellent theoretician, but no match as an experimentalist. Although he showed no resentment, others did. In 1940, the dean of Liberal Arts called her a “trouble-maker”.

She became disillusioned with university life and after five years she left Missouri because she did not fit the male stereotype and placed no importance on the university’s formal calendar. McCIntock said she would, “do things others didn’t do – I never thought anything about it” (McCIntock cited in Keller, 1983:83). “It meant that there was no hope for a maverick like me to ever be at a university” (McCIntock cited in Keller, 1983:86). McCIntock recognised her disconnectedness with colleagues and the university, but maintained connectedness in her passion for research.

Throughout her career McCIntock dealt with many scientific and personal challenges from scientists who felt threatened by her independence, originality, and extraordinary accomplishment. One such scientist was her advisor Lowell Randolph, who became irritated when McCIntock solved a problem he had
been struggling with his entire working life. When she became the dominant member of his research team he found the situation intolerable.

Despite the institutional difficulties, interpersonal conflicts, and lack of a professional niche, McClintock still had the enthusiastic support of her most respected colleagues. Her institutional and relational marginality, and professional dislocation, actually strengthened her intellectual and emotional commitment to her work, which by then had taken on a life of its own in the form of a spirituality of connectedness to the natural world. She said:

They thought I was crazy. …When you know you’re right, you don’t care what others think. You know sooner or later it will come out in the wash. (McClintock cited in Wallis, 1983:43-4)

4.5  McClintock’s way of working as a scientist

As a mature scientist, her individual style (partly learned, partly self-generated) was highly idiosyncratic. Her method was to look for difference, rather than similarities, which is an alternative form of connectedness.

Her passion is for the individual, for difference. “The important things is to develop the capacity to see one kernel that is different, and make that understandable,” she has said. “If [something doesn’t fit, there’s a reason, and you find out what it is.” McClintock believes that the current focus on classes and numbers encourages researchers to overlook difference, “To call it an exception, an aberration, a contaminant.” She sees the consequences as very costly, as it is easy for them to miss “what is going on”. (Keller, 1983:xiii)

“She possessed a special talent to recognize the underlying order and provide an explanation for the most perplexing observations” (Nelson cited in Peterson, 2004:2). Rhoades remembered and commented: “I’ve often marvelled that you can look at a cell under the microscope and can see so much!” She said, “Well, you know, when I look at a cell, I get down in that cell and look around” (Keller, 1983:69).
Her amazing capacity to process and interpret her observations meant that it became difficult to delegate any part of her work. McClintock’s highly developed ability to observe and experiment “has drawn as much from herself as from her milieu. The role of vision in her experimental work provides the key to her understanding” (Keller, 1983:xiii). Her trained, direct perception resulted in a unique blend of observational and cognitive skills. Importantly she recognised the limits of oral explanation and came to rely on her “feeling for the organism”. “She insists on the utmost critical rigor, and, like all good scientists, her understanding emerges from a thorough absorption in, even identification with, her material” (Keller, 1983:xiv). There was a spirituality of connectedness in her way of working.

It was her conviction that the closer her focus, the greater her attention to detail, to the unique characteristics of a single plant, of a single kernel, of a single chromosome, the more she could learn about the general principles by which the maize plant as a whole was organized, the better her “feeling for the organism”. (Keller, 1983:101)

McClintock sought intimate and total knowledge about each and every maize plant. She believed that the larger whole could be understood by focusing on the smallest of details. She also saw the problem clearly. “The problem is not something that’s ordinary, but it fits into the whole picture, and you begin to look at it as a whole…. It isn’t just a stage of this or that. It’s what goes on in the whole cycle. So you get a feeling for the whole situation of which this is [only] a component part” (McClintock cited in Keller, 1983:67).

Keller wanted to know what enabled McClintock to see sharper, further and deeper into the mysteries of genetics than her colleagues. “Over and over again she tells us one must have the time to look, the patience to ‘hear what the material has to say to you,’ the openness to ‘let it come to you’ ”(Keller, 1983:198). McClintock could deal with broken chromosomes, and recognise them as an issue, but this was not the case with broken relationships.
McClintock wondered how plant cells sense the presence of broken chromosomes and activate the appropriate repair mechanisms, and she marvelled at the ‘smart cells’ that underwent specific migrations in animal embryogenesis. McClintock was known to ask seminar speakers, “How does it all fit together?” She considered reductionism as an approach, not an answer. The secret of McClintock’s success in the face of incomprehension and prejudice was her fearless and complete intellectual freedom - to admit, “I don’t know,” and then to wrestle the answer from the data. (Shapiro, cited in Peterson, 2004:2)

McClintock did not objectify her subject, nor did she take the textbook approach and analyse it into bits of data. Instead, she approached the genetic material assuming it could best be understood as a communal phenomenon. McClintock “made a crucial discovery by recognising that the genetics of living organisms is more complex and interdependent than anyone had believed. By observing how genes function in their environment rather than regarding them merely as isolated entities, she discovered that bits of genes can move about on chromosomes” (Rosser, 1992:46). McClintock recognised the importance of connectedness issues in the area of cellular information processing.

With the tools and the knowledge, I could turn a developing snail’s egg into an elephant. It is not so much a matter of chemicals because snails and elephants do not differ that much; it is a matter of timing the action of genes” (McClintock cited in Wallace, 1992:176)

4.6 Spirituality as connectedness was integral to her scientific discoveries

McClintock was a geneticist whose way of working included a spiritual dimension. “Although McClintock had the reputation of a mystic, she always drew her conclusions from her observations—this is what she meant when she admonished us to ‘listen to the plant’ ” (Sundaresan cited in Peterson, 2004:2). McClintock advocated that the scientist needed to ‘connect’ with the material being investigated.
When Keller interviewed McClintock for the biography, it became clear that the communal premise of her work went well beyond the relationship among genes: it included the relationship between the genes and the scientist who studied them. Keller says that McClintock’s knowing came from “the highest form of love, love that allows for intimacy without the annihilation of difference” (Keller cited in Palmer, 1998:55).

Knowing that there are limits to rational explanations, McClintock trusted and valued the process of creative insight. Therefore she cultivated insight and respected its mysterious workings. Below she describes how her understanding seemed to bypass any conscious awareness.

When you suddenly see the problem, something happens that you have the answer – before you are able to put it into words. It is all done subconsciously. This has happened too many times to me, and I know when to take it seriously. I’m so absolutely sure. I don’t talk about it; I don’t have to tell anybody about it, I’m just sure this is it. (McClintock cited in Keller, 1983:103)

By incorporating a different form of connectedness, of integration, in her scientific work McClintock was able to make some major discoveries. For example, when she returned to her microscope after a time of meditation and contemplation, her changed level of consciousness enabled her to see things differently and she then discovered the *Neurospora* chromosomes.

McClintock was frustrated by her inability to see the transposition of genes under the microscope. She retreated to sit under a eucalyptus tree and meditate. …When she felt she was ready, she returned to the microscope, and the chromosomes were now to be seen. (Lebacqz, 1997:24)

McClintock felt that what happened under the eucalyptus tree was crucial to her observations of the meiotic cycle of *Neurospora*. A change had occurred whereby she became re-oriented, and this new orientation enabled her to
immediately integrate what she saw looking down the microscope. With a mindset that “everything is going to be all right”, instead of disorder, she could identify the chromosomes easily. “I found that the more I worked with them the bigger and bigger [they] got, and when I was really working with them I wasn’t outside, I was right down there and these were my friends” (McClintock cited in Keller, 1983:117). Here we see her connectedness with nature. She then said: “As you look at these things, they become part of you. And you forget yourself. The main thing about it is you forget yourself. I’m not there! The self-conscious “I” simply disappears” (McClintock cited in Keller, 1983:117-118).

This experience with the Neurospora chromosomes was consistent with the feelings of total absorption she knew as a child. Now as an adult, she was using this capacity to make her scientific discoveries.

After this experience “she returned to Cold Spring Harbor ready to embark on the work that would lead to the major discovery of her career” (Keller, 1983:118). McClintock continued to treat the organisms she studied as subjects rather than objects, which is an alternative form of relationship – spirituality. She loved her maize plants and spoke of them as her friends. Her attentiveness to these plants facilitated the idea that they responded to their environment by changing their genes, and led her to propose a ‘jumping genes’ theory.

McClintock was a scientist who in addition to valuing science, also valued different ways of knowing. Her attitude to nature, and to what is to be known, reflects a different image of science from a purely rational endeavour. McClintock’s ‘contemplative frame of mind’ became an asset to her scientific work. “Scientists observe closely and mindfully and, by contemplation, allow their minds to make original connections” (Erricker, 2001:89). But data and logic form only one pole of the paradox of great science. When McClintock, arguably the greatest biologist of our century, is asked to name the heart of her knowing, she invariably uses the language of relationship, of connectedness, of community. McClintock “gained valuable knowledge by empathizing with her
corn plants, submerging herself in their world and dissolving the boundary between object and observer” (Rosser, 1992:46). McClintock’s way of doing science was distinguished by precise analytical thinking, impeccable data collection and an alternative connectedness.

4.7 Peer reactions to McClintock’s discoveries in genetics

McClintock’s initial groundbreaking work in maize cytogenetics earned her a place among the leaders in genetics. She was elected to the prestigious National Academy of Sciences in 1944, and the next year became the first woman President of the Genetics Society of America. Despite such recognition, her classic paper detailing the function of the nucleolar organizer region (NOR) was in the main not registered by the biological community. “I find that it was only a relatively few people who got the point of the organization – of why I called it an organizer” (McClintock cited in Keller, 1983:69).

McClintock described herself as a ‘maverick’ and valued her privacy. She deliberately chose a reclusive lifestyle that assured her autonomy and independence. However, living as a recluse helped to position her on the peripheral of the science community in which she worked (Keller, 1983). McClintock was living in *an alternative relational world*.

In 1944, Evelyn Witkin came to Cold Spring Harbor as a student geneticist. For a decade McClintock shared her intuitions and discoveries with Evelyn. McClintock recalls, “She was the only one who really had any understanding of what I was doing” (McClintock cited in Keller, 1983:137). Unlike others in the scientific community, Witkin understood because she had looked over McClintock’s shoulder and shared in her vision.

As McClintock’s discoveries became more complex, the scientific community lost interest in her papers. She remembers a geneticist visiting Cold Spring Harbor saying, “Now, I don’t want to hear a thing about what you’re doing. It
may be interesting, but I understand it is kind of mad” (cited in Keller, 1983:140). The scientific community described her as “incomprehensible”, “mystical” and “mad” but she said, “it didn’t bother me at all” (McClintock, cited in Keller, 1983:142).

McClintock was ineffective at getting her new findings accepted by the scientific community for several reasons. Firstly, the findings had revolutionary implications. Secondly, the particular nature of her knowledge and understanding was complex, and thirdly, they were generated from a very different spiritual world. Her way of knowing was by seeing (compare with Dillard, 1985), which was central to her scientific endeavours. This reciprocity between cognitive and visual was well developed for McClintock who had continuity between mind and eye. Through “integrating what you saw” (McClintock cited in Keller, 1983:151) she built a theoretical vision of the ordered world within the cell. Thirdly, she was isolated, having worked alone for the past six years, and the problem was one of communication. She spoke an alternative language, because she was not in dialogue with colleagues.

The results “she reported in 1951 were totally at variance with the view of genetics that predominated” (Keller, 1983:144). In the 1950s a common vision was elusive because geneticists were following a different path, molecular biology, with the emphasis being on simple models. In 1953 Watson and Crick proposed the DNA double helix, with its precise sequences of bases, as the code for genetic information. McClintock did not agree with models and was critical of the dogma at the time. She argued, “Trying to make everything fit into set dogma won’t work… So if the material tells you, ‘It may be this,’ allow that. Don’t turn it aside and call it an exception, an aberration, a contamination…. If you’d only just let the material tell you” (McClintock cited in Keller, 1983:179). This view is very important and consistent with Kuhn’s (1970) ideas of revolutionary science.
In 1960, after failing to communicate her findings at yet another seminar, she withdrew and retreated further, still determined to carry out her research on transposition. In 1965, after a fourth attempt to describe her findings, with little effect, she said, “I knew I was right” (McClintock cited in Keller, 1983:182).

Though her research was often dismissed as wildly unorthodox, she pursued it, making discoveries that changed the map of modern genetics. “Her reports on transposable genetic elements were not readily accepted by her scientific peers until her genetic insights were verified by molecular biologists in the 1970s” (Peterson, 2004). Nearly thirty years passed before she received several major awards, which included the National Medal of Science (1970), the Lasker Prize, and the first MacArthur Foundation grant (1981), and culminated in 1983 with the individual Nobel Prize in Physiology or Medicine, for her work on ‘mobile genetic elements’, or genetic transposition, the ability of genes to change position on the chromosome. By then she was 81 years old having “lived most of her life alone – physically, emotionally and intellectually” (Keller, 1983:17). After receiving these prestigious awards she merely tolerated the inevitable publicity that impacted on her solitary lifestyle. She remained affiliated with the Cold Spring Harbor Laboratory, New York, until her death at Huntington Hospital, on September 2, 1992, at the age of 90.

As a scientist who worked by linking the two different ways of knowing, science and spirituality, McClintock is a role model for students who read about her life.

### 4.8 Brief Chronology and Summary

- 1902 - Born Eleanor McClintock in Hartford Connecticut on June 16
- 1908 - McClintock family moves to Brooklyn, New York
- 1919 - Graduates from Erasmus Hall High School, Brooklyn
- 1919-25 - Earns undergraduate (1923) and graduate (1925) degrees in botany, Cornell University
• 1927 - Receives PhD (botany), Cornell University
• 1927-31 - Instructor and researcher in maize genetics, Cornell University
• 1931 - Publishes (with H. Creighton) article on genetic crossing-over in maize
• 1931 - Fellow, National Research Council; conducts research at Cornell, University of Missouri at Columbia, and California Institute of Technology
• 1933-34 - Fellow, Guggenheim Memorial Foundation; conducts research at Kaiser Wilhelm Institute, Berlin, and Botanical Institute, Freiburg (Germany)
• 1934-36 - Researcher, Cornell University
• 1936-1940 - Assistant Professor of Genetics, University of Missouri at Columbia
• 1944 - Elected to the National Academy of Sciences
• 1945 - Elected President, Genetics Society of America
• 1951 - Gives controversial lecture at Cold Spring Harbor Symposium on her theories of “controlling elements” in maize
• 1957-66 - Embarks on series of research trips to South America to study different races of maize
• 1967 - Distinguished Service Award, Carnegie Institution of Washington; stays on as Distinguished Service Member until 1992
• 1971 - Receives National Medal of Science from President Richard M. Nixon
• 1981 - Inaugural recipient, MacArthur Foundation Grant (lifetime award)
• 1981 - Recipient, Albert and Mary Lasker Award
• 1983 - Receives Nobel Prize in Physiology or Medicine
• 1992 - Dies in Huntington, New York (September 2, 1992)

(http://profiles.nim.nih.gov/LL/Views/Exhibit/narrative/biographical.html#chronology accessed 20/12/04 p. 2)
In this chapter I generated a narrative of McClintock by looking firstly through the personal lens to identify the influences in the early years that shaped her personality. Secondly, the interpersonal lens enabled me to focus on important peer relationships in various institutions where she carried out her scientific endeavours. Thirdly, the community lens led me to examine the reactions of the scientific community at that time to McClintock’s scientific discoveries and radical theories.

In the next and final chapter of this thesis I offer a new a vision for science education, one that encourages a curriculum that has as central, narratives of non-stereotypical scientists, such as McClintock. Narratives of the stories associated with these scientists can introduce students to positive role models that in turn foster an appreciation of science as being multi-dimensional and not just an objective process. McClintock had a spiritual dimension to her work as a scientist that enabled her to connect with the organisms in her experiments and treat them as friends rather than objects. This form of spirituality involved contemplation as well as action and valued the individual and communal.
CHAPTER 5   A NEW VISION: SCIENCE EDUCATION INCLUSIVE OF SPIRITUALITY

5.1 Introducing the problem

Living in a technologically developed country, most Australians embrace the latest technological products, such as mobile phones, iPods and computers. However, during recent years, university enrolments in science and engineering courses have continued to decline, with young Australians choosing to steer away from careers in science. In the country’s interest, such a downward trend is an important issue that must be addressed. The growing shortage of science and engineering graduates is symptomatic of the underlying problem of student disconnectedness to the science they are expected to learn in their compulsory years of schooling. The disconnectedness occurs because the ‘nature of science’ taught has little relevance for students.

In this thesis I have argued that any attempt to address the problem identified above must take into account the media’s influence on students’ perceptions of scientists in addition to the ‘nature of science’ being promoted in classrooms. The stereotypical representations of scientists in science fiction films were described in Section 1.3 and students’ perceptions of scientists were discussed in Section 2.2. The media persist in portraying scientists as stereotypical images that young people have difficulty relating to. The characteristics of these images are frequently revealed in children’s drawings as a male scientist with facial hair (beard, moustache, very long sideburns) wearing glasses and a white lab coat. He works alone in a laboratory surrounded by bubbling solutions, scientific instruments, books and filing cabinets. Technological products and captions (such as formulae and eureka) also can be seen in children’s drawings. Refer to section 2.3 where my recent study of children’s drawings of scientists is reported.
5.2 Theoretical framework, research approach and research questions

This thesis was framed from a socio-cultural-historical perspective, where development is understood as a cultural process. This process occurs in community, and individuals learn through participation in cultural activities that are mediated by cultural tools. As science is an activity defined by community, I used Rogoff’s (1995) three foci of analysis - personal, interpersonal and community - to examine the issues surrounding children’s experience of science at school. This tool enabled me to consider the interpersonal relationships associated with the activity of doing science. While I brought one of these foci to the forefront, I kept the other two in the background, so that they were still part of the analysis.

From a socio-cultural-historical perspective, I identified the meaning of spirituality in this thesis as “an individual (personal) desire for connectedness with others (interpersonal) and with a transcendental dimension greater than ourselves. There is a transpersonal aspect of spirituality, that affects society (community), which may or may not, be associated with organized religion” (Jane, 2007b).

I examined the problem of student disconnectedness to science using a shared praxis research approach and Groome’s (1980) five movements: present action, critical reflection, dialogue, story and the vision arising from the story that leads to new action to bring about transformation. This approach enabled me to address the following research questions.

1. Does spirituality have a role in science education, one that might challenge students’ stereotypical views of scientists and science?
2. How can spirituality and science be linked in the education process?
3. What might be the benefits of science education that includes spirituality?
4. What is the transforming potential of such an integrative science education?
5.3 Critical reflection on present action in science education

My critique of current research and practices in science education in Chapter 3 enabled me to offer reasons for why most students choose not to select science subjects in their senior school years. This student avoidance of science as a career is precipitated by two main factors. First the ‘nature of science’ promoted in curricula is limited, locked in, and foreclosed of possibilities (as was the scientific community at the time of McClintock) making secondary school science seem remote to most students. Second, the media promote stereotypical representations of scientists showing them in a negative light, as being mad, bad and out of touch with the real world. In particular, the stereotypical portrayals of scientists that persist in popular science fiction films tend to not only distort young people’s perceptions of scientists, but also misrepresent the way they work.

Research Question 1. Does spirituality have a role in science education, one that might challenge students’ stereotypical views of scientists and science?

The answer to this question is in the affirmative. The mismatch between student willingness to embrace the latest products of science and technology and their disinterest in school science, occurs because an essential ingredient, namely spirituality, is missing from science education. When spirituality is purposefully blended into the science curriculum, students better understand how scientists work, which in turn challenges the stereotypical images of scientists that are frequently seen in science fiction films. In Chapter 1 the types of stereotypical images of scientists depicted in sci-fi films were described as modifications of the ones Haynes (1994) identified in Western literature. These were alchemist, stupid virtuoso, heroic adventurer, helpless scientist and idealist. McDuffie Jr. (2001) identified ways to dispel these stereotypes of scientists.

5.3 Pedagogical strategies to challenge distorted images of scientists

Several pedagogical strategies have been recommended to counter these stereotypical images of scientists. These strategies provide opportunities for
students to meet practising research scientists and learn about their work, and to reflect on the nature and benefits of science. To foster positive and more realistic images of scientists and their work teachers can organise:

- Incursions with scientists who are good communicators as role models;
- Hands-on and meditative activities; and
- Research projects with students interviewing scientists and reflecting on narratives of scientists’ biographies.

5.3.1 Strategy: Incursions with scientists as role models
The ‘incursion strategy’ was tried out in a project designed to demonstrate to children the diversity of scientists, that they “are not always ‘nerdy males’ wearing white lab coats” (Buck, Leslie-Pelecky & Kirby, 2002:7). Female scientists in primary classrooms did little to shift the children’s stereotypical views of disconnectedness. The children perceived the visiting scientists as teachers. Further research is needed to determine the effect this strategy may have on students’ perceptions of scientists and relational worlds.

5.3.2 Strategy: Hands-on and meditative activities
As described in Chapter 1, in our recent study with primary pre-service teachers, we found that hands-on activities in small groups help children connect their prior knowledge to the new topic teachers (Jane & Gipps, 2006). These investigations were designed to build on the children’s interests and maximise motivation. The pre-service teachers listened attentively to the children’s ideas and explanations for their observations. Participation in these practical investigations influenced the children’s perceptions of science and how scientists work. By the end of the program some children began to see themselves as mini-scientists engaged in scientific processes, and felt a sense of connectedness to the scientific enterprise.
While there is considerable evidence to show the effectiveness of hands-on science investigations, other types of activity - of a meditative nature - can facilitate an alternative form of connectedness. Meditative activities in science lessons enable students to move easily from cognitive learning to the meditative activity and back again. When meditative skills are included in school science students’ process skills of observation can be maximised. Simple activities such as pond dipping, and learning about muscles in the human body, can be enhanced by brief periods of meditation. For example, during a visit to a pond, students can use nets or buckets to take samples from various depths (the surface, part way down in the water, and from the bottom of the pond), and place them in a white plastic tray. Before observing the water samples, students are encouraged to take some time to relax and become centred. The right frame of mind allows many tiny organisms to be seen moving about in the water. A magnifying glass or stereomicroscope can be used to closely examine the complexity and diversity of freshwater pond organisms. Drawings can be made, showing the differences and similarities between the various organisms. This kind of activity is similar to Annie Dillard’s (1985) writing of her experiences of nature. The meditative activity of pond dipping fosters connectedness to nature, whereas walking meditation fosters connectedness to our bodies. Meditation in motion, that encourages students to focus on one muscle at a time as they walk, can raise awareness of the muscles in the human body. Students can visualise and then draw these muscles, beginning with the leg and foot, and also write down any questions that come to mind.

The strategy of including meditative activity that fosters connectedness is one answer to Research Question 2. How can spirituality and science be linked in the education process?

Another strategy for linking science and spirituality in the curriculum is to provide students with opportunities to reflect on narratives of scientists whose scientific endeavours encompass a subjective way by being as described below.
5.3.3 Strategy: Reflections on narratives of scientists

While the literature recommends introducing students to biographies of scientists, specific examples of non-stereotypical scientists are rarely included. Consequently in this thesis I have addressed the gap in the literature by focusing on the story of the life and scientific endeavours of McClintock. The narrative by Evelyn Fox Keller (*A Feeling for the Organism*, 1983) of this non-stereotypical scientist offers a different perspective on how a scientist works. McClintock was awarded a Nobel Prize for her discoveries in genetics. She was a scientist who had a ‘feeling for the organisms’ she studied, treating them as if they were her friends.

No two plants are exactly alike. They’re all different, and as a consequence, you have to know that difference…. I start with the seedling, and I don’t want to leave it. I don’t feel I really know the story if I don’t watch the plant all the way along. So I know every plant in the field. I know them intimately, and I find it a great pleasure to know them. (McClintock cited in Keller, 1983:198)

McClintock had a deep emotional investment in her scientific work, and developed a sympathetic understanding for plants. “Every time I walk on grass I feel sorry because I know the grass is screaming at me” (McClintock cited in Keller, 1983:200). She explains further:

Animals can walk around, but plants have to stay still to do the same things, with ingenious mechanisms…. Plants are extraordinary. For instance, …if you pinch a leaf of a plant you set off electric pulses. You can’t touch a plant without setting off an electric pulse…. There is no question that plants have [all] kinds of sensitivities. They do a lot of responding to their environment. They can do almost anything you can think of. But just because they sit there, anybody walking down the road considers them just a plastic area to look at, [as if] they’re not really alive. (McClintock cited in Keller, 1983:199-200)

When students can reflect on biographies of scientists who value subjectivity, and treat their objects of study as subjects, their stereotypical views of scientists
are challenged. In particular, Keller’s (1983) narrative of the life and work of McClintock and Dillard’s (1998) contribution *Pilgrim at Tinker Creek* both encourage students to take a new perspective and view scientists and science differently.

5.4 McClintock’s connectedness to the world of nature

As a naturalist, McClintock’s confidence in the underlying order of nature fuelled a spirituality of connectedness that manifested in her way of working. While she valued reason and experiment, she also knew that these are insufficient for a scientist to articulate the laws of nature. For her, a strong feeling for the oneness of nature, unity of experience, and mystery underlying the laws of nature, are essential in the process of scientific discovery. She deliberately sought alternative ways to connect with the plants she was investigating.

Her interest in alternative approaches, such as the Tibetan Buddhists’ way of learning, led her to see the limitations of the scientific method. “I was so startled by their method of training and by its results that I figured we were limiting ourselves by using what we call the scientific method” (McClintock, cited in Keller, 1983:202). She acknowledged openly and proudly, that in her work as a scientist she drew on these other, mystical ways of knowing.

Throughout her life, the natural world continually provided intellectual and emotional energy, and a relational world that was consistent. As a child, her relationship with nature substituted for a lack of intimacy in her personal relationships, particularly with her mother, and this continued to be the case throughout adulthood. Her creativity stemmed from her spiritual connection with the organisms she studied.

From reading the text of nature, McClintock reaps the kind of understanding and fulfilment that others acquire from personal
intimacy. In short, her “feeling for the organism” is the mainspring of her creativity. It both promotes and is promoted by her access to the profound connectivity of all biological forms – of the cell, of the organism, of the ecosystem. (Keller, 1983:205)

McClintock’s way of working scientifically is an excellent example of contemplation-in-action by a scientist. Unlike the fast moving molecular scientists, she took advantage of working with the slow growing maize that allowed time for contemplation, which in turn became a catalyst for her scientific discoveries. A period of contemplation, or being present, was a key element in the way she worked as a scientist.

Even though at that time, many colleagues misunderstood her approach, she continued her work, albeit in isolation, outside the scientific community. McClintock thrived working this way because she was not pre-occupied with herself, but instead gave full attention to her maize plants. Her unique way of working involved being fully absorbed in the material, and a coming to know through seeing, and being “one with nature”.

Many authors have recognised that observations of nature can evoke a sense of spirituality. The theme of Dillard’s book was “the uncommon spiritual possibilities afforded by the commonplace in nature” in which she explored “the wonder of life manifest in the simple and routine processes of nature – in the creek behind her house. For her the observation of mundane elements, routine growth, and daily decay offers opportunities for discovering beauty, simplicity and harmony” (Price, 1996:431). McClintock’s intimate interaction with and observation of nature, gave her the energy to do her scientific work. Being a naturalist, she patiently immersed herself in the variety and complexity of organisms, rather than seeking answers to leading questions that can put pressure on nature.
McClintock’s “spirituality of connectedness to the world of nature”, led her to argue for reincorporating the naturalist’s approach into science research. She predicted an impending paradigm shift that: “will reorganize the way we look at things, the way we do research… I think it’s going to be marvellous, simply marvellous. We’re going to have a completely new realization of the relationship of things to each other” (McClintock cited in Keller, 983:207). In this new paradigm, science is viewed as a human endeavour involving contemplation and intuition, as well as logical processes.

5.5 Vision of science education inclusive of spirituality

The narrative of McClintock shows that scientific discoveries can occur when a scientist develops a frame of mind that allows space for new thoughts, and a stepping back to see the bigger picture. “Scientists observe closely and mindfully and, by contemplation, allow their minds to make original connections” (Erricker, 2001:89). For her contemplation was integral to her work as a scientist, yet currently the spiritual dimension is absent from science education. Through the process of reflection on the narrative of scientist McClintock and a critique of current practice, a new vision has emerged for science education, one that will enable students to begin to appropriate such a scientist’s way of working. This vision that involves students in new ways of connecting and participating, necessitates a paradigm shift, one that takes into account the relational world of nature.

Research Question 3. What might be the benefits of a science education that includes spirituality?

Spirituality, understood as connectedness, particularly to nature, has an important role in science education one that can help secondary students make vital connections that will assist their learning. Implementing the proposed vision - science education inclusive of spirituality - would engage students in hands-on and meditative activities, both in the classroom and in the natural world. Students would benefit from working in small groups and engaging in
shared dialogue as they reflect on narratives of scientists such as McClintock. The students’ communication skills would develop when situated in safe and supportive learning environments.

From a socio-cultural-historical perspective, in terms of Rogoff’s (1995) three planes of participation; on the individual plane, this vision for a science education inclusive of spirituality would encourage each student to be attentive and take notice of his/her experiences and surroundings. On the interpersonal plane, it would foster thoughtful peer and teacher co-operation. On the community plane, such an approach would give students opportunities to feel a connectedness to nature, a desire to treat all living things as subjects, and develop an understanding of nature in relational terms.

5.6 Potential of the vision for transformation

Research Question 4. What is the transforming potential of such an integrative science education?

Groome’s (1980) fifth movement – vision - is essential if students are to regard science as a way of knowing and being in the world. Science education can be transforming for students when it is integrative of spirituality because it invites them to a lived response and to action, rather than focusing on theory. When a science curriculum is inclusive of spirituality it has the potential to offer students choice, and to give them opportunities to participate in decision-making within the boundaries set by the learning environment. Science educators have a responsibility to provide an environment of openness that will allow students to risk take during the decision-making process. An effective science educator is one that is able to implement the vision by leading students to new places beyond his or her own position. While various teaching strategies could be used during implementation of the vision, it is important that the pedagogical methods involve creativity and imagination.
5.7 Conclusion and recommendation

It was the decline in science graduate numbers that led me to question the current science curriculum in Victorian schools. An exploration of this problem has enabled me to offer a new vision for science education, one that is inclusive of spirituality. A narrative of geneticist Barbara McClintock showed that her way of working centred on the connectedness she felt with nature, which enabled her to interpret observations in a unique way. There was a contemplative dimension to her scientific endeavours that facilitated her highly developed scientific skills.

I recommend that students in the middle years of schooling be given opportunities to engage with a range of narratives about scientists. By including McClintock’s biography, students will be introduced to an alternative view of a scientist, one that is different from the male stereotype so often depicted in science fiction films. McClintock’s connectedness with nature led to her bold explorations and complex discoveries in the field of genetics. However, the scientific community’s lack of recognition of her discoveries and theories was a disservice to humanity. Students can be challenged to imagine how society might have benefited if such recognition was given much earlier. When students reflect on how this female, contemplative scientist made her scientific discoveries that led to groundbreaking theories, they appreciate alternative ways of engaging with the material they encounter in the science classroom.

Studies of individuals, their passions and career milestones are relevant today as science and technology are advancing at an alarming rate. The scientific community is facing a crisis in numbers entering the profession, and change is occurring with greater frequency in our lives. We can learn a great deal by reflecting on the past and looking at individuals who made a difference in their particular sphere. Future research could generate a series of narratives of scientists that demonstrate alternative ways of working scientifically that include contemplation. When students discuss these narratives in small groups
they become more interested in science and see themselves as fledgling scientists. This pedagogical strategy can be transforming for students who would experience an alternative science education, one that makes them more likely to choose pathways that lead to science careers.

In conclusion, this new vision for science education that includes spirituality and contemplation has the potential to lead students to action resulting in personal transformation. When science educators begin to consider the inner life of students by fostering a spiritual dimension in the curriculum, students will be moved to use their imagination and creativity as well as developing their scientific skills. Contemplation and action in the science classroom can be transformative for young people who will shape society in the future.
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