Exploring the implication of science communication practices on a model for teacher professional development:
Serving up the Pierian Waters

Pettikirige Sean Francis Perera

A thesis submitted for the degree of Doctor of Philosophy of
The Australian National University

April 2009

Centre for the Public Awareness of Science
The Australian National University
Declaration

I certify that this thesis does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any university; and that to the best of my knowledge and belief it does not contain any material previously published or written by another person except where due reference is made in the text. The empirical work within was not carried out with any other person.

Sean Perera
Acknowledgement

The journey towards this final product has not been a solitary one. It has been made possible by the support and generosity of many, a few of whom I mention here.

First, I thank my supervisor Professor Sue Stocklmayer. Neither her guidance along this highway of intellectual pursuit nor the support she has generously extended to overcome numerous detours along life’s byways can be extolled sufficiently in the space I’m permitted here. One could only be fortunate to have such a guiding beacon.

At the Centre for the Public Awareness of Science, I thank Professor Chris Bryant, Professor Mike Gore, and Professor John Rayner for their academic support and guidance. I also thank the staff members and fellow PhD students at the Centre for their friendship and numerous support during my candidature.

I acknowledge the generosity of the Dean of the College of Science (ANU), the Centre for the Public Awareness of Science, Mr Charles Gunasekera and my parents for the financial support to fund this research degree.

I thank the organizers and facilitators of the CPAS workshops for science teachers, which formed the core of this study. I thank the science teachers from Australia, Sri Lanka and Indonesia who generously offered their time for interviews. I thank Dr Yovina Sontani for translating the interviews with the Indonesian teachers. I acknowledge the groundwork by the National Science Foundation in Sri Lanka during the CPAS workshop there.

At the ANU, I wish to thank the International Education Office, the College of Science Marketing and Outreach Division, University House, the Research Student Development Centre, and Mrs Diane Hutchens at the Postgraduate and Research Students’ Association.

Next, I thank my family and loved-ones, for keeping in touch over the miles, for worrying about me and for all their well-wishes, prayers and love, which have not been contained to the last few years alone. I specially mention my Grandmother who understood the importance of this thesis and excused me from her 90th birthday celebrations this year.

No journey is complete without a companion. I’ve been very fortunate to have Dulamanie who has put up with my frustrations and shared the many tribulations along this journey. I thank you for cooking, looking after me, editing my drafts and making me sit down and write when I just wanted to run away from it all.

To all the many eyes, ears, lips, hands and feet which embodied the universal forces during my this journey, I dedicate this thesis.
Abstract

Science communication, over the last two decades, has shifted its onus from public understanding to public engagement. These efforts have been paralleled in science education, which strives to promote continued student engagement with science. Persistence with more traditional forms of pedagogy by teachers in middle school is a chief deterrent to this endeavour. Since many teachers’ inadequate understanding about science is regarded as inhibiting their use of inquiry-based pedagogy, professional development based on constructivist principles has been identified to remedy this problem. This study investigates the constructivist basis for a model of short-term professional development, which has not been addressed in the literature. The one-day workshops offered to middle school science teachers in Australia and overseas by the Centre for the Public Awareness of Science (ANU, Canberra) are investigated here. While the workshops did facilitate conceptual change in the teachers, it was found that the constructivist principles which were incorporated into the workshops’ design and delivery were underpinned by science communication practices. The conclusions presented include: the possibility of a constructivist framework for short-term professional development; the need for greater involvement of science communication in science education reform; and the unique challenges which confront science teachers from non-Western cultures.
# Table of contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Chapter 1: Introduction</td>
<td>2</td>
</tr>
<tr>
<td>Background</td>
<td>15</td>
</tr>
<tr>
<td>Chapter 2: Communicating science</td>
<td>16</td>
</tr>
<tr>
<td>Chapter 3: Science in middle school</td>
<td>40</td>
</tr>
<tr>
<td>Chapter 4: Science teacher education</td>
<td>100</td>
</tr>
<tr>
<td>Research methods</td>
<td>150</td>
</tr>
<tr>
<td>Chapter 5: Research methods</td>
<td>151</td>
</tr>
<tr>
<td>Results and discussion</td>
<td>182</td>
</tr>
<tr>
<td>Chapter 6: Observations</td>
<td>183</td>
</tr>
<tr>
<td>Chapter 7: Interviews</td>
<td>244</td>
</tr>
<tr>
<td>Conclusions</td>
<td>311</td>
</tr>
<tr>
<td>Chapter 8: Conclusions</td>
<td>312</td>
</tr>
<tr>
<td>References</td>
<td>330</td>
</tr>
<tr>
<td>Appendices</td>
<td>357</td>
</tr>
</tbody>
</table>
List of tables

Table 1: Purposes of science in the compulsory years 43
Table 2: Teacher perceptions of student attitudes to science 46
Table 3: Teaching for scientific literacy 57
Table 4: Perceived relevance of science in the secondary school 74
Table 5: Factors limiting the quality of secondary science teaching 109
Table 6: Disciplinary backgrounds of the middle school science teachers 122
Table 7: Flanders interaction analysis system 166
Table 8: List of observational variables 167
Table 9: Questions used in the interviews with teachers 173
Table 10: A typical one-day CPAS workshop program 184
Table 11: A sample set of activities in a typical one-day CPAS workshop 186
Table 12: Numbers of teacher-participants in CPAS workshops in Australia 187
Table 13: Frequencies of Category 1 communications 189
Table 14: Frequencies of Category 2 communications 192
Table 15: Frequencies of Category 3 communications 200
Table 16: Frequencies of Category 4 communications 207
Table 17: Frequencies of Category 5 communications 221
Table 18: Frequencies of Category 6 communications 222
Table 19: Frequencies of communications in each category 320
Table 20: Three Stages of constructivist learning as exemplified by the CPAS workshop model 321
Table 21: Science communication practices as exemplified in the CPAS workshop model 324
List of figures

Figure 1: Representation of the mountain-climbing analogy 28
Figure 2: A model for the Personal Awareness of Science and Technology 30
Figure 3: Grid illustrating the role of communication in constructivist classrooms 34
Figure 4: Model for science and technology as components of culture 36
Figure 5: Flowchart outlining the underlying argument of the present study 153
Figure 6: Webpage advertising CPAS workshops 154
Figure 7: Different perspectives of the overarching research question as viewed by the three supplementary research questions 160
Figure 8: Flowchart showing the topics and role of key informant interviews 163
Figure 9: Flowchart showing the development and role of observational data 168
Figure 10: Flowchart showing the structure and role of interviews with workshop participants 174
Figure 11: Research procedures informing overarching research question 179
Figure 12: A quiz used in some of the CPAS workshops 194
Figure 13: Diagram showing the experiment with a burning candle 197
Figure 14: Photograph showing a roadside safety marker 203
Figure 15: Photograph showing the Guesstimation minds-on activity 211
Figure 16: Photograph showing the hands-on activity titled Film can rocket 213
Figure 17: Photograph showing the hands-on activity titled Making a cloud 214
Figure 18: Photograph showing teachers experimenting with Parallax 217
Figure 19: Photograph showing a Clucking cup 225
Figure 20: A diagram which apparently shows that pressure increases with depth 233
Figure 21: Photograph showing a charged balloon used to move a ping pong ball 250
Figure 22: Photograph showing the action of detergent on milk 267
Figure 23: The TSE explanatory framework for public physics lectures  
Figure 24: Pie chart showing the average percentage of the frequencies of the six categories of CPAS workshop communications  
Figure 25: A map for short-term professional development
I wondered through a mire:
The literature; deep and waywardly,
To find an un-hewn precious stone,
One that I could polish and make my own.
Since then I’ve spent years,
Sometimes laughing, through often in tears.
With a shining beacon at my side to be my guide,
I laboured to make that stone shine:
Refining my questions
And shaping my arguments.
Along the way a shard may have been cast aside,
Which may one day be another’s.
And now before you I lay my labours:
My thesis, a diamond in my eye.
(The author)
Prologue

Drink deep, or taste not the Pierian spring:

There shallow draughts intoxicate the brain,
And drinking largely sobers us again.

Fir'd at first sight with what the Muse imparts,
In fearless youth we tempt the heights of Arts,
While from the bounded level of our mind
Short views we take, nor see the lengths behind;
But more advanc'd, behold with strange surprise
New distant scenes of endless science rise!

(Alexander Pope, Essay on Criticism)

The Waters of Pieria have long been the fabled seat of the Muses of mythical Greece. In the extract above, Pope refers to the Pierian Spring as a source of inspiration and deep understanding. The short-title of this thesis draws on that meaning. The following pages describe a study which has explored how science communication can participate to develop deeper understandings about science, and thereby inspire more effective science teaching. The model of teacher professional development described here, acts as a metaphorical pitcher with which science communication serves up the Pierian Waters.
Introduction
### Chapter 1: Introduction

#### Chapter Overview

- **Background to the study** 3
- **Statement of problem** 8
- **Research question** 9
- **Method** 10
- **Significance of the study** 11
- **Limitations of the study** 11
- **Structure of the thesis** 12
- **Chapter Summary** 14
Chapter 1: Introduction

*I think the system of education that could leave the mental condition of the public body in the state in which this subject has found it, must have been greatly deficient in some very important principle.*

Michael Faraday.

Background to the study

Science communication studies in the late 1980s revealed that the general public was unaware about science (see Durant, Evans & Thomas, 1989). In an attempt to address the public’s science knowledge *deficits*, the then Committee on the Public Understanding of Science decided that it was important to educate the public about science and its processes. Later studies (see Stocklmayer, Gore & Bryant, 2001) point out it is not essential for the public to be proficient in science in order to foster public engagement with science. While the former *deficit model* has been criticised as unrealistic (see House of Lords Select Committee on Science & Society, 2000), contemporary science communication efforts aim at engaging the public with science in more feasible ways that are personally relevant (see Burns, O’Connor & Stocklmayer, 2003). While it is not established in the literature, there is a resemblance between these contemporary science communication efforts and the trends in science education during the last two decades. In fact, a parallel can be drawn between the aforementioned developments in science communication and those in formal science education.

Pursuant to the Public Understanding of Science movement in the 1980s, there emerged efforts to inform school students about the nature, practices and knowledge of science (see Gregory & Miller, 1998). One such example was *Project 2061* that was developed by the
American Association for the Advancement of Science in 1985. This Project was intended to develop a scientifically literate American citizenship by the return date of Halley’s Comet in 2061. This effort was later influenced by *National Science Education Standards*, which were developed by the National Research Council in 1996, as a means to benchmark science education in the US. An important feature of these National Standards was the emphasis placed on grounding classroom science in active explorative investigations similar to those of real scientists; *viz.* inquiry or inquiry-based active learning approaches.

Inquiry-based teaching and learning is characterised by the onus it places on the learner (see, for example, Goodrum, Hackling & Rennie, 2001). Such an emphasis is intended to ensure learning experiences that have personal significance to the learner (see Simon & Johnson, 2008). Due to this learner-centred approach, it is believed that inquiry-based pedagogy is closely allied with the Constructivist Learning Model (see Yager, 1991\(^1\)). Constructivist learning stipulates that new knowledge should be built on existing understandings so that actual learning translates into a more active, personally meaningful exercise.

Several international education directives, including those in Australia; *viz.* the *National Goals for Schooling in the Twenty-First Century* (MCEETYA, 1999), have endorsed recommendations to model formal science education on inquiry and constructivist approaches. It is hoped, as a result, that students will foster a continued interest with science outside the classroom (see, for example, Tytler, Osborne, Williams, Tytler & Clarke, 2008). An important observation is that these reform efforts have been targeted at

---

\(^1\) Yager’s (1991) Constructivist Learning Model was re-published in January 2000 issue of *The Science Teacher*: 61 (1) 44-5.
middle school; i.e. school years between late-primary and early-secondary level (see Tytler, 2007). It is believed that by aiming science education reform at middle school level it would be possible to develop more positive attitudes about science among preadolescent learners, to regain proficient levels of science aptitude among students in post-industrial societies in the West, and to increase the enrolment numbers for science subjects at late-secondary and tertiary level courses.

Despite these efforts, recent surveys of science aptitude of middle school students, such as the *Programme for International Student Assessment* (OECD, 2006), and studies which have examined students’ interest in science (see, for example, Sjøberg & Schreiner, 2005) have revealed contradictory findings. These findings have impelled researchers to examine the actual processes by which science is taught in classrooms. Recent research indicates, unfortunately, that the primary reason for students’ disenchantment and subsequent disassociation from science is because many teachers still teach science based on elements of traditional models of pedagogy (see, for example, Osborne, 2006). These include, according to Lyons (2006), transmissive pedagogical approaches used to teach science, the decontextualised nature of school science content, and its perceived unnecessary difficulty. The literature offers two further reasons for, particularly, non-Western and female students' disassociation from science. These are the impersonal language used to communicate science (see Sutton, 1996), and the apparent Western ownership of scientific knowledge (see Aikenhead, 2001a). The challenges posed by this latter feature of science, to non-Western learners, particularly school students from non-Western cultures, are widely documented in the literature (see, for example, Costa, 1995; Pamba, 1999).

Studies that have examined teachers’ beliefs about pedagogy have found that their persistence with traditional models of instruction is not a result of their doubts about the
efforts to reform science education. These studies reveal, instead, that teachers are unaware of the actual means by which to implement pedagogy based on inquiry in the classroom (see, for example, Porlán & Martín del Pozo, 2004). They point out that teachers have been endoctrined into school cultures which promote the belief that students are passive recipients of knowledge, and that the teachers’ role is to bestow that knowledge absolutely for students to succeed at standardized examinations. Such beliefs about pedagogy permit little room, outside the confines of textbooks and curriculum guides, for the uncertainty that is inherent to student-centred constructivist classrooms. More importantly, there is evidence to suggest that teachers lack deeper understandings about science which are required to facilitate inquiry-based pedagogy (see, for example, Barnett & Hodson, 2001).

Science teaching which is based on student-centred inquiry is acknowledged unanimously as a complex activity (see, for example, Borko, 2004). It requires teachers to have flexible understandings about scientific concepts, which need to be interwoven with suitable pedagogy to facilitate the construction of scientific knowledge that is personally meaningful to students (see, for example, Goodrum et al., 2001). This means that, in order to facilitate inquiry in the classroom, teachers need to have confident understandings about science. Teachers’ inadequate understandings about science are, therefore, a tremendous impediment to education reform. The literature endorses strongly that teachers need support to address this challenge (see, for example, Lumpe, 2004).

While researchers agree that pre-service training, such as university based education courses, is not capable of equipping teachers to teach science based on inquiry (see, for example, Rodriguez, 1993), there is contention about the type of inservice/professional development program that would be most effective in offering teachers the support they require (see Fensham, 2007). Researchers maintain that professional development should,
ideally, enable teachers to construct personally meaningful understandings about science (see, for example, Taitelbaum, Mamlok-Naaman, Carmeli & Hofstein, 2008), and that it should not aim to address merely the teachers’ knowledge deficits (see, for example, Posnanski, 2002). It is believed that this is best achieved through professional development programs that are modelled on constructivist learning approaches, that are similar to the ones which are offered to students (see Loucks-Horsley, Love, Stiles, Mundry & Hewson, 1998). Professional development of this type would empower teachers to be confident about their own understandings of science and to use those understandings uninhibitedly to teach science through inquiry (see Dillon, Osborne, Fairbrother & Kurina, 2000). Professional development which is grounded on constructivist principles would also offer teachers the opportunity to experience collaborative learning with peers, to engage in hands-on experiments, and to observe inquiry-based pedagogy in practice (see Borko, 2004).

There is, however, a deficiency in the literature with regard to short-term professional development to offer support to science teachers to address reform recommendations. While most studies have investigated long-term professional development (i.e. summer schools and longer-term interventions) as a suitable vehicle to provide necessary support (see, for example, Goodrum et al., 2001), very little has been done to investigate the possibility of short-term professional development, such as one-day workshops, to offer the support teachers require. In fact, only three studies, all of which focus on elementary teachers (viz. Posnanski, 2002; Taitelbaum et al., 2008; van den Berg, 2001), have even mentioned that there exists the possibility to further explore short-term professional development from a constructivist perspective. However, these studies do not offer any confirmatory evidence.
Statement of problem

In summary, teaching science modelled on inquiry-based student-centred pedagogy is recognized as a complex process. Professional development has been identified, therefore, as a means to offer science teachers the support they require to develop confident understandings about science, that are necessary to overcome the challenges involved therein. It is agreed that the most suitable form of professional development, for this purpose, is that which is modelled on principles of constructivist learning. This would offer teachers the opportunity to construct personally meaningful understandings about science. However, very little has been done to investigate the possibility of short-term professional development to offer similar support to science teachers.

Therefore, the main purpose of this study is to investigate whether short-term professional development that is based on constructivist principles can offer teachers the opportunity to develop confident understandings about science.

This study has two auxiliary purposes. It was mentioned that parallel developments have occurred in the areas of science communication and formal science education. The first auxiliary purpose of this study is, therefore, to examine the premises on which science education reform can further be informed by practices in science communication.

Second, it was also stated that the literature focuses predominately on the challenges which are encountered by non-Western school students when learning science. Because this study examines teachers as learners of science, the other auxiliary purpose of this study is to investigate issues that may concern non-Western teachers when learning (Western) science.
Research question

The following overarching research question is used in this study:

Do short-term workshops that are based on constructivist principles enable teachers to construct personally meaningful understandings about science?

The above research question offers a two-pronged approach to the study. This means that it is necessary to investigate a model of short-term professional development to examine whether elements that exemplify constructivist principles are evident in its design and delivery. It also means that it is necessary to inquire from the teachers who participate in that model of professional development about the scientific understandings they develop as a result; i.e. whether those understandings are developed in ways that were personally meaningful to them.

The short-term professional development model which is investigated in this study was the one-day workshop that is offered to science teachers by the Centre for the Public Awareness of Science (CPAS) at the Australian National University in Canberra, Australia. A set of three supplementary research questions are used to obtain empirical evidence with which to answer the overarching research question above. These three supplementary research questions are listed below:

Are constructivist principles used to design the CPAS workshops?

Are constructivist principles used to deliver the CPAS workshops?

Do the teachers who attend these workshops construct personally meaningful understandings about science?
Method

Based on each of the supplementary research questions, three separate investigations were carried out in the present study. It is intended that each of these investigations offer a unique perspective to the overarching research question. A descriptive account of the research methods is given in Chapter 5 of this thesis.

First, observational data were obtained from the CPAS workshops using participant observation methods. These investigations offered a perspective of the workshops while they happened and served to inform whether constructivist features are employed in their delivery. Cross-cultural perspectives which were observed in two of the workshops for teachers from outside Australia (viz. Sri Lanka and Indonesia) are also recorded. This information was used to examine the issues that might be encountered by non-Western teachers, as learners of science.

The second set of investigations was interviews that were conducted with teachers who participated in the CPAS workshops. Data from these interviews offered the opportunity to examine elements of the workshops after they were completed, based on what the teachers experienced.

Finally, two workshop facilitators were interviewed. These interviews offered a perspective of the developmental stages of the CPAS workshops, from which to investigate whether constructivist principles are deliberately employed therein.
Significance of the study

This study is significant for three reasons. First, it serves to inform teacher professional developers. Because this study investigates the possibility of modelling short-term professional development on constructivist principles, it will help in the design of future short-term programs aimed at addressing middle-school teachers’ concerns about teaching science through inquiry.

Second, this study offers information to science communicators to inform reform recommendations in formal science education. The parallel trends in the disciplines of science communication and science education, that are investigated in this study, will help to inform future science communication interventions directed at science education reform, in the context of science teacher professional development.

Third, this study offers insights to researchers in the area of cross-cultural studies in science education. The findings based on the two workshops for science teachers from Sri Lanka and Indonesia offer a perspective of non-Western learners, who in fact teach (Western) science in their home cultures. The insights from this study will contribute to future research that examines the dynamics that are unique to that type of non-Western learner of science.

Limitations of the study

This study has two limitations. First, this study is based on the investigations of how a single professional development program has an impact on its participants’ conceptual framework. One may argue that a more variable approach that examined the participants’
conceptual change across several other programs, all with the same outcome in mind, would provide more credibility to the argument. However, this latter view poses several issues that could not be overcome given the current practices in place for science teacher professional development. One could even say that it would be unrealistic to expect from teachers a commitment over a considerably prolonged period of exposure to different models of professional development, all of which would be targeted at the same outcome.

Second, this study has not investigated the workshop participants’ subsequent classroom practices. While this might be seen as a limitation, it should be emphasised that the purpose of this study was to examine teachers’ perceptions related to personal understanding and experience. It was not the aim of this study to investigate how those understandings would influence the teachers’ pedagogy.

Structure of the thesis

This thesis comprises six sections: the Introduction, Background, Research methods, Results and discussion, Conclusions and the Appendices. As indicated in the Table of contents, the first five sections are further divided into chapters. Each chapter overview lists the different topics that are covered in that chapter. The page numbers which are listed alongside are intended to give the reader a perception of the depth of description that is offered by each of those topics. Each chapter concludes with a summary of the information therein.

Background: Chapter 2 offers a science communication backdrop to this thesis by examining contemporary ideas in the discipline. It also explains principles of constructivist learning and finally comments on the cultural aspect of science. This is followed by
Chapter 3, which comprises two parts. Part 1 offers a review of the literature in the area of formal science education in middle school. The trends and practices which are current in that domain are described in Part 2. Chapter 4 also comprises two parts. Part 1 reviews studies which have examined teachers’ beliefs about pedagogy. Part 2 describes the support that is offered to teachers to implement inquiry-based pedagogy.

Research methods: In Chapter 5 the research methods that have been used to investigate the research questions that are explored in this thesis are described. Measures to address possible shortcomings of those methods are discussed, as is the influence of triangulation on the data.

Results and discussion: Chapter 6 presents and discusses the observational data that was collected from the workshops which were investigated in this study. This chapter also describes the different cross-cultural perspectives that were recorded in the workshops for teachers from Sri Lanka and Indonesia. This is followed by Chapter 7 which describes the interviews with teachers and facilitators. Part 1 of Chapter 7 describes the interviews that were conducted with teachers who participated in the workshops. Part 2 describes the interviews with the facilitators who designed the workshops.

Conclusion: Finally, Chapter 8 draws conclusions from the findings made by this study, and offers recommendations for future studies.
Chapter Summary

Chapter 1 offered an introduction to what is contained in the body of this thesis.

It has been highlighted here that science teachers are confronted by challenges when they move away from traditional models of pedagogy, to which they have hitherto been accustomed. Most teachers are unaware of how to they are meant to confront these challenges, and lack adequate scientific understandings that are required to implement inquiry-based pedagogy.

While professional development that is based on constructivist principles is recognised to remedy this problem, there currently exists a dearth in studies which have investigated the possibility of short-term professional development to enable teachers to overcome the aforementioned challenges. This research study addresses that deficiency. The research procedures by which this is achieved have been briefly mentioned here. Some mention has also been made about the significance and limitations of this study.

The next chapter describes the science communication framework within which this thesis is grounded.
Background
# Chapter 2: Communicating science

## Chapter Overview

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public understanding versus public awareness of science</td>
<td>17</td>
</tr>
<tr>
<td>Science communication</td>
<td>22</td>
</tr>
<tr>
<td>Constructivist learning</td>
<td>31</td>
</tr>
<tr>
<td>The culture of science</td>
<td>35</td>
</tr>
<tr>
<td>Chapter Summary</td>
<td>38</td>
</tr>
</tbody>
</table>
Chapter 2: Communicating science

For the past twenty years at least, research coming from the area of science education has revealed a public that is fearful, mistrustful and ignorant of simple scientific principles. Why has education failed to address these problems and what should science communication know in order to be more effective?

Stocklmayer, 2001, p.3

Public understanding versus public awareness of science

Modern science is an important achievement of Western culture. As Durant et al. (1989) have stated, it is desired ideally that the general public should, therefore, have an understanding about science:

First, science is arguably the greatest achievement of our culture, and people deserve to know about it; second, science affects everyone’s lives, and people need to know about it; third, many public policy decisions involve science, and these can only be genuinely democratic if they arise out of informed public debate; and fourth, science is publicly supported…based on at least a minimal level of public knowledge (p.11).

Based on their study of two national surveys carried out in the summer of 1988, Durant and his colleagues state, however, that the British and American publics had relatively low knowledge about science, technology and medicine:

…only 34% of Britons and 46% of Americans appeared to know that the Earth goes round the Sun once a year, and just 28% of Britons and 25% of Americans knew that antibiotics are ineffective against viruses. Equally striking, in the context of current public and political concern about technology and the environment, is that only 34% of British respondents knew that nuclear power stations are not a source of acid rain, whilst a mere 23% recognised a link between the burning of fossil fuels in coal-fired power stations and the problem of global warming. (p.11)
Durant et al. concluded, therefore, that despite modern science being an important achievement, “it is one of which most members of our culture are widely ignorant” (p.13).

Other scholars (see, for example, Stocklmayer et al., 2001) agree that it is important to know about the underlying cultural, economic, democratic, utilitarian and social roles that are played by science in contemporary society. Stocklmayer et al. do not agree, however, that it is essential for everyone to have proficient understandings about all these aspects of science. They point out that the above conclusions drawn by Durant et al. (1989) serve to promote a *deficit model* about the public’s understanding of science:

> It is good to be sceptical of studies that indicate that the public has a poor grasp of science. Many of these studies contain the seeds of a self-fulfilling prophecy, for example, Durant, Evans & Thomas (1989) describe work in which general scientific knowledge questions are asked of a randomly selected sample of people. This necessarily constructs an image of a public that is deficient in its understanding of science. Only if everyone answered all questions correctly could this deficient model be challenged. (Stocklmayer et al., 2001, p.xi)

The concept of the deficit model was founded on views that the public lacks knowledge and understanding about science. It was believed, therefore, that the public needed to know more about scientific facts and understand the processes involved in science (see Miller, Suchner & Voelker, 1980). These views gathered momentum in the 1980s pursuant to efforts by the *Committee on the Public Understanding of Science*, which was a joint venture of the British Association for the Advancement of Science, the Royal Society and the Royal Institution in the UK. Many of these efforts were aimed at addressing the public’s science knowledge deficits in anticipation of greater public appreciation for science. It is believed that several formal science education frameworks, such as *Project 2061: Science for all* campaign by the American Association for the Advancement of
Science in 1985, were influenced by the onus placed on the public to understand science (see Gregory & Miller, 1998).

Since then, the deficit model has been criticised as an unrealistic concept. Stocklmayer and her colleagues (2001) contend that “as far as the community is concerned, science is invisible until such time as it has a need for it” (p.x). They state:

Only when the public have a specific interest will they turn to the science pages. When they are personally engaged, they will read voraciously and be capable of mastering difficult material with ease. It is the task of the science communicator to increase the need to know and nurture it. (p.xi emphasis in original)

In 2000, the Select Committee on Science and Society, appointed by the House of Lords in the UK, examined efforts, including science education in schools, that were meant to improve the public’s attitudes to and knowledge about science. The Committee reported that to address the public’s science knowledge deficits in an attempt to promote a better understanding about science was a futile enterprise:

It is argued that the words (i.e. public understanding of science) imply a condescending assumption that any difficulties in the relationship between science and society are due entirely to ignorance and misunderstanding on the part of the public; and that, with enough public understanding activity, the public can be brought to greater knowledge, where upon all will be well… This approach is felt by many of our witnesses to be inadequate; the British Council went so far as to call it “outmoded and potentially disastrous”. (p.140)

Views that favoured public understanding of science diminished consequently. The emphasis has shifted instead to communication of science to the public in ways that would engage them. Burns et al. (2003) state, however, communicating science “is not simply
encouraging scientists to talk more about their work, nor is it an offshoot of the discipline of communications” (p.183)\(^2\). As Stocklmayer et al. (2001) state, communicating science for public awareness has different objectives to those of public understanding of science:

\[\text{...increasing public understanding of science is a worthwhile endeavour that creates an intelligent, informed and skilled group within the community. Such a group is an extremely valuable resource for the community. Increasing public awareness of science, however, is a longer term project, but one that, if successful, can contribute enormously to social well-being as it creates a community that is confident in its possession of scientific ideas and is comfortable about raising children to have the same confidence. (p.xii)}\]

An important element in this latter disposition (\textit{i.e.} public awareness of science) is its emphasis on scientifically empowering communities so that they are confident to share their understandings with learners of science (\textit{viz.} “comfortable about raising children to have the same confidence”). In essence, public awareness of science is aimed at longer-term goals which would foster continued engagement with science, by enabling communities to understand scientific concepts based on personal significance and by offering learners a sense of ownership of that knowledge. As Gilbert, Stocklmayer and Garnett (1999) state:

\[\text{The skills of accessing scientific and technological knowledge and a sense of ownership of that knowledge will impart a confidence to explore its ramifications. This will lead, at some time, to an understanding of key ideas/products and how they came about, to an evaluation of the status of scientific and technological knowledge and its significance for personal, social and economic life. (p.18)}\]

\(^2\) A claim that sits close to this definition has been suggested by the author in an essay titled \textit{Pillar-roots of knowledge}, and is included in Appendix 1.
Contemporary efforts to promote scientific literacy in schools have been closely allied to the above view. As Kemp (2000) states, scientific literacy needs to move towards instructing students about science in ways that they find personally meaningful:

…scientific literacy as a necessity for all students may not be a defensible goal, but it seems defensible to say that science educators are responsible for making the opportunity to become scientifically literate equally available to all students. All students may not need or want to learn the same things in science, but all deserve quality science education experiences. We suggest that science educators carefully re-examine the goals and assumptions of their discipline so that all students can equitably experience quality school science instruction that will provide them with the knowledge, skills, and dispositions they want or need for their lives. (http://eric.ed.gov/ERICDocs/data/ericdocs2sql/content_storage_01/0000019b/80/17/1e/07.pdf)

Recent efforts to reform science education, in middle school in particular, focus on engaging students with school science so that they would develop a life-long interest with science. While these recommendations to reform science teaching in middle school are described in the next chapter, it would suffice to say for the present that these recommendations strongly discourage conventional pedagogical models that endeavour to address students’ knowledge deficits. Instead they recommend pedagogy based on inquiry (see Chapter 3). It would be safe to say that these recommendations closely resemble models of science communication that promote an awareness of science. This would suggest that science communication practices can inform the recommendations to reform science education. It is important, therefore, to look at the practices involved in science communication.
Science communication

Some of the earliest practices involved in communicating science are to be found in the writings of Michael Faraday and Lawrence Bragg, both of whom were eminent scientists in their day (see The Royal Institution of Great Britain, 1986; Thomas, 1991). In fact, one statement by Bragg reverberates in the Durant et al.’s (1989) lamentations quoted earlier in this chapter about the general public’s indifference towards science:

The importance of science in everyday life is often stressed. The influence of advantages in scientific knowledge on the achievements of engineering and technology has altered the way in which we live and continues to do so with bewildering rapidity. At the same time, it is stressed that the man in the street has little conception of what science is and how it advances. (The Royal Institution of Great Britain, 1986, p.1)

While Bragg blames scientists who are “often singularly inept at explaining to non-scientists what they are doing”, he and Faraday have described practices which they believed were important for lecturers\(^3\) to follow when communicating science with the general public. Some science communication practices that are based on these writing are listed below with corresponding quotes\(^4\) from those scientists:

(a) Good delivery: “The most prominent requisite to a lecturer…is a good delivery.” (Faraday)

---

\(^3\) The term *lecturer* was used in the context of scientific experts communicating (*viz.* lecturing) to the general public about science. It is noted that the term *lecturer* is always used in the male gender, as it may have been customary at the time.

\(^4\) Quotes from the writings of Michael Faraday and Lawrence Bragg were obtained from The Royal Institution anthology titled *Advice to Lecturers* (1986). This handbook does not list page numbers.
(b) Relevance: “A lecture is made or marred in the first ten minutes… A guiding principle of the popular lecture is that of starting with something with which the audience is thoroughly familiar in everyday life and leading them further with that as a basis.” (Bragg)

(c) Engagement: “A lecturer should exert his utmost effort to gain completely the mind and attention of his audience, and irresistibly make them join in his ideas to the end of the subject... A flame should be lighted at the commencement and kept alive with unremitting splendour to the end. (Faraday)

(d) A plan: I always find myself obliged…to draw up a plan on paper… This done, I have a series of major and minor heads in order, and from these I work out my subject matters.” (Faraday)

(e) Timing: “One thinks ‘that point will only take a minute or so to explain’ and realises to one’s horror in the actual lecture that…it takes ten times as long. Of course the way in which each ten-minute section is to be put has to be carefully thought out and its timing roughly estimated. (Bragg)

(f) One main point: “How many main points can we hope to ‘get over’ in an hour? I think the answer should be ‘one’… No breaks or digressions foreign to the purpose should have a place in the circumstances of the lecture, and no opportunity should be allowed to the audience in which their minds could wander from the subject…” (Faraday)

(g) Expression: “In order to gain the attention of an audience…it is necessary to pay some attention to the manner of expression. The utterance should not be rapid and hurried… but slow and deliberate, conveying ideas with ease from the lecturer and infusing them with clearness and readiness into the minds of the audience.” (Faraday)
(h) Simple language: “A lecturer should endeavour by all means to obtain a facility of utterance and the power of clothing his thoughts and ideas in a language smooth and harmonious and at the same time simple and easy.” (Faraday)

(i) Repetition: It is boring in a written account to be repetitious; it is right in a spoken account to put the key idea in several ways to make sure the audience has grasped the point. (Bragg)

(j) Pauses: “Pauses and changes of tempo are essential.” (Bragg); “By these interruptions he allows the minds of his company to return to their wonted level and they are in a short time again ready to accompany him into the celestial regions.” (Faraday)

(j) Humour: “Above all, jokes have a marked and enduring effect.” (Bragg)

(k) Visuals aids: “Diagrams, tho’ ever so rough, are often times of important use in a lecture… A diagram on a table…should be left in the view of the audience for a short time after the lecturer himself has explained that they may arrange the ideas contained in them in their minds…” (Faraday); “Some information can only be conveyed as slides, photographs, or records of actual events…but slides of graphs or tables off figures are in general out of place in a lecture.” (Bragg)

(l) Simple experiments: “The best experiments are simple and on a large scale, and their workings are obvious to the audience… Audiences love simple experiments… There are tricks too about demonstration.” (Bragg); “They (i.e. experiments) should rather approach to simplicity and explain the established principles of the subject than the elaborate…” (Faraday)
(m) Demonstrations: “The wrong way is to do the experiment, ask the audience if they noticed this or that, and then explain what this or that meant. The right way is to start by explaining the significance of the effect you are aiming at producing, tell the audience what to look for, and then, after a pause to make sure you have their attention, to bring it off. These tricks are important because they are all part of fixing your message in the mind of the audience…” (Bragg).

(n) Organisation of props: “If the lecture table appears crowded, if the lecturer (his by his apparatus) is invisible, if things appear crooked, or aside, or unequal, or if some are out of sight without particular reason, the lecturer is considered as an awkward contriver and bungler.” (Faraday)

(o) Room layout: “The seats should be so arranged that no obstruction intervene between the spectator and the lecture table…each person should be situated in a manner the most convenient for observation and hearing.” (Faraday)

The above examples from Faraday and Bragg’s writings highlight elements, such as audience participation and enjoyment, engaging the interest of the audience, and offering the audience opportunities to make informed decisions based on what they experience. In doing so, it is seen that these early writings encapsulate current practices of science communication, more than two centuries later. One such instance is the definition for science communication which Burns et al (2003) offer in the context of science presentations. They describe science communication as interactions which produce Awareness, Enjoyment, Interest, Opinion-forming or Understanding (viz. the AEIOU vowel analogy) about science:
Science Communication (SciCom) may be defined as the use of appropriate skills, media, activities, and dialogue to produce one or more of the following personal responses to science (the vowel analogy)

- **Awareness**, including familiarity with new aspects of science
- **Enjoyment** or other affective responses, e.g. appreciating science as entertainment or art
- **Interest**, as evidenced by voluntary involvement with science or its communication
- **Opinions**, the forming, reforming, or confirming of science-related attitudes
- **Understanding** of science, its content, processes, and social factors

Science communication may involve science practitioners, mediators, and other members of the general public, either peer-to-peer or between groups. (p.191)

Given the differences raised earlier, between the fundamental premises of public *understanding* and *awareness* of science, some pause for thought is required to establish the exact meaning of these two words which both appear in the above definition. Burns *et al.* point out that *understanding*, in the present context, does not suggest the dictionary meaning of acceptance or consent. Instead they state that:

> Understanding is not a binary condition, something that you either have or don’t have, but rather a developing comprehension of both the meaning and implications of some knowledge, action or process based on appropriate commonly accepted principles. For scientific understanding, the appropriate commonly accepted principles would be science’s theories, laws, and processes identified in the science section together with some appreciation of their ramifications. (p.186)

Moreover, Burns *et al.* add that public awareness of science is a prerequisite for understanding science:
On occasions, the term “public awareness of science” (PAS) has been used as a synonym for “public understanding of science” (PUS). Their aims are similar and their boundaries do overlap, but PAS is predominantly about *attitudes* towards science. PAS may be regarded as a prerequisite – in fact, a fundamental component – of PUS and scientific literacy. (p.187)

In terms of science education this would imply that learners first need to be aware of scientific phenomena before they can develop understandings about the underlying scientific concepts. Burns *et al.* offer a conceptualisation of this idea based on a modified version of a model proposed by Koballa, Kemp and Evans (1997) (see Figure 1). In this model an individual’s scientific literacy is compared to a three-dimensional mountainous landscape, where “the position of the peak along the y horizontal axis indicated the *domain* or area of literacy…the height of the peak in the vertical z direction represents the level of personal achievement within that domain… (and) the depth of the peak (*i.e.* the x dimension in the x-y horizontal plane) reflected the value that person associated with the domain” (p.192, Burns *et al.*, 2003). Burns *et al.* state with reference to this *Mountain-climbing analogy* that:

Developing literacy in one particular area of science may be likened to climbing a mountain. It is dynamic, participatory, and it inevitably changes the participants’ view of the world. This climbing process is facilitated by science communication. Appropriate skills, media, activities, and dialogue are used to improve individuals’ awareness, enjoyment, interest, opinions, or understanding (AEIOU) of science. When viewed at the public level, this equivalent to moving upward through the continuum of public awareness of science, public understanding of science, and scientific literacy… *Public awareness of science* begins the scientific literacy ascent. The awareness that a mountain (a scientific domain) exists may lead to the subsequent adoption of the skills and methods required to ascend it. Public understanding of science is the consequence of individuals (and therefore society of which the individuals comprise), building on their awareness of science to achieve higher levels of comprehension and application of scientific matters. (pp.193-4)
Burns et al. maintain that an individual’s mountain range profile (i.e. “the extent of literacy, in a variety of (scientific) domains” (p.193)) is unique and changeable. They state, moreover, that science communication can, in fact, influence these changes; i.e. “…science communication works in two ways, for ascent and descent…it allows access between people at different levels” (p.194). This reference to ascent and descent could also imply construction and deconstruction, respectively, of scientific knowledge. As Lawson, Abraham and Renner (1989) explain, there are two types of fundamental knowledge that influence learning: declarative knowledge (i.e. knowing that), and procedural knowledge (i.e. knowing how). They point out that in order to construct declarative knowledge, learners need to make use of procedural knowledge. Quoting these researchers, Odom, Stoddard and LaNasa (2007) state:
The motivation to improve procedural knowledge is provided when students participate in the constructive process, then the learning of declarative knowledge becomes more meaningful...thus giving students the means to better understand and explain nature by being able to generate and test their own ideas. (p.1331)

Stocklmayer and Gilbert (2002) present such a model of science communication, based on the term *Personal Awareness of Science and Technology* (PAST). PAST describes “all of the complexity of an individual’s attitudes, beliefs and relevant contextual knowledge” (p.853). The researchers maintain that an individual’s PAST is based on all of that individual’s previous experiences. By providing an individual with experiences which remind and inform her/his PAST, it is possible to enhance that PAST to a new level. Stocklmayer and Gilbert use the representation shown in Figure 2 to illustrate this model. The model proposes that providing reflective experiences could help to establish a coherent link between an individual’s PAST and the desired level of scientific awareness (viz. the target) that is meant by a given science communication exercise. They state:

In this model, an individual...having PAST1 encounters Experience 1 (a teaching model) that enhances PAST 1 in some way. Links between PAST 1 and engagement with Experience 1 are informed by remindings and by nature of the interaction undertaken with Experience 1. The result is a new level of awareness, PAST 2. The connection made by the person with the desired target (the consensus model) will be variable at the time of the interaction with Experience 1. A further, probably later, Experience 2 related to the same target will be informed by a new, stronger set of remindings (drawn from one of the earlier experiences). These, in their turn, will increase the connection made with the target: new or refined scientific knowledge will result. This interactive process can occur indefinitely, resulting in the gradual development of PAST, driven by appeal, need or interest. This development will be personal, idiosyncratic, for all individuals. (pp.853-4 emphasis in original)
An important feature in the PAST model is its reliance on previous experiences to further an individual’s scientific awareness. Essentially, the extension of links from one PAST level to another is founded on previous experiences which are personal and meaningful to the learner. It could be said that what this model proposes for science communication closely resembles principles for constructivist learning in science education. It is important, therefore, in the context of this thesis, to understand what is meant by constructivist learning.
**Constructivist learning**

There is debate about the origins of constructivist learning. Scholars like Thera Piyadassi (1987) state that the concept of Constructivism is rooted in early Buddhist philosophy. The concept of cognitive construction could be traced back to the philosopher Giambattista Vico in the 18th Century (see Yager (1991). Vico has stated, quotes Yager, “to know means to know how to make…one knows a thing only when one can explain it” (p.54). In more recent times, cognitive research by Jean Piaget and Ernest von Glasersfeld has played an important role in modelling constructivist learning.

Constructivist learning, as the name implies emphasises the building (viz. construction) of information to produce a comprehensible whole which is personally meaningful to the learner. As Bencze (2004) states “apparently, what each person sees (or observes) depends more on what is already stored in that person’s brain. This suggests that learning…is an active, rather than a passive, process” (p.1). Active participation in the learning process and use of the learner’s previous experiences to construct new knowledge are the two cornerstones of constructivist learning. Bencze lists several principles that embody constructivist learning. Some of those which have a bearing on this thesis are listed below:

- Learners have their own ideas
- Learners like their ideas
- Learners see what they want to see
- Learners’ ideas often contradict those of their teachers
- Learners often are not aware of what they know
- Learners deserve the right to determine their beliefs
- Learners need to know how to learn
• Learners need *first-hand* experiences
• Learners need other people (pp.2-4)

It is clear that the above principles emphasise a strong tradition of learning which focuses on the learner, rather than the teacher. There is, first, the recognition that *ideas* are the learner’s own purview. It is recognised that these ideas are closely linked to the learner’s personal experiences and preferences; *i.e.* see what they want to see and like what they see. It is agreed that the ideas held by one learner are not necessarily the same as another, and that there is often disparity between the learners’ and the teachers’ ideas. The statement that the “learners often are not aware of what they know” implies that learners lack deeper, more metacognitive understandings about the basis for their ideas. As Bencze explains:

> Students are frequently not consciously aware of reasons (e.g. laws and theories) for their actions. They just *know* why they do things a certain way. For example, few stop to think how gravity, wind, surface friction, *etc.* affect how they walk… Teaching and learning should begin by encouraging learners to express and clarify their pre-instructional conceptions. (p.3)

Constructivist principles maintain that learning experiences should enable learners to determine the basis for their ideas. It is recommended that these experiences should be grounded on activities that are personally meaningful to the learner:

> Learners need to use and test their ideas…through relevant activities. Often, this involves concrete experiences that combine with abstract ideas that have just been presented to learners. For example, while a teacher can show students on a blackboard that various atoms can be rearranged to make new molecules in a chemical reactions, students often need to try such reactions with concrete materials before they fully understand the new ideas…(p.2)
Last, there is the requirement to involve a group perspective to the learning experience. As Bencze states “for students to learn…experiences alone are not enough, they need to receive different lenses…through which to view objects and events, design experiments and interpret data” (p.3). This implies that collaborating and learning together with peers is essential for students to construct meaningful understandings.

The above principles for constructivist learning consistently identify with Yager’s (1991) analysis of the *Constructivist Learning Model*. Yager states that:

…learning is an active process occurring within and influenced by the learner as much as by the instructor and the school… learning outcomes do not depend on what the teacher presents. Rather, they are an interactive result of what information is encountered and how the student processes it based on perceived notions and existing personal knowledge. (p.53)

Moreover, Yager points out that communication plays an important role in constructivist learning. He describes the varying degrees of communication that occur at different levels of learner-interaction (see Figure 3). The last column in that grid (viz. Results) shows how a consensus between two students could evolve to a new level of awareness when it is communicated within the larger learning community. By doing so it allows learners to scaffold that awareness for further constructivist learning; *i.e.* by identifying new problems and actions.
<table>
<thead>
<tr>
<th>Who</th>
<th>Problems</th>
<th>Responses</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual student</td>
<td>Identify problem</td>
<td>Suggesting response</td>
<td>Self-analysis</td>
</tr>
<tr>
<td>Pairs of students</td>
<td>1. Comparison of ideas</td>
<td>Agreeing on approach to problem(s)</td>
<td>Two person agreement</td>
</tr>
<tr>
<td></td>
<td>2. resulting questions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small group review</td>
<td>1. Consider different interpretations</td>
<td>1. Consider different responses</td>
<td>Small group consensus</td>
</tr>
<tr>
<td></td>
<td>2. Achieve consensus</td>
<td>2. Achieve consensus</td>
<td></td>
</tr>
<tr>
<td>Whole class</td>
<td>1. Discussion</td>
<td>Acts to gain consensus</td>
<td>Whole class agreement</td>
</tr>
<tr>
<td></td>
<td>2. Identify varying views</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Science community</td>
<td>Comparison of class views vs. those of scientists</td>
<td>Comparison of class views vs. those of scientists</td>
<td>Consensus/ new problems/ actions</td>
</tr>
</tbody>
</table>

Figure 3: Grid illustrating the role of communication in constructivist classrooms (Source: Yager, 1991, p.54)

These different levels of communication in constructivist learning enable learners to determine their own ideas through self-analysis. The interactive communication with the learning community offers the learners opportunities to examine those ideas from different perspectives (*i.e.* different lenses, see Bencze, 2004). In doing so it helps learners to obtain an accurate interpretation of the real world. As Yore (2001) states, an interactive constructivist perspective enables learners to examine their explanations and interpretations against other sources of information, such as scientific data and canonical theories, to arrive at a consensus regarding their claims about reality. This social dimension of constructivist learning beckons a communal view. Some researchers argue, therefore, that such views
foster a *culture* for science, and that this culture plays an important role when promoting scientific literacy. The Final section of this chapter examines those premises

**The culture of science**

The construction of scientific knowledge is a social endeavour. Scientific knowledge is constructed through a consultative process within communities of scientists. As Bencze (2004) states, it is collective conclusions drawn by communities of scientists, and not individual ideas, that become the domain of public scientific knowledge:

> public knowledge – that is, ideas and information stored and made available for the general public – usually goes through some sort of debate amongst people. Groups of scientists, for example, read each others’ articles, write for the same journals, and attend the same conferences. After they have debated ideas about which they have been investigating in their labs, *etc.*, their *collective conclusions* get published in school texts and other records frequented by the public. (p.2 *emphasis added*)

As a consequence, these collective conclusions share “…values, and ethos, practices, methods and attitudes based on universalism, logical reasoning, organized scepticism and tentativeness of empirical results that exist within the scientific/academic community” (p.188, Olugbemiro, 1997, as quoted by Burns *et al.* 2003). These features determine what is known subsequently as a *scientific culture*. While the collective conclusions by scientists get assimilated into the public domain so do the features of that scientific culture. As Godin and Gingras (2000) state “scientific and technological culture is the expression of all modes through which individuals and society appropriate science and technology” (p.55). The model which is used by these researchers to illustrate this concept shows, accordingly,
science and technology as intrinsic forms of social organization within a culture (see Figure 4).

![Figure 4: Model for science and technology as components of culture](Source: Godin & Gingras, 2000, p.53)

Burns et al. (2003) state that “scientific culture is an integrated societal value system that appreciates and promotes science, per se, and widespread scientific literacy, as important pursuits” (p.189). In North Atlantic cultures the term culture scientifique is used to describe this concept which in essence denotes attempts to promote appreciation for science among the public (see Solomon, 1997). Efforts to promote science by the Committee on the Public Understanding of Science in the UK and Project 2061 in the US are two such examples, which have been mentioned. Culture scientifique is closely linked to the pursuits of science communication. As Bryant (2003) states, science communication is “the process by which the culture and knowledge of science are absorbed into the culture of the wider community” (p.7).
There is contention, however, that the scientific culture which these efforts endeavour to promote is characteristically Western in origin. The fact that Durant et al. (1989), as quoted earlier, state that “science is arguably the greatest achievement of our culture”, implies a strong Western ownership of science and its endeavours. Aikenhead (2001a) points out that this apparent Western ownership of science “is not because of any intellectual or moral superiority” (p.38) of the West. Instead, it is due to the dominant Western political worldview:

…Western science is embedded in a culture that has colonised large portions of the planet. Western science has been invested with much more authority than, for instance, everyday commonsense science, not because Western science is necessarily more valid in that context, but because its culture is associated with prestige, power, progress, and privilege.

While several other reasons for the apparent Western ownership of science are described in the next chapter, it suffices to say presently that a Western worldview marginalises non-Western learners of science. It also poses a considerable challenge when communicating Western science to non-Western audiences. As Johnson (2007) states, therefore, it is prerequisite to acknowledge that science in itself fosters a culture, when attempting to resolve such challenges: i.e. “The first step in making science more engaging….is…to recognize that science has a culture, and that certain types of students may find it challenging to understand and navigate this culture” (p.819).
Chapter Summary

Chapter 2 offered a science communication framework for the subsequent chapters of this thesis.

Concern has been voiced in recent years about the public’s lack of understanding of science. Efforts to address the science knowledge deficits, in an attempt to promote public appreciation for and understanding of science, have been criticised vehemently. Communicating science in ways that foster the public’s continued engagement with science has emerged instead as a more realistic endeavour. An important feature in middle school science education reform is its close resemblance to this model of public awareness of science. Contemporary models which describe science communication for public awareness have been, therefore, described in this chapter. A fundamental characteristic of one of these models; i.e. Personal Awareness of Science and Technology, is its emulation of principles of constructivist learning.

Constructivist learning implies active construction of knowledge, based on the learner’s prior experiences to derive personally meaningful learning outcomes. The literature states that communication, which involves the learning community, promotes desirable learning outcomes, as it fosters consensus and scaffolding of new knowledge. This level of social interaction offers a communal aspect to scientific knowledge. Researchers believe, therefore, that it promotes what is known as a scientific culture.

While the concept of a scientific culture is admittedly recognised when promoting science, there is contention about the values that are permeated by this culture. It is believed that these values are predisposed towards a Western worldview. Given that science communication is described as a process by which the scientific culture is absorbed into the
public domain, researchers warn about the possibility of marginalisation of non-Western
learners of science. These issues will be discussed further in subsequent chapters.

The next chapter looks at the actual processes of formal science education in middle
schools in several countries.
### Chapter 3: Science in middle school

#### Chapter Overview

**Part 1: Middle school science education**

- Contemporary trends 41
- Inquiry-based teaching 49
- Inquiry and Constructivism 52
- Inquiry in educational directives 56
- Science teachers’ role in inquiry 60
- Summary 63

**Part 2: Features of current science teaching in middle school**

- Transmissive pedagogy 65
- Decontextualized context 70
- Unnecessary difficulty 77
- Language of science 82
- Apparent Western ownership of science 88
- Summary 98

**Chapter Summary** 99
Chapter 3: Science in middle school

There is evidence that identity formation for youth in late modern societies, such as Australia, is focused more strongly on self realisation, and contributing to the future. It is argued that school science needs to move away from instrumentalist emphases and value free presumptions if it is to capture the imagination of young people.

Tytler, Osborne, Williams, Tytler & Clarke, 2008, p. viii.

Part 1: Middle school science education

Contemporary trends

There is consensus across the literature that students’ experiences of formal science education in middle school\(^5\) should yield outcomes that extend beyond the confines of mere classroom learning. Hence it is strongly recommended that the boundaries of school science should include experiences from daily life, and that students should continue to participate actively in science and technology as a result of such experiences. This view has been reiterated more vehemently in recent years. For example, as Black and Atkin (1996) have quoted from Project 2061:

The terms and circumstances of human existence can be expected to change radically during the next human life span. Science…and technology will be at the centre of that change – causing it, shaping it, responding to it. [Scientific literacy] is essential to the education of today’s children for tomorrow’s world. (p.15)

---

\(^{5}\)Middle School refers to late-primary and early-secondary schooling-years, i.e. Years 7 through 10 (i.e. 11 to 15-year-olds) (Tytler, 2007).
In *Beyond 2000: Science Education for the Future*, a report about the science education landscape in the UK, Millar and Osborne (1998) also state that a well developed understanding about science is essential to contemporary society:

…the ever-growing importance of scientific issues in our daily lives demands a populace who have sufficient knowledge and understanding to follow science and scientific debates with interest, and to engage with the issues science and technology poses – both for them individually, and for our society as a whole. (p.1)

Recent seminal science education research literature in Australia (see, for example, National Science Standards Committee, 2002; Goodrum, *et al.*, 2001; Tytler, 2007) widely agrees with these statements regarding transatlantic science education. Hackling and Prain (2005), for example, recommend that science education is only effective when “classroom science is linked with the broader community; students are actively engaged with inquiry, ideas and evidence, and students are challenged to develop and extend meaningful conceptual understandings” (p.19). Researchers agree that science needs to be appreciated in a broader social context, and not only within the confines of the classroom. Rennie, Goodrum and Hackling (2001) point out, for instance, that *all citizens*, not only those who seek to pursue a career in science, need to foster an appreciation for science beyond schooling years. The researchers state:

…a quality science education promotes the development of scientific literacy, a high priority for all citizens, helping them to be interested in and understand the world around them, to engage in the discourses of and about science, to be sceptical and questioning of claims made by others about scientific matter, to be able to identify questions, investigate and draw evidence-based conclusions, and to make informed decisions about the environment and their own health and well-being. (p.466)
Symington and Tytler (2004), in another more recent Australian study, reiterate findings from earlier reports in the UK. They state that teaching science in middle school helps to achieve specific educational purposes (see Table 1). In addition to the cultural, democratic, economic and utilitarian purposes of learning science, which have been listed in Table 1, the researchers identify *personal development* as an essential purpose for learning science in middle school. They point out that by learning science for personal development students are able to contribute more completely as members of society.

Table 1: Purposes of science in the compulsory years

<table>
<thead>
<tr>
<th>Cultural purpose</th>
<th>to ensure that all members of society develop an understanding of the scope of science and its application in contemporary culture.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Democratic purpose</td>
<td>to ensure that the students develop a confidence about science which would enable them to be involved in scientific and technological issues as they impact on society.</td>
</tr>
<tr>
<td>Economic purpose</td>
<td>to ensure that Australia has the number and quality of people with strong backgrounds in science and technology in business and public life, as well as in science and technology, that are needed to secure the country’s future prosperity.</td>
</tr>
<tr>
<td>Personal development purpose</td>
<td>to ensure that all members of society benefit from the contribution that the values and skills of science can make to their ability to learn and operate successfully throughout life.</td>
</tr>
<tr>
<td>Utilitarian purpose</td>
<td>to ensure that all members of society have sufficient knowledge of science to enable them to operate effectively and critically in activities where science can make a contribution to their personal wellbeing.</td>
</tr>
</tbody>
</table>

(Source: Symington & Tytler, 2004, p.1411)

Several studies, like the one cited previously, specifically mention *middle school* as a focal point for the proposed educational reform. Three main reasons have been identified in the
literature for this strong focus on middle schooling years. The first of these reasons is the highly impressionable nature of middle school students. Researchers state that it is during middle school that students consolidate attitudes and make decisions, and frame the way they will interact with science in their later lives (see, for example, Lindahl, 2007; Lyons, 2006; Royal Society, 2006). They point out that students’ formal engagement with science during this period is crucial to the way they will perceive science in their lives. Hence it is vital for students in middle school to be encouraged to develop positive attitudes towards science. Researchers opine that fostering positive attitudes about science would encourage students to seek formal engagement through prospective careers in science. They also claim that, more importantly, a positive outlook to science serves to develop an interest and a belonging with science among all members of technologically advanced societies (see Speering & Rennie, 1996). In a review of several high level reports, Tytler and his colleagues (2008) have summarised these sentiments as follows:

For the majority of students, their life aspirations are formed before the age of 14…Interventions and resources aimed at encouraging student engagement in science…thus need to be prioritized to engage and capture the imagination of students in upper primary and early secondary school years. (p.viii)

The second reason is the alarming level of student performance in science across middle schools in many First World countries. In the US, for example, the National Centre for Education Statistics (NCES) (2001) reported that students between fourth and eighth grades perform far worse than their counterparts internationally. These findings are reiterated by more recent reports (see, for example, American Electronics Association, 2008), which state that on average only 27% of US eighth-graders between 1996 and 2005 were proficient in science. Another study, viz. Programme for International Student
Assessment (PISA) (OECD, 2006), which examined 15-year-olds (i.e. Year 10 equivalent) from 57 Organisation of Economic Co-operation Development member countries, reported that among the 400,000 students who were surveyed only 1.3% (on average) attained very high proficiency in science. Findings from this study further state that less than half (47%) of the students said they found school science easy; and that only 57% believed the scientific information they were taught in school was personally meaningful.

Recent studies show that students’ poor performance in middle school science is augmented by a pronounced dislike towards learning science. The Relevance of Science Education (ROSE) Project (Sjøberg & Schreiner, 2005) found that students in many post-industrial countries have negative attitudes towards learning science6 (also see International Bureau for Education, 2001). A study of grade-nine Dutch students by Taconis and Kessels (2008) found that although these students performed better in science, compared to their peers in Germany, they did not wish to identify with the specific culture of (Western) science. Parallels to these findings have been identified by Tytler and his colleagues (2008) with regard to science learning in middle school in Australia. The researchers state that “Australian studies over the last two decades have shown a general decline in students’ interest and enjoyment of science across the middle years, with a particularly sharp decline across the primary to secondary school transition” (p.59).

Similar results, which corroborate this statement, have emerged from other contemporary studies in Australia. A study of primary and secondary teachers in the State of Victoria by Gough, Marshall, Matthews, Milne, Tytler and White (1998) is one such example. The researchers found that secondary school teachers, when compared with primary school

---

6 Contrary findings are, however, apparent in developing nations, where science and technology are viewed as crucial to the nations’ development efforts and science education enjoys a high social status (Sjøberg & Schreiner, 2005).
teachers, held more negative views about their students’ attitudes to school science, (see Table 2). Gough et al. state, for instance, while 70.3% of primary school teachers agreed and strongly agreed that their students thought science was interesting, only half as many (i.e. 35.9%) secondary teachers held this same view.

Table 2: Teacher perceptions of student attitudes to science

<table>
<thead>
<tr>
<th>Student attitudinal statement</th>
<th>Percentage of teachers who agree or strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students:</td>
<td></td>
</tr>
<tr>
<td>Think science is interesting</td>
<td>70.3</td>
</tr>
<tr>
<td>Are enthusiastic about their science studies</td>
<td>59.6</td>
</tr>
<tr>
<td>Think science is relevant to them</td>
<td>37.5</td>
</tr>
<tr>
<td>Have an out-of-school interest in science</td>
<td>13.6</td>
</tr>
<tr>
<td>Think a career in science would be worthwhile</td>
<td>10.5</td>
</tr>
</tbody>
</table>

(Source: Gough et al., 1998, p.36)

In another study, based on findings from the Third International Mathematics and Science Study (TIMSS), Martin, Mullis, Gonzales, Gregory, Smith, Chrostowski, Garden and O’Connor (2001) reported that the attitudes to learning science by Year 8 students in Australia were by far the most alarming among all English speaking countries. More recent TIMSS findings (see Thomson and Fleming 2004) also stated that in Australia Year 8 students were 20% less likely to report that they liked science to some extent than students in Year 4. The researchers found that while 66% of Year 4 students reported high self-confidence in science, only 49% did so in Year 8. With reference to the 2006 PISA survey, Tytler et al. (2008) report that concern has been expressed once again about Australian middle school students’ low levels of interest in science:
Australian students have a below average interest in learning science. They clearly do not spend much of their spare time on science-related activities. The one positive element is that they are interested in learning science for its instrumental value for future careers but, sadly, not for its intrinsic interest. (p.79)

The third reason to reform science education in middle school is based on the concern that has been determinedly voiced internationally about the dearth in enrolments in science subjects at higher secondary and tertiary levels (see, for example, Bordt, De Broucker, Read, Harris & Zhang, 2001; Garg & Gupta, 2003; National Science Foundation, 2002). Studies have continued to show that students are not opting to learn science in post-compulsory years. In countries like Germany, for example, where science is a compulsory subject at senior high school, fewer university enrolments for science have been reported (see Paul, Föll & Jäger, 2001). In the UK, student enrolments for higher-secondary maths and science courses have decreased by 13% during the previous two decades (Osborne, 2006). Goodrum et al. (2001) draw equal attention to the significant decrease in enrolments in core science subjects (viz. physics, chemistry, biology and geology) in Australian schools during the past three decades (also see DEST, 2003). These sentiments have been echoed more recently by Peacock (2007), Australia’s Chief Scientist. In his address to the 16th Annual Royal Australian Chemical Institute Conference he lamented the fall in Year 12 enrolments for chemistry (from 30% to 15%), biology (from 55% to just over 20%), and physics (from 27% to 12%), between 1978 and 2002.

Apart from decreasing numbers of student enrolments in post-compulsory science, there has also been an overall decrease in enrolments across individual core science subjects. A study by Dekkers and De Laeter (2001), for example, reported that, between 1980 and 1998, the average number of science subjects in which students were enrolled in Australian
schools had fallen by more than 16%. In another survey, the Department of Education Science and Training (2003) found that the number of students taking two or more science subjects at Year 12 had steadily declined between 1990 and 2001.

Studies in the US and UK have also shown that fewer students are expressing an interest to take up careers that involve science. For instance, Atwater and Wiggins (1995) found that only 25% of the US students they interviewed wished to work in science. Jenkins and Nelson (2005) have pointed out more recently in the UK that only 10% of high school students expressed an interest to work in a profession that involved science.

Researchers also believe that vocational courses appear to be more appealing to students (and their parents). As a consequence, these courses compete with the subject choices students make at high school (see Ainley, 1993; Lyons; 2006). As schools offer a greater variety of vocational courses, with incentives like potential workplace guarantees, fewer students are opting for post-compulsory physics and chemistry courses, which are prerequisites at university.

As a result of the three reasons that are mentioned above, consternation about science teaching in middle school has become more pronounced during the last decade. Several recommendations to reform middle school science have emerged as a consequence. One of these recommendations is highlighted in the next section.
Inquiry-based teaching

Due to reasons mentioned previously, several recommendations have been proposed to make learning science in middle school more purposeful and engaging. Walker and Zeidler (2007) state, for example, that these recommendations focus on “empowering students to consider how science-based issues and decisions made concerning them reflect, in part, the moral principles and qualities of virtue that encompasses their own lives, as well as the physical and social world around them” (p.1387). By encompassing a more meaningful engagement with science, Burbules and Linn (1991) state that students would not merely understand scientific phenomena but, more importantly, “generate fruitful and relevant questions and frame them in an effective way for investigation” (p.228). Another such recommendation by PISA (OECD, 1999) stated that school science should equip students with “the capacity to use scientific knowledge, to identify questions, investigate and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity” (p.60). These sentiments have been repeatedly echoed in the literature for almost two decades. For example, the US National Commission on Excellence in Education (NCEE, 1983) reported that:

The teaching of science (at secondary level) should provide graduates with an introduction to: (a) the concept, laws, and processes of the physical and biological sciences; (b) the methods of scientific inquiry and reasoning; (c) the applications of scientific knowledge to everyday life, and (d) the social and environmental implications of scientific and technological development. (p.25 emphasis added)

More recently Simon and Johnson (2008) have stated:

There is a growing need...to see science as a distinctive and valuable way of knowing. Such a shift in emphasis requires that the teaching of science should focus more on the nature of science and on the evidence and arguments of scientific ideas, and help students develop skills of engaging in fruitful argumentation. (p.670)
In order for science to be meaningful in everyday life, Hodson (1992) has proposed that it is necessary to have an educational framework which allows students to learn science (i.e. understanding of scientific concepts); learn about science (i.e. understand the nature of science); and most importantly do science (i.e. actively contribute to construct scientific knowledge). This view has been endorsed by later researchers who point out that a science educational framework of this type would require students to be actively engaged in their learning process. More specifically, Rennie and her colleagues (2001) state that, as part of such an educational framework, students would need to:

- be interested in, and understand the world around them;
- be engaged in the discourses of and about science;
- be sceptical and questioning of claims made by others about scientific matters;
- be able to identify questions, investigate and draw evidence-based conclusions; and
- make informed decisions about the environment and their own health and well-being. (p.7)

The emphasis to ground school science in inquiry-based active learning experiences has emerged, therefore, as a feature of these recommendations (see, for example, Lee & Krapfl, 2002). Inquiry or Guided Discovery requires teachers to guide classroom learning experiences so that students could develop deeper understandings about scientific concepts (see McBride, Bhatti, Hannan & Feinberg, 2004). Welch (1981) has described inquiry-based pedagogy as follows:

Instruction...in inquiry classrooms reflects a variety of methodologies – discussions, investigative laboratories, student-initiated inquiries, lectures, debates. Teachers serve as role models in deliberating issues, examining values, in admitting error, and in confronting areas of their own ignorance. The classroom atmosphere is conducive to inquiry. It is easy for students to ask questions. Risk-taking is encouraged and student responses are listened
to, classified, and deliberated upon with high frequency of student-student transactions. Classroom climate stimulates a thorough, thoughtful exploration of objects and events, rather than a need to finish the text. Inquiry transactions are concerned with students’ developing meaning. Thus, in an inquiry classroom there is time for doing…a time for reflection…a time for feeling…and a time for assessment. (p.35)

The US *National Science Education Standards* (NRC, 1996) use the following processes to describe inquiry-based pedagogy:

- pose a productive question
- design an investigation directed toward answering that question
- carry out the investigation
- interpret and document findings
- publish and present the findings (based on pp. 52, 100 & 113)

It is recommended, consequently, that teaching and learning science should be centred on inquiry-based approaches, where students are involved in investigating, constructing and testing ideas and coming up with explanations about natural phenomena in the world around them. This means that “students need to observe scientifically, not just observe without thinking, and to infer scientifically, linking observations and other evidence with scientific knowledge” (p.468, Rennie *et al.*, 2001,).

Early proponents of inquiry-based teaching, such as John Dewry, Jerome Bruner and Joseph Schwab, believed that such an approach to teaching science would resemble closely what *actual* scientists do (see, for example, Schwab, 1962; AAAS, 1993; Roth, 1995; Watson, Goldsworthy & Wood-Robinson, 1999). They believed, therefore, that inquiry-based approaches would offer students the opportunity to reflect on the actual nature of scientific inquiry (*i.e.* “the diverse ways in which scientists study the natural world and
propose explanations based on the evidence derived from their work.” (p.2, Anderson, 2002). As Goodrum et al. (2001) state “inquiry approaches expose students to the nature of science and the scientific enterprise, and provide an effective approach to meaningful learning, which is grounded in personal experience of natural phenomena and engagement in the learning process” (p.144). It is expected, therefore, that greater appreciation for science among students would develop as a consequence of these personally meaningful learning experiences. As McBride et al. (2004) summarise:

…when students learn science by inquiry, the process of inquiry becomes the means by which the currently accepted science knowledge is better understood. Through learning science as inquiry, students also better understand how scientists develop the currently accepted body of science knowledge. Hence the students learn to apply these processes in order to go beyond the information needed to discover new knowledge. (p.435)

Advancing learners’ scientific knowledge based on meaningful learning experiences is also strongly advocated in constructivist pedagogy. Hence an important feature of inquiry based teaching is its parallels with Constructivism, some of which are described in the next section.

**Inquiry and Constructivism**

Researchers believe that the elements of inquiry are consistent with and complement constructivist approaches to teaching (and learning) (see, for example, Joyce & Weil, 1986). As Matthews (1994) states “Constructivism attempts to steer a path between teacher-dominated instruction, the traditional didactic model of education, and student-led discovery learning, the progressive model of education” (p.146). It is accepted that inquiry-
based teaching would allow students the opportunity to construct new knowledge through active exploration based on inherent curiosity. Shymansky, Henriques, Chidsey, Dunkhase, Jorgensen and Yore (1997) points out that learning through inquiry would require students to scaffold prior knowledge, construct understandings, evaluate alternative conceptions, apply ideas in a socio-cultural context, and engage in open-ended questions, co-operative learning and reflection. Active investigation and constructing meaningful knowledge, of this type, are key features of Constructivism. Matthews (1994) states, in fact, that a classroom which is described by the characteristics in the earlier quote from Welch (1983) “would pass equally as a model constructivist class” (p.146). Tobin (1990) has explained further that the anticipated outcomes for inquiry-based learning are consistent with those of constructivist principles:

Learning is defined as the construction of knowledge as sensory data are given meaning in terms of prior knowledge. Learning always is an interpretive process and always involves construction of knowledge…Constructivism implies that students require opportunities to experience what they are to learn in a direct way and time to think and make sense of that they are learning. (pp.404-5)

Moreover, as Yager (1991) explains, the Constructivist Learning Model closely resembles recommendations to facilitate learning through inquiry. This Model describes, for instance, constructivist strategies, such as looking for information, designing and conducting experiments, collecting and organizing data, and discussing solutions, all of which are consistent with the recommendations for inquiry:

- Seeking out and using student questions and ideas to guide lessons and whole instructional units;
- Accepting and encouraging student initiation of ideas;
Using student thinking, experiences, and interests to drive lessons (this means frequently altering teachers’ plans);

- Encouraging the use of alternative sources for information both from written materials and experts;
- Using open-ended questions and encouraging students to elaborate on their questions and their responses;
- Encouraging students to suggest causes for events and situations, and encouraging them to predict consequences;
- Encouraging students to test their own ideas, *i.e.* answering their questions, their guesses as to causes, and their predictions of certain consequences;
- Seeking out student ideas before presenting teacher ideas or before studying ideas from textbooks or other sources;
- Encouraging students to challenge each others’ conceptualizations and ideas;
- Encouraging adequate time for reflection and analysis; respecting and using all ideas that students generate; and
- Encouraging self-analysis, collection of real evidence to support ideas, and reformulation of ideas in light of new experiences and evidence. (p.56)

Goodrum and his colleagues (2001) point out that facilitating knowledge construction based on experimental investigation requires teachers to use suitable pedagogy. They state that both “minds-on, as well as hands-on, practical work” (p.144) are essential components of this type of pedagogy. Mortimer and Scott (2003) point out that minds-on science requires students to reflect and think about science. This means that, when dealing with minds-on inquiry-based approaches teachers need “to make scientific ideas available to their students, assist them in making sense of these ideas and support students in applying them” (pp.874-5). Teachers also need to scaffold students’ ideas to construct a climate of scientific awareness through which they (*i.e.* the students) may view their everyday-environments more richly (Tytler, 2007). In terms of hands-on inquiry, teachers need to offer students opportunities to manipulate the *things* they are studying and help them to “learn by experience” (p.5, Rutherford, 1993). As the National Science Board (1991) has
explained further, learning by inferred experiences promotes a deeper understanding of scientific concepts because “students are likely to begin to understand the natural world if they work directly with natural phenomena, using their senses to observe and using instruments to extend the power of their senses” (p.27).

Moreover, studies have found that teaching science based on minds-on and hands-on approaches improves students’ attitudes about science (see Tien, Roth & Kampmeier, 2002). A recent study by Odom et al. (2007) found that teaching science based on such inquiry-based approaches helped to effectively convey to students the nature and methods of science and scientific reasoning. The researchers state that “experimentation and discussions about problem-solving may cause students to conclude that many questions and problems may have more than one viable answer or solution” (p.1344). Such minds-on and hands-on approaches used to teach inquiry are, however, dissimilar to methods hitherto used to teach science at secondary level.

Rennie et al. (2001) state that the main methods of teaching science hitherto used are lecture-type, teacher-centred, chalk and talk lessons in the classroom, and practical classes where students replicate experiments in the laboratory by following instructions from the teacher. These methods focus primarily on teacher-led student acquisition of information, rather than students’ understanding and using scientific knowledge as a meaning-making experience (see, for example, Yore, 2001). AbuSharbain (2002) points out that inquiry-based approaches conversely recommend that teachers need to “focus on students’ learning of scientific concepts, science process skills, and the nature of science, rather than the traditional memorised set of facts and vocabulary” (p.2).
Teaching science through inquiry is, therefore, far removed from traditional chalk-and-talk methods of instruction. It places on the teachers a more demanding set of expectations than those to which they have hitherto been accustomed. As Taitelbaum et al. (2008) state “teaching by using the inquiry-approach is much more complex and different from traditional classroom teaching. It requires from the teacher different kinds of skills and a high level of expertise” (pp.614-5). This statement reiterates sentiments of an earlier British Council for Science and Technology report (2000) which claimed that teaching science, more than any other school curriculum, challenges teachers with “subjects, issues, and boundaries that are continually changing” (p.10). As Haney, Lumpe, Czerniak and Egan (2002) state the ultimate challenge of implementing these reform recommendations falls upon teachers in classrooms all over the world. It is, therefore, appropriate to spend some time to look at how various international education directives inform teachers about recommended pedagogical reform.

**Inquiry in educational directives**

The *National Science Education Standards*, which attempts to benchmark science education in the US as part of the *Science for All* campaign of *Project 2061*, is consistent with teaching approaches that are based on inquiry. The Standards state that “inquiry into authentic questions generated from student experiences is the central strategy for teaching science” (p.31). Among its *Guidelines for Science Teaching* it states that school science should: be inquiry-based (Standard A); guide and facilitate student learning (Standard B); present learning environments that support science as inquiry (Standard D); and strive to develop communities of science learners (Standard E) (NRC, 1996). To achieve these
outcomes it is proposed that teachers should focus less on transmitting information and focus more on facilitating inquiry-based active-learning experiences for their students. Similarly, teachers are encouraged to base their lessons on content that is meaningful and is of interest to all students (see Table 3).

Table 3: Teaching for scientific literacy

<table>
<thead>
<tr>
<th>Less emphasis on</th>
<th>More emphasis on</th>
</tr>
</thead>
<tbody>
<tr>
<td>Memorising the scientific names and definitions of</td>
<td>Learning broader concepts that can be applied in new situations</td>
</tr>
<tr>
<td>scientific terms</td>
<td>Providing opportunities for scientific discussion</td>
</tr>
<tr>
<td>Asking for recitation of acquired knowledge</td>
<td>Communicating the findings of student investigations</td>
</tr>
<tr>
<td>Providing answers to teacher’s questions about content</td>
<td>Assessing understanding and its application to new situations</td>
</tr>
<tr>
<td>Assessing recall of scientific terms and facts</td>
<td>Learning science actively from multiple sources</td>
</tr>
<tr>
<td>Learning science mainly from textbooks provided to</td>
<td>Open-ended activities that investigate relevant questions</td>
</tr>
<tr>
<td>students</td>
<td>Guiding students in active and extended inquiry</td>
</tr>
<tr>
<td>Activities that demonstrate and verify science content</td>
<td>Science being interesting for all students</td>
</tr>
<tr>
<td>Presenting science by talk, text and demonstration</td>
<td>Content that is meaningful to students’ experiences and interests</td>
</tr>
<tr>
<td>Science being interesting for only some students</td>
<td>Studying a few fundamental concepts</td>
</tr>
<tr>
<td>Theoretical, abstract topics</td>
<td></td>
</tr>
<tr>
<td>Covering many science topics</td>
<td></td>
</tr>
</tbody>
</table>

(Source: Based on NRC, 1996, pp.52, 100, 113)

A similar focus on inquiry is apparent across education directives in Australia. With regard to science teaching in Australian schools, Rennie et al. (2001) state that “all k-12 curriculum frameworks are outcomes-focused and endorse teaching and assessment
strategies that reflect an *inquiry view of learning* and decrease focus on content coverage” (p.457). Correspondingly sentiments have been echoed in several Australian high level documents. The *National Goals for Schooling in the Twenty-First Century* (MCEETYA, 1999), which was the first of its kind in Australia, recommends that inquiry-based active approaches should be used to extend the boundaries of conventional classroom instruction, and to accommodate meaningful learning experiences. As an outcome of having learned science in school, this document adds, students in later life should “have the capacity for, and skills in, analysis and problem solving, and the ability to communicate ideas and information, to plan and organise activities and to collaborate with others” (p.8).

Another such document is the *National Framework for Professional Standards for Teaching* (MCEETYA, 2003). It states that teachers should develop critical thinking, creativity and the ability to solve complex problems (among other skills) in their students. The document adds, not too differently from the one mentioned previously, that such exposure during schooling years is necessary for students to participate in a knowledge-based society. In making these recommendations the Framework acknowledges the strong correlation between “quality teaching and improved student learning outcomes” (p.8).

*Good teaching*, it states, is integral to how students as a community would interact with knowledge in future. A more local document, the *Curriculum Framework of the Australian Capital Territory* (DET, 2005), which makes learning recommendations for students from preschool through to Year 10, also lists “students’ ability to understand and apply the inquiry process and scientific knowledge” among its 26 Essential Learning Achievements.

Attempts to promote inquiry-based science teaching are not limited to post-industrial countries in the West. Several developing countries, including Sri Lanka and Indonesia, recommend inquiry-based approaches in their national education directives. The *Sri
*Lankan Science and Technology Curriculum* (NIE, 2004) prescribes, for instance, that “students should be allowed to construct knowledge, through active learning experiences (that are not limited to the classroom); and that teachers should enable such experiences, instead of attempting to directly transmit information to students” (p.8, translation). Such an approach is essential, the document adds, if students are to develop a proper understanding about the nature of science. The document points out further that an understanding of science, as recommended, is necessary if students are to appropriately employ their scientific skills.

In Indonesia, *Kurikulum 2004* (Ministry of Education, 2004) also emphasizes that science teaching needs to be student-centered and actively engaging. It is stated in the document’s *Guidelines for Physics Teaching*, for instance, that “all students are invited to be actively involved in learning…and classroom activities should be directed more towards learning than towards teaching” (p.12, translation). Widely agreeing with previous international recommendations, this document also reiterates that teachers need to function as facilitators to the learning process, rather than in their conventional role of transmitters of content.

Based on the recommendations in the literature and the above directives to science teachers it is clear that inquiry-based reform efforts are strongly focused on enabling students to understand school science meaningfully. Helping students to develop these understandings has become, therefore, the role of today’s science teachers. In the context of subsequent investigations in this thesis, it is important to examine how science teachers are coping in this new role.
Science teachers’ role in inquiry

While the education directives, described earlier, commonly identify that school science should move towards inquiry-based teaching, they clearly acknowledge that the changes they prescribe cannot happen in a vacuum. The aforementioned documents and scholarly publications unanimously acknowledge that science teachers play a pivotal role in effecting those outcomes. Yager (1991), for instance, states that while learning is an active process that occurs within and is influenced by the learner, it is equally influenced by the teacher (p.53). Correspondingly, an extensive number of studies that abound in the literature, both in Australia (see, for example, Cuttance, 2001; Education Queensland, 2001) and elsewhere (see, for example, Connelly & Clandinin, 1988; Darling-Hammond, 2000; Justi & Gilbert, 1999; Santiago, 2002), acknowledge the crucial role teachers need to play when called to teach science through inquiry. It is stated, for instance, by Lumpe (2004) in an editorial of the *Journal of Science Teacher Education* that teachers are the most critical factor affecting curriculum reform. Others, like Goodrum *et al.* (2001), also report that “the most significant factor in improving the quality of teaching and learning is the teacher” (p.168).

Despite the numerous forms of literature that state that teachers are key to science education reform, there is an equal body of evidence to suggest that the pedagogy teachers currently use to teach science defeats the aims of previously described reform efforts (see, for example, Odom *et al.*, 2007). As Davis (2002) states, for example, “despite a decade of reform efforts in science education, student achievement in science at middle school level is less than desired” (p.3). Osborne (2006) is, however, less lenient in his accusations. He laments that in spite of almost a century’s worth of recommendation efforts, teachers have yet to fully embrace inquiry-based pedagogy:
Four decades after Schwab’s (1962) argument that science should be taught as an *enquiry into enquiry*, and almost a century since John Dewey (in 1916) advocated that classroom learning be a student-centred process of enquiry, we still find ourselves struggling to achieve such practices in the science classroom. (p.2)

Findings by those like Rennie and her colleagues (2001) reveal that actual science teaching in many Australian schools sharply contrasts with recommended pedagogy that was mentioned earlier. In fact, the researchers add, traditional models of pedagogy are still practiced as widely as they were almost two decades ago when an investigative study of secondary science pedagogy was undertaken by Staer, Goodrum and Hackling (1998). It is apparent, therefore, that despite reform efforts teachers are predisposed to traditional forms of science instruction. As a consequence, inquiry-based approaches do not feature frequently in their pedagogy. This means that students do not receive the opportunity to experience inquiry as part of middle school science. It has been established previously, however, that students need inquiry-based active experiences to meaningfully construct scientific knowledge (since it is believed that continued engagement with science in post-compulsory years is made possible through such experiences: see Goodrum *et al.*, 2001). Speering and Rennie (1996) hold, therefore, that the primary reason for mounting levels of pronounced indifference towards science could be attributed to the manner in which science is taught in middle school classrooms:

Many of those students who had enjoyed science in primary school expected that they would continue to enjoy it... Instead, most students…were generally bored with their science lessons, and had failed to create a strong relationship with their science teachers. The reality was, that for many students beginning secondary school, science lessons involved lectures, note-taking exercises or working from a text. The enthusiasm for science with which these students had entered secondary school seems to have been somewhat dampened by this and the unexpected boredom which followed. (p.295)
Similar sentiments have been voiced by Goodrum et al. (2001). The researchers report that many students who enjoyed learning science in primary school are disenchanted by the way science is taught in middle school:

When students move to high school, many experience disappointment, because the science they are taught is neither relevant nor engaging and does not connect with their interests and experiences. Traditional chalk-and-talk teaching, copying notes, and “cookbook” practical lessons offer little challenge or excitement to students. Disenchantment with science is reflected in the declining numbers of students who take science subjects in the post-compulsory years of schooling. (p.viii)

These researchers and others (see, for example Tytler, 2007) maintain that students’ disenchantment with school science correlates with declining upper-secondary science subject enrolments (which was mentioned earlier in this chapter). It is also believed that, due to the less positive experiences with middle school science, students foster an antipathy for science in general (see, for example, Désautels, 1998; House of Lords Select Committee on Science & Technology, 2000; Levy, Wubbles, Brekelmans, & Morganfield, 1997). These perceptions which remind students of their disenchantment with science are carried by many into later life. Because of these perceptions Sutton (1996) states, students consequently strive to disassociate themselves from science:

There is an allegation, or at least an implication, in recent research reports and critiques, that school experience is responsible for the persistence of views…which help to maintain an inadequate public understanding of the scientific enterprise and the degree of (societal) alienation from it. (p.1)

If experiences of learning science in middle school are responsible for alienating students from science in post-compulsory schooling years, then it is of essence, in the context of this
thesis, to look at the actual processes of science instruction in middle school that enables this outcome. These processes need to be examined with attention to the pedagogy therein, particularly how they fail to achieve recommended outcomes that are intended by inquiry-based teaching.

**Summary: Part 1**

Part 1 of this chapter reviewed recommendations in the literature to reform science education in middle school.

Efforts to reform middle school science education, whereby students actively participate in their own learning, have been advocated with the aim of fostering life-long interaction with science. Teaching science through inquiry-based approaches has emerged as an important feature of this reform. Teachers are encouraged, therefore, to move away from traditional models of instruction, and instead facilitate explorative learning experiences through which their students could develop personally meaningful understandings about science. Although middle school teachers are recognised as pivotal to this reform effort, it is apparent from their persistence with traditional models of pedagogy, that they are challenged by teaching approaches that are based on inquiry. It is, therefore, opportune to spend sometime in Part 2 of this chapter to examine the bases and processes of science teaching that are endemic to most middle school classrooms.
Part 2: Features of current science teaching in middle school

Davis (2002) states that traditionally in middle school “students have held little status and voice regarding their learning and what happens in the classroom” (p.8). Models of instruction that advance such a perception have been associated with students’ disassociation from science in post-compulsory years (see Speering & Rennie, 1996). This claim is supported by several Australian studies (see, for example, Baird, Gunstone, Penna, Fensham, & White, 1990; Tytler, 2007). The disengaging manner in which science is taught in middle school and the irrelevance of school science content to students’ daily life, re-emerge in these studies as causes for dissatisfaction with school science. Research shows that the same reasons are broadly consistent with student-antipathy towards science internationally.

In Japan, for example, the Ministry of Education, Science and Culture (1994) states that examination-oriented science teaching has created a climate of knowledge transfer, which is far removed from inquiry-based pedagogy. The Ministry states that this has led students to “drift away from science and technology” (p.92). Similar teaching practices for maximum examination reward in India have rendered students passive recipients of scientific knowledge (Koul & Fisher, 2002). Although content-based teaching of this type equips students for written examination regimes, it minimally promotes skills that are necessary for future interactions with science. In another international example: Europe needs more scientists, a study by the European Commission (2004) states:

There is a strong tendency to regard the teaching of science not as an area of educational development of the student, but solely for the pursuit of the subject matter. Science education is viewed as the learning of science knowledge, rather than education through a context of science. There is thus pronounced confusion between science on the one hand and science education (that which is promoted in schools) on the other. (p.9)
Irrespective of the different national contexts, Lyons (2006) identifies three recurring features in middle school science teaching that are responsible for students’ declining interest in science. They are transmissive pedagogy, decontextualized content and the unnecessary difficulty of school science (p.592). Each of these features is now discussed separately.

**Transmissive pedagogy**

Transmissive pedagogy (*i.e.* knowledge transfer) aims at transmitting “knowledge, skills and values of the scientific community to students” (p.277, Aikenhead & Otsuji, 2000). The role of teachers, within this pedagogical framework, is to dispense knowledge, direct students’ actions and explain conceptual relationships (see Anderson, 2002). In essence transmissive pedagogy is teacher-centered content transmission, which when used to teach science creates an impression that science is a fixed body of knowledge with definite (*i.e.* correct) answers that are best learnt by rote (see Lyons, 2006). In such situations, Fensham (2007) complains:

> Learning is simply a matter of being like a sponge, and soaking up this knowledge as it comes from the teacher (or later from the text). Science knowledge is dogmatic and correct. There are no shades of grey about science. You are right or wrong. There is no room for your opinion. Discussion and debate are not parts of these science classes. (p.6, *emphasis added*)

Yager (1991) states, however, that “knowledge is not acquired passively” (p.55), but instead constructed by students actively engaging in their learning. Moreover, Greenwood (2003) states, although transmissive pedagogy aims to increase students’ knowledge, there
is little evidence to suggest that the information which is conveyed to students through this form of instruction relates to their prior experiences and understandings. This is because, as Ausubel (1968) has explained, although rote learning allows for information to be incorporated in students’ cognitive structures, this information is non-substantive. Verbatim transfer of information, he pointed out, rarely bears relevance to the students existing conceptual frameworks. There is even the possibility of information that is memorised to interfere with prior knowledge structures resulting in mis-associations. Moreover, Ausubel stated that recall of memorised information has a short life-span. As Novak (1990) points out, unless rote learning is rehearsed repeatedly, residues of that information may impede future attempts at learning.

Justi and Gilbert (1999) agree that transmissive pedagogy makes learning science a meaningless experience, as it neither establishes relationships between science and its social history nor does it “require students to think about the process of construction of scientific knowledge” (p.177). Instead, transmissive pedagogy focuses on students’ ability to learn rather than their ability to actually do science. Osborne and Collins (2001) state, as a consequence, transmissive pedagogy “frogmarches students across the scientific landscape, from one feature to another, with no time to stand and stare, and absorb what it was that they had just learned” (p.450). These sentiments are highlighted in students’ responses in the two studies conducted by Lyons (2003) and Osborne and Collins (2001), respectively:

...in Years 7 and 8, (science) wasn’t very interesting at all because we never really got to do anything. They (i.e. teachers) just said “Oh, this happens and that happens,” and we sort of went “Oh,...OK”. (p.99)

...it’s too much to learn...Suddenly, your mind is saying, “Look this is interesting, but I really don’t want to learn it like this, I don’t want to pump it into my brain.” (p.452)
This model of teaching, Koballa and Tippins (2000) point out, works well with content-overloaded science curricula. The researchers point out that *Block Scheduling*\(^7\) in the US, for instance, does not permit teachers the luxury of letting their students to “stand and stare and absorb” (p.7). This is essentially because there is not enough time to spend on activities and reflection. Rennie *et al.* (2001) have found parallels in Australia. They report that 40% of students they surveyed “never or only sometimes had time to think about what they are doing in science” (p.474). As many as 61% of the students they surveyed said that almost all their science classes comprised copying notes dictated by the teacher.

Needless to say, such an approach to teaching science does not offer an opportunity for inquiry nor anticipate questions that arise in the students’ conceptual framework (see Sutton, 1992). Due to the immense weight placed on content coverage and teaching students the *correct* answers, transmissive pedagogy reinforces a facts-based approach that mainly targets students’ success at examinations (see Osborne & Collins, 2001). As MacFarlane (2002), then Chair of the Royal Society Education Committee, has been quoted in *Nature* to have said, “school science concentrates too much on churning out exam candidates who feel like potential contestants for a quiz show” (p.266).

It is, therefore, hardly surprising for students in transmissive pedagogy-dominated classrooms to remain passive recipients of scientific information (see Lyons, 2006). In such situations students are encouraged to wait for information to be dispensed by the teacher and to commit these scientific facts to memory. They are also expected to defer to the teacher, whose knowledge they come to perceive as absolute and irrefutable. These

---

\(^7\) *Block Scheduling* requires teachers to allocate a limited time duration for teaching a specific scientific concept (Koballa & Tippins, 2000).
elements of transmissive pedagogy are highlighted in a response by one of Lindahl’s (2003) students, who states:

*I do not understand what we are doing. I just learn it by heart and do what the teacher says. And if you do so and smile to the teacher you will have good marks.* (http://www.mna.hkr.se/~ll/summary.pdf)

It is evident that transmissive pedagogy focuses on students’ ability to regurgitate correct scientific facts, that have previously been conveyed by their teachers. Geddis and Roberts (1998) point out that, as a result, transmissive pedagogy bestows an element of absolutism on the part of the teacher. Such authoritarian delivery of science as canonical abstract knowledge, however, hardly conforms to the recommendations for middle school science teaching. Researchers, like Tytler, Doig, Groves, Gough and Sharpley (2003), reiterate, therefore, that science which is taught in this way, without the benefits of exploration and reflection, could hardly produce the desired outcomes of greater engagement and continued interest.

Moreover, Southerland and Gess-Newsome (1999) remark that epistemological absolutism (*i.e. true knowledge* that is immutable in its basic concepts), as described above, “is the most powerful obstacle to the development of constructivist epistemology” (p.147) and desired instructional change. McDermott (1991) claims that even when attempts are made to teach science through pedagogy based on inquiry and hands-on approaches, they frequently result in equipping students with the correct models of understanding as opposed to fostering a spirit of inquiry. Quoting studies done by Wong and Wong (1998), Huber & Moore (2001) explain:
…the presentation of science as a process of following step-by-step instructions and filling in blanks on worksheets promotes erroneous and impoverished concepts regarding the nature of science. The hands-on activities tend to be dominated by the mechanical tasks characteristic of the work of laboratory technicians rather than the creative endeavours of scientists…perhaps the most problematic, the written directives deprive students of ownerships over their investigations. Rather than designing and carrying out investigations to answer their own questions, they are following instructions to find if they guessed the correct answer to the teachers’ questions. (p.33)

Science teaching based on learning activities that are tailored to remediate student errors and ensure conventional understanding through reinforcement pedagogy are in conflict with recommendations to create a school science environment for research-based thinking. As Riggs (2007) said on the ABC radio program *Ockham’s Razor* “revision, repetition (or reinforcement as it is called in education) actually drives out learning…the difference between the words *research* and *reinforcement* points up the difference in the two activities, search as opposed to force” (http://www.abc.net.au/rn/ockhamsrazor/stories/2007/1965395.htm). Students find this autocratic view, which allows them less influence on their learning and little room for negotiation or creativity extremely frustrating. As Lyons (2003) findings reveal, many students are unwilling to simply accept such scientific knowledge that is dispensed by their teachers:

*Things were presented as fact. Teachers never said, “this is what someone discovered”, or “this is what someone thought 200 years ago”. You know, they always said, “this is what happens”. So they never presented it as a theory, or as something to be argued against.* (p.184)

Because students have minimal control over their own learning, Wallace (1996) states that it is not surprising that such perceptions disadvantage students when opting for post-
compulsory engagement with science. Hence science teaching that is based on transmissive pedagogy defeats the purposes of science education reform as it does not give students ownership of their knowledge nor involvement in the learning process. Lyons (2006) has also mentioned that the decontextualized nature of school science content may also produce similar outcomes in students. This feature, which is also endemic to most middle school science instruction, is described next.

**Decontextualized content**

For more than two decades, the lack of relevance of school science, or decontextualized context, has been widely criticized as cause for boredom and subsequent estrangement from science (see, for example, Bennett, 2001; Head, 1985). It is argued that when students are unable to view science as relevant to everyday life they are unable to construct knowledge meaningfully. As a result students are discouraged from pursuing further engagement with science (see Lyons, 2006).

The need for school science to be personally meaningful to students is more pronounced in the individualistic culture of contemporary post-industrial nations (see Schreiner, 2006; Schreiner & Sjøberg, 2007). Tytler *et al.* (2008) explains that the young people in contemporary post-industrial societies are not interested in the values, such as obedience and humility, which characterized the momentum towards industrial development. Instead, they are concerned about "their potential individual contribution to the future" (p.84). In an attempt to contextualized science in terms of relevance to these students, Schreiner (2006) states that school science should “aim to develop in young people a feeling that they can
influence the development at a personal as well as at a wider local, national and even global level” (p.269) (also see Inglehart, 1990).

Neurological studies into behaviour and cognitive development within the past two decades (see, for example, Haier, 1999) further claim that young adolescent students need educational environments that are challenging if they are to learn effectively. For science learning to be meaningful to young minds, Wildy and Wallace (1995) state that classroom science needs to make links which stimulate connections between students and their real world experiences. This claim is consistent with Roberts (1998) who points out that “students always learn scientific concepts in a context, with a purpose” (p.121, emphasis in original).

As a means of contextualizing school science, Davies (2006) recommends that science teaching should be done by “weaving scientific understanding and logic into cultural, social, historical, legal and ethical perspectives” (p. 57). Including social perspectives with which to make meaningful links is consistent with constructivist epistemology (see, for example, Shymansky et al., 1997). In terms of providing constructivist learning experiences Yager (1991) states that “teachers should explore how students see the problem and why their paths towards solutions seem promising to them” (p.55). These views are consistent with Bybee’s (1997) criteria for selecting school science content. Instead of focusing exclusively on abstract scientific facts, Bybee recommends that school science should emphasize the social context of knowledge. Bybee’s criteria for contextualizing school science content are stated as follows:

- Content should have immediate and obvious personal and social meaning to the student: i.e. it extends and elaborates the student’s previous experiences, understanding, and skills.
Content must be challenging, but it must also be achievable at some level by all students.
Content should be taught in a variety of ways that allow the student to demonstrate understanding, skills, and values. (p.75)

There is evidence to suggest, moreover, that context-based teaching actually helps students to learn science more meaningfully. Referring back to intended outcomes for middle school science education, Bennett, Campbell, Hogarth and Lubben (2005) state (in a review paper) that learning science contextually promotes more positive learning experiences about science:

The review has, with some caveats, demonstrated that there is good evidence to support the claim that context-based approaches motivate students in their science lessons ... The in-depth review has further demonstrated that there is reasonable evidence to suggest such approaches also foster more positive attitudes to science more generally. The in-depth review also provides reasonable evidence from four of the five studies to suggest that context-based approaches do not adversely affect students’ understanding of scientific ideas. The fifth study indicated understanding was enhanced (p.4)

However, as documented in the literature, there is little evidence of contextual science teaching in most classrooms. Findings by Rennie et al. (2001) reveal that conventional forms of science instruction featured in most middle schools “offer little challenge or excitement to students” (p.486). Rennie and her colleagues add, moreover, that “the type of science being taught and the learning outcomes being achieved are not those that prepare students for the future world in which they will work and live” (p.473)

In another study of classroom practices of British science teachers, Mayoh and Knutton (1997) found that teachers rarely refer to experiences from students’ daily life (i.e. “no
more than once per lesson” p.861). The researchers lamented that those teachers who attempted to make science more accessible to their students by providing relevant contexts were not only confronted by time limitations but also by their peers, who subscribed to more conventional models of science teaching (also see Fensham & Corrigan, 1994; Volkman, 2000). Moreover, the literature reports alarmingly that while several worldwide efforts which attempt to make science relevant to students reap success in the form of increased post-compulsory science enrolments (see, for example, the LUMA Support Group (2003) in Finland; and Board of Studies (2003) in NSW, Australia), some countries are opting to reinstate examination-specific curricula. The *Hoshangabad Science Teaching Program* in Madhya Pradesh India, for example, which functioned on the principles of teaching scientific content that was relevant to students’ interests, was discontinued in 2000 (Ramachandra, 2002). It was replaced by a more conventional model for science teaching.

While it may be argued that students in middle school find most of their subjects irrelevant and boring, researchers state that students have poorer attitudes towards science than towards other subjects (see Lindahl, 2003; Lyons, 2006). Even among the high-achieving students in Lyon’s (2006) study, for instance, 20% reported that they found classroom science “boring”. These findings are further supported by students’ statements, like the one quoted below. In this statement one of the students in Osborne and Collins’ (2001) study expresses her opinions about school science content, which she believes lacks (immediate) relevance:

*The blast furnace, so when are you going to use a blast furnace? I mean, why do you need to know about it? You’re not going to come across it ever. I mean look at the technology today, we’ve gone onto cloning, I mean it’s a bit away off from the blast furnace now, so why do you need to know it?* (p.449)
Based on these findings it is evident that students are skeptical about the relevance of the science content they are taught in schools. Results from Rennie et al.’s (2001) survey of students’ perceptions of the relevance of school science confirm this notion (see Table 4). The researchers report that while the students held mixed perceptions, the students were broadly consistent in their views that school science was only marginally meaningful at most times:

For most lower secondary students, the science they are taught lacks relevance to their needs and interests, and fails to develop key aspects of scientific literacy. Only about one-fifth of lower secondary students report that science lessons are relevant or useful for them, very often or almost always. About one-third of these students indicate that science never deals with things they are concerned about or helps them make decisions about their health, which raises questions about the appropriateness of the selected content and learning contexts. (p.473)

Table 4: Perceived relevance of science in the secondary school (n=2802)

<table>
<thead>
<tr>
<th>Statement</th>
<th>Percentage of responses</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>The science we learn in school:</td>
<td>Almost never</td>
<td>Some-times</td>
<td>Often</td>
<td>Very often</td>
<td>Almost always</td>
</tr>
<tr>
<td>Is relevant to my future.</td>
<td>19</td>
<td>36</td>
<td>23</td>
<td>13</td>
<td>9</td>
</tr>
<tr>
<td>Is useful in everyday life.</td>
<td>18</td>
<td>40</td>
<td>24</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td>Deals with things I’m concerned about</td>
<td>31</td>
<td>36</td>
<td>19</td>
<td>10</td>
<td>4</td>
</tr>
<tr>
<td>Helps make decisions about my health</td>
<td>35</td>
<td>35</td>
<td>17</td>
<td>9</td>
<td>4</td>
</tr>
<tr>
<td>Helps understand environmental issues</td>
<td>12</td>
<td>31</td>
<td>28</td>
<td>19</td>
<td>10</td>
</tr>
</tbody>
</table>

(Source: Rennie et al., 2001, p.474)
Other researchers have also found that students’ complaints about the irrelevance of school science to their daily life are echoed by the students’ parents. Simplicio (2005), for example, states that many parents are expressing concern about the science their children are learning in schools. These parents do not believe that most of the content which is covered in school science is relevant to actual science learning. Teachers are, however, reluctant to accept that such core-concepts in science (like the basics of iron-ore extraction, in the preceding quote, for example) could be regarded as irrelevant. Teachers continue to argue that students need to know such information, in order to learn science (see, for example, Kennedy, 1991).

Lindahl (2003) points out, however, that it is the way in which scientific content is presented rather than the content itself that troubles students. This is illustrated by one of her students’ responses, which compares school science to science in the popular media:

\[ I \text{ like to read scientific books and magazines and watch such programs on TV. All I know I have learned that way, and I really like science. But I don’t like that sort of science we have to learn in school. (http://www.mna.hkr.se/~ll/summary.pdf) } \]

While science in the media and popular culture are often presented as exciting and adventurous, Fensham (2007) remarks that these features of science do not transfer to the classroom. Often school science is presented as boring. This is also observed by Bryson (2003), the author of *A Short History of Nearly Everything*. In the following extract Bryson describes his experience with a “forth or fifth grade” science textbook that featured a sectional drawing of the Earth’s interior:
Excited, I took the book home that night and opened it before dinner...And here’s the thing. It wasn’t exciting at all. It wasn’t actually altogether comprehensible. Above all, it didn’t answer any of the questions that the illustration stirred up in a normal inquiring mind...There seemed to be a mystifying universal conspiracy among textbook authors to make certain the material they dealt with never strayed too near the realm of the mildly interesting and was always at least a longdistance phone call from the frankly interesting.” (Third page)

Experiences with school science that fail to be personally meaningful have thus given rise to the widespread belief among students that science is important – but not for me (Costa, 1995): a predominant attitude that resurfaces in the ROSE Project (Sjøberg & Schreiner, 2005). Other contemporary studies have come across similar results. One such example is a revelation by one of Lyons’ (2006) students when quizzed about the importance of science:

Oh, of course I do. Science is everything! But I’m not particularly interested in it...That’s quite a contradiction really...(p.128)

It is evident from the above statement that the student is trapped between socially accepted fact that science is important and his personal perception that science is not particularly interesting. As Roth (1994) explains, one cause for this dilemma is that science teaching continues to be fashioned on models that answer questions which are external to students’ interests. The models attempt to teach science through cookbook-type laboratory exercises, aimed at reproducing conventional wisdom with scant room for originality, creative use of language, or speculation. Teaching science in this way, Cavicchi (2006) points out, “leaves personal questions unanswered and perhaps even invalidated” (p.88). These negative perceptions of school science, being either boring, irrelevant or both, predispose students’ against science and effectively discourage them from further formal engagement with
science (see Lindahl, 2003). Lyons (2006) adds that such an approach may also serve to dissuade those who already foster a general interest in science. He states that “not only is school science failing to engage students who are ambivalent towards science, but it is discouraging many who already have such an interest” (p.601). Discouraging students who are interested (and even proficient) in science is also assisted by the perception of school science being unnecessarily difficult. This third (and last) feature, that Lyons has identified to be endemic to science teaching in middle school, is described next.

**Unnecessary difficulty**

The perception that science (particularly the physical sciences) is difficult, is shared even among students who are proficient in science. This is, however, hardly the consequence of the intellectual challenges associated with learning science. Instead, as Lyons (2006) points out, the perception that science is difficult emerges cumulatively from students being exposed to the two previously mentioned features of middle school science teaching; i.e. the lack of relevance of school science content to students’ daily lives, and the disengaging manner by which science is taught, (i.e. “the difficulty of school science comes from the frustration associated with passive learning, memorization, or the irrelevance of the content, rather from any intellectual challenge” (p.603).)

Other researchers also share similar views. Stocklmayer (2001) states, for instance, that because of the emphasis school science places on remembering facts and formulae, it deprives students from seeing the relevance of science in everyday life. For these students, learning science translates into an exercise that is “hard, boring and not important for real life” (p.18 emphasis added). Tytler (2007) echoes similar sentiments. He states that:
Student attitudes towards and engagement with school science relate to the transmissive and limited pedagogies used, and the major focus on canonical abstract content that fails to enlist student interest and renders science ideas unnecessarily difficult. The fact that this is the case for all students, including successful science students, must give pause for thought. (p.12)

Another key element associated with the difficulty of science is found when students are asked to list a comparative hierarchy of difficulty across science subjects. A study by Hendley, Stables and Stables (1996) found that students considered physics by far the most difficult, followed by chemistry and then biology. Later studies by Osborne and Collins (2001) agree that pedagogical differences in these subjects contribute to their perceived levels of difficulty among students. The researchers state that “physics teaching often begins with an abstract concept, only belatedly referring to its technological applications. Biology, on the other hand, is routinely taught with reference to examples and applications” (p.406).

There is also evidence to suggest that many (but not all) female students perceive science to be unnecessarily difficult (see, for example, Jones, Howe & Rua, 2000; Speering & Rennie, 1996). Studies have found that a greater proportion of high-achieving female students rate their ability in science significantly lower than their male counterparts (see, for example, Lyons, 2003; Leslie, McClure & Oaxaca, 1998). Speering and Rennie (1996) point out that this belief held by female students stems from the less positive teacher-student relationships at secondary level. Since learning science is often associated with teachers guiding students through unfamiliar terminology and concepts, (especially but not exclusively) female students relate better to teachers who could guide them through uncertain terminology and scientific concepts, hitherto alien to them (i.e. “help you through it” p.40, Osborne & Collins, 2001). As one of Lyons’ (2003) students, explains:
(I chose chemistry) because of our teacher, last year. He was really good at explaining things and even if we asked, like really stupid questions he didn’t laugh, he sat down and answered them. (p.109)

Unfortunately, fewer elements of guidance of this type are part of the abstract, content-oriented middle school pedagogy. Less involvement in decision making and collaboration between teachers and students (\textit{i.e. Balkanization}, see Hargreaves & Earl, 1994), which characterize the academically-inclined, subject-fragmented orientation at secondary level, are sharp contrasts for students (girls in particular) who have been accustomed to more caring cultures endemic to primary school. Due to the impersonal nature associated with science teaching in middle school “many students – especially, but not only, women – are convinced that science is exclusive and denies them admission” (p.88, Cavicchi, 2006). As a result of this, Speering and Rennie (1996) point out that most female students are predisposed to disassociate themselves from learning science.

The argument that female students are predisposed against science is also supported by Hanrahan (2003) by what she calls the \textit{mystery of scientific discourse}. Hanrahan points out that unfamiliar terminology and the disengaging way in which scientific concepts are taught create an exclusivity that denies access to those who are unable to participate in this (mysterious) discourse. Although not pertaining directly to female students, other researchers like Lemke (1990) have agreed that the apparent mysterious nature of science contributes to it being perceived as difficult:

…the content of the science curriculum, and the values that often go with it, science education, sometimes unwittingly, also perpetuates a certain harmful \textit{mystique of science}. That mystique tends to make science seem dogmatic, authoritarian, impersonal, and even inhuman to many students. It also portrays science as being much more difficult than it is…It alienates students from science. (p.xi)
Hanrahan (2003) states that in such situations it is easy for female students to perceive themselves to be excluded from science which emphasizes masculine values.

Kelly (1985) has identified several masculine features that are endemic to science. Among these features, she claimed that textbooks and other media that are used to present school science engendered more masculine examples of scientific concepts. As a consequence, she pointed out, these materials perpetuated a masculine interpretation of the natural world.

Drawing on earlier research Taconis and Kessels (2008) add that:

(Science) comprises elements historically rooted or functional within classical academic scientific practice: a certain kind of masculinity (or more precisely, non-femininity), a preference for the conveying of content rather than the process of communication, a tendency to be rational and to put emphasis on rational explanation over emotional aspects of communication, a tendency to make things technically objective wherever possible, and a tendency to refrain from placing emphasis on personal presentation. (p.16)

Although attempts have been made in recent years to redress masculine overrepresentation in school science curricula and textbooks, Stocklmayer (2001) states that these media still communicate predominantly to a male audience. Stocklmayer points out, for example, that despite the efforts to include gender-neutral examples in textbooks, these nouns are often translated into male characters by female students:

From my own observation, when a group of 14-year old girls were given a physics problem involving a bird, it evoked responses from all 30 students which referred to the bird as he. Reasons for this are not well understood...(p.7)

Feminist perspectives into the nature of science support claims that science is communicated to appease masculine ways of knowing (see, for example, Belenky, Clinchy,
Goldberger & Tarule, 1986). These studies argue that the processes of female cognition are dissimilar to those of males. Women’s ways of knowing involve holistic approaches based on intuition and non-hierarchical interactions. The researchers point out that these processes are, however, contradictory to the objective, abstract and value-free representations endemic to formal science instruction.

Irrespective of the disengaging manner in which school science is taught, the irrelevance of its content to students, the fact that some scientific concepts are easily grasped than others, the exclusivity of classroom science discourse rendered by unfamiliar terminology or gender exclusivity, or a combination of these reasons, the literature is consistent in the view that the composite image students develop about science “has significant implications for our understanding of declining enrolments in science courses” (p.605, Lyons, 2006), and may also explain why “adolescents who associate science with difficulty due to their school experiences are likely to carry that association into adulthood” (p.604).

As the preceding sections described, transmissive pedagogy, decontextualized content and the unnecessary difficulty of school science, are identified prominently in the literature as features that discourage students from learning science in middle school. Researchers like Lyons (2006) argue that the continued effects of these features predispose students against post-compulsory engagement with science. These three features of teaching are, however, not the only reasons for students to find school science disengaging. A reading of the literature reveals that two other properties of science, which when transferred into the contexts of the classroom, serve to make school science unappealing to some students. These are identified as the language of science and the apparent Western ownership of science. The possibility that these two properties of science may dissuade large cohorts of students from learning and engaging with science requires pause for thought.
Language of science

It has been stated earlier in this chapter that unfamiliar scientific terminology that is often used to teach science promotes ambiguity among students. The *mystery of scientific discourse*, as Hanrahan (2003) called it, alienates students who find it difficult to communicate across this divide. As Montgomery (1996) states, “technical language sets up a barrier between those who can speak and understand and those who cannot” (p.7). He adds that “the language of science is the tongue of foreigners, equally exotic whether spoken in the narrative hut of the laboratory or the villages and cliff-dwellings of the professional meeting” (p.9). The technical vocabulary and structure of scientific discourse emphasize that it is exclusively for the scientific community.

Halliday and Martin (1993) describe, however, that the language of science has developed to provide an effective medium for communication within the scientific community. As Johnson (2007) states:

Science has a rich history of service to humanity. When scientists present their lectures with no allusion to this context, it may not be because they are uninterested in it but only because such ties are so obvious to them already. (p.819)

As a result of their many years of training, science teachers may, therefore, be more accustomed to the language and terminology used to conventionally communicate science (see Larochelle, 2002). Consequently, in most instances, they (unconsciously) perpetuate this element of inaccessibility when they teach science. However, Palmer (1999) points out that such precise and unfamiliar usage of language “makes considerable demands on students” (http://www.ul.ie/~childsp/CinA/Issue60/TOC28_Crisis.htm).
In addition to these technical difficulties, which need to be negotiated when communicating science, researchers point out that the utterly objective tone of scientific discourse makes science more inaccessible to students. Meyer (1998) states that scientific discourse in the classroom poses numerous obstacles: “its formal nature, the vernacular is unheard of, and comfortable patois has no place” (p.467). Sutton (1992) argues that the impersonal language that is absent of actual human involvement adds to the perceptions of science being difficult and irrelevant. Expounding this view, Sutton (1996) states that elements of human agency, such as, curiosity, tentativeness, uncertainty and speculation, are inherent features of scientific discovery; and that they need to be reflected when science is communicated to students:

A mixture (of personal, figurative analogy and tentativeness) is probably fundamental to the process of communication, persuasion and counter-persuasion which occur in scientific groups in any age, and if we disguise it or ignore it in school, the classroom experience will continue to be a misrepresentation of what scientists do. (pp.3-4)

Other researchers also share this view. Abd-El-Khalick, Bell and Lederman (1998), for instance, state that students need to experience science as the product of human inference, imagination and creativity. Others like Gopnik, Meltzoff, and Kuhl (1999), have attempted to illustrate these features about science through the descriptive accounts of scientists. They draw similarities, for example, between the curiosity of young children and the inquisitive, speculative and often playful research of scientists, whom they state are like big children and intent on making sense of their world. In one such example, Gooding (1990) states that “Faraday's work often displays this creative use of ambiguity and uncertainty” (p.207); where it is seen that “a threshold of ambiguity or confusion must be reached before thought
is compelled to experiment in a manner that is open to conceptual reform”. Another more recent quote that attempts to similarly describe the curiosity of Isaac Newton states:

> There is not a single idea in the head of the most brilliant of scientists that did not start with at least one of the senses... Consider Newton: whether or not the apple physically fell on his head, he would have seen it, felt it, heard it fall, smelled it - undoubtedly tasted it and his sixth sense did the rest. (Riggs on *Ockham’s Razor*, http://www.abc.net.au/rn/ockhamsrazor/stories/2007/1965395.htm)

The perceptions rendered by the above two quotes (*i.e.* that science is a truly human enterprise), reverberate consistently with science historians’ definitions of science. For example, science as defined by Mason (1953) is a “human activity which develops a historical cumulative body on interrelated techniques, empirical knowledge and theories, referring to the natural world” (p.488 *emphasis added*). Another more recent definition by Kelly, Carlsen and Cunningham (1993) identify science as “a socially constituted enterprise shaped at many levels by human values, beliefs and commitments” (p.210 *emphasis added*).

The eminent science historian Sarton (1948) points out that teaching science with reference to its actual human involvement is consistent with the historical and philosophical rationale for science; *i.e.* a “human activity which is truly cumulative and progressive” (p.48). Moreover, pedagogy of this nature helps to emphasize that “science is not about truth, but about the collection and interpretation of data, followed by reformulations of explanations as more data are collected” (p.220, Greenwood, 2003). This opinion is consistent with earlier recommendations for inquiry-based active approaches in science teaching (see, for example, NRC, 1996). It is further elaborated, in terms of goals for science education improvement, in the *Benchmarks for Science Literacy* (AAAS, 1993) as follows:
All (scientific) research revolves around inquiry – a question to which the answer is not readily available...The second element of research, investigation, involves gathering data in a critical, exhaustive way. Experimentation is often necessary and leads the way to discovering new facts. Equally important as an element of research is interpretation, making sense of the data by using critical analysis skills, knowledge of the area, and imagination. (p.179 emphasis added)

Sutton (1996) laments, however, that these human elements do not follow through when science is communicated in the context of most classrooms. Instead, he states, they are replaced by a tacit labelling system, which as a consequence provides students with an impression far removed from what science actually is. In doing so, Sutton points out, these attempts disguise, under-represent and sometimes even suppress the human agencies that are endemic to science. He states that “school science is often conducted as if it were a study of Nature directly, rather than a study of what people have thought and said about Nature” (p.15).

This feature is aggravated further by the fact that many science education settings fail to present scientific information as interpretations derived from models invented by people to explain natural phenomena. Instead, as Yager (1991) describes, they use language itself as a source of meaning:

…the use of language per se in teaching cannot be a means of transferring information. Language must have meaning and not a source for it. We use language to cope with the environment, to help us make sense of our world, and to communicate how we can use the meaning formulated. (p.55)

A review of school science textbooks by Selly (1989) reveals that secondary school science texts, in particular, portray such a distorted image of science. They depict science as a
sequential logical process where scientific evidences apparently pave the way for the
discovery of pre-existing scientific truths. Selly found that human elements of scepticism
and adventure that were used to present scientific knowledge (as tentative and open to
philosophical debate) to younger learners (i.e. 11-14 year-olds) did not continue into upper
secondary level science texts. It is paradoxical, he states, “while passages discussing the
rudiments of scientific method are not rare for younger pupils, almost nothing of this kind
is to be found in books for the 13-16 age range” (p. 27). Selly adds:

Most school science textbooks are utterly unsceptical. Indeed, there seems to have been a return, since 1980, to a non-participatory transmission style, in which it is implied that the information and explanation being presented is simply the truth...thus the reality status seems to be also attributed to such defined quantities as density, electrical resistance, specific heat capacity, force, and kinetic energy (examples from other sciences might include chemical elements, valency (or oxidation number), the electrochemical series of metals; and biological constructs such as the organ and the cell, and taxonomic sets such as phylum, and even species). Students are never invited to question whether something, like Centre of Gravity, is real, nor asked by what means they might test its reality. (p.29, emphasis added)

Eltinge and Roberts (1993) findings are consistent with these views. Based on a linguistic analysis of textbook content they have stated that “science textbooks tend to present science more as a body of information than a method of inquiry” (p. 81). Brush (1989) states that science teaching modelled on representing science as a series of significant outcomes, that are contextualized within the framework of successful experiments, does not allow students to reflect upon the actual nature of science. Teaching science in this manner

---

8 These findings are collaborated by Rennie et al. (2001) who observed that student-centered, activity-based science teaching in primary school, also allowed for greater freedom for investigation and inquiry. As a consequence they promoted higher levels of student satisfaction. The researchers report that while 62% of their primary school respondents described science lessons as “always” and “often” “fun”; only 30% described science to be “boring”.

86
deprives students of an awareness of the complementarity of scientific progression with respect to human history (see Driver & Bell, 1986). In doing so, Aikenhead (2006) adds, it censors the great human drama involved in science. This aspect of school science is explained by Black and Aitkin (1996) as follows:

...school programs have usually portrayed [science] as a relentless search for the truth. This is how scientists seek to understand how the world works, students are told: they put questions to nature; they hypothesize about why certain things happen; they test their hypothesis; and they draw conclusions based on their observations and experiments. Next, other scientists, following well-understood and accepted canons, verify (or fail to verify) their claims. And thus new knowledge is generated. It is an objective process. There is little room for the personal, little acknowledgement of human feeling or failing...But scholars who study the nature of science more and more perceive that science is not the disembodied and idealized search for new knowledge portrayed in most elementary and high-school textbooks. It is a human activity. Real men and women do science. They do not work mechanically... Also, scientific activity has no single purpose that transcends all others, no overriding goal that energizes all scientists. (p.33)

Cavicchi (2006) points out that teaching science as a logical and sequential process reiterates previous concerns about presenting science as canonical and absolute. Moreover, Brush (1989) states, doing so deprives students of an opportunity to build links by which to construct scientific knowledge for meaningful learning. Many students, Brush claims, therefore, share a disconnected belief about scientific experiments and theory because of this false dichotomy; i.e. separating science content knowledge from the scientific processes by which it was developed. They are prone, as a consequence, to identify theory with the term discovery, as opposed to invention⁹ (see, for example, Duveen, Scott & Solomon, 1993; Ryan & Aikenhead, 1992). The anxiety, expressed by Sarton (1948) earlier, that such a naïve view would allow students too synthetical an approach towards

---

⁹ An ‘invention’ is only an interpretation and thus may provide an explanation that is modified to suit socio-cultural contexts and not entirely consistent with the actual nature of scientific discovery (see Strathern, 2001).
science learning, has been confirmed half a century later by Justi and Gilbert (1999) who state:

In many present day science courses science is presented as a collection of agreed upon facts; the methodology for the production of scientific knowledge is presented as homogenous and based on empiricism, leading to a static and context-independent creation/discovery view of outcomes; and students memorize the specific facts presented to them without questioning either their development or relationship to other scientific or non-scientific knowledge. (pp.163-4)

Fensham (2000) states that to foster such a view in regard to science discredits the democratic human spirit behind scientific enterprise. Moreover, he states in a later paper (see Fensham 2007) that doing so defeats education efforts aimed at fostering an overall understanding of science and its role in society:

Many students who are successful in school science know a lot of bits of scientific information, but have little or no sense of how this knowledge has been established, and what might lead to it changing. Without a good sense of these aspects of the strengths and limitations of the science knowledge…they are deprived of what gives science the power and influence it has on our lives as members of society. (p.2)

**Apparent Western ownership of science**

Costa (1995) claims that students from non-Western cultures are further challenged when attempting to learn science content that is decontextualized. Because these students find it more difficult to relate to abstract scientific ideas, Costa argues, it is not surprising that they use phrases like “the world of chemistry” (p.313), to describe bodies of abstract scientific knowledge. Needless to say, school science presents these students with a foreign world that is incongruent with their daily lives and own cultures. One such example is presented
by Akatugba and Wallace (2008) with reference to the alien nature of the concept of proportional reasoning to West African students. They state:

While adolescents in western countries use proportional reasoning in everyday activities, such as in the use of road maps, cooking recipes, comparison shopping in price per kilogram, fuel economy, and unit prices, adolescents in many developing countries rarely engage in such activities. In Nigeria, for example, shopping is done mainly by bargain and haggle, while successful cooking is done by mental calculations, tasting, and experience. (p.16)

Waldrip and Taylor (1999) point out, however, that students from non-Western cultures are compelled to compartmentalize their learning of (Western) science if they are to survive the processes of schooling. This is because, as Pamba (1999) has described with reference to Melanesian students studying abroad, the prospects of employment and other social benefits encourage non-Western students to learn science by separating information from their own cultural constructs in order to guarantee success at examinations. Findings from the ROSE Project substantiate the fact that non-Western students are compelled to learn Western science because of the high social status that is involved (Sjøberg & Schreiner, 2005). This study and other recent studies (see, for example, Koren & Bar, 2009) have revealed that students in several non-Western nations, particularly under-developed countries, foster more positive attitudes to school science.

Phelan, Davidson and Cao (1991) point out, however, that attempts at learning science by non-Western students are not always smooth (as illustrated in the above example about Melanesian students studying abroad). School science can conflict with students’ traditional cultural constructs, especially when these latter constructs are in wide use by their family and peers (see, for example, Hodson, 1999; Pauka, Treagust & Waldrip, 2005).
Aikenhead (2001b) states that bridging between unfamiliar concepts in school science and the familiar “world-views, identities, and mother tongues” (p.338) is, therefore, a challenge that disadvantages students from non-Western cultures. He states elsewhere (see Aikenhead, 2001a) that:

Because science is necessarily embedded in a culture, science does not transfer easily into other cultures,…This problematic transferability was amplified by communication problems that arose when Western science was taught to a non-Western public. Western science, with its own set of norms, values, beliefs, expectations, and conventional actions, turns out to be only one way of making sense of nature. (pp.41-42)

Aikenhead and Ogawa (2007) state that an uncontested single (Western) view towards science marginalizes a considerable proportion of students worldwide. These students’ cultural self-identities make learning science a cross-cultural experience (also see Harris, 1978; Kawasaki, 1996; Larochelle, 2002, Ogawa, 1995). The researchers point out, therefore, that learning science can challenge students from non-Western cultures by confronting them with cultures-frontiers. These frontiers or borders are often represented by science classrooms, practical laboratory classes and even in the general discourse that accompanies school science. For some students, Palmer (1999) explains, these cultural frontiers can be extremely confrontational; so confrontational that learning science becomes a “source of symbolic violence”; where they “feel their world views threatened by the content and discourse of science teaching” (http://www.ul.ie/~childsp/CinA/Issue60/TOC28_Crisis.htm).

Johnson (2007) supports this view, and claims that by merely posing a question to the classroom, for instance, a teacher may enforce white male values of competitiveness and self-confidence. These have the potential to translate into intimidation which might be felt
by non-Western (and female) students. As Fox Keller (1985), quoted in Stocklmayer (2001), explains it is reasonable to expect such outcomes from science, given that “the Royal Society of the 17th Century which formed the foundation of Western science explicitly stated that their science was *masculine and durable*, seeking to capture and control a *female* Nature in ways not hitherto sought” (pp.4-6).

Inarguably, an important element of science since the 16th Century has been its strong Western characterisation (see McMullin, 1990). Despite secular knowledge extricating itself from Christian belief systems in the early Seventeenth Century, Gascoigne (1990) points out that a strong Western presence has continued to dominate all realms of science since the *scientific revolution*. Historians believe that the fall of Muslim Spain and the separation of the Jews, which permitted Christian supremacy in affairs of governance, may have caused the Western presence to engulf all intellectual pursuits at the time (see, for example, Huff, 1995; Sarton, 1948). Historians agree that in such a climate it would have been difficult to conceive anything other than a Western-Christian presence for science. Sadly, these historians add, any claims to the Eastern origins of science were gradually disowned while science, as we see it today, adopted an exclusively Western image and discarded its oriental garbs.

While the above argument purports that a Western presence for science has been accomplished by historic transitions that favoured Judaeo-Christian political structures, other scholars state that the culture of science has (in itself) perpetuated Western culture (see, for example, Baker & Taylor, 1995; Ogawa, 1995). Aikenhead (2001a) states that this is because science presents itself as a “Western cultural icon of prestige, power, progress, and privilege” (p.31), hence it is possible to disseminate Western values when science is presented to non-Western audiences. The researcher further explains that “the
encroachment of Western culture occurs, in part, because it is hidden in the Trojan horse of Western science” (p.32).

Harding (1991) argues, however, that these explanations do not solely justify the inclination of science towards the West (which she describes as “North Atlantic white Caucasian male science” p.209). Instead this feminist scholar states that the historical over-representation of achievements by North Atlantic Indo-Aryan races is exclusively responsible for the Western perception of science today. Similar sentiments have been echoed by Sarton (1948) earlier:

Universal histories have been almost exclusively devoted to the achievements of the Indo-Aryan race. Everything in them gravitates around the development of Europe. Of course this point of view is absolutely false. The history of (hu)mankind is too obviously incomplete if it does not include, on the same level as the Western experience, the immense experience of the East. (p.56)

Khan (2006) from the Science Museum in London supports this argument. She states that negligible effort is made to make students aware about how modern science has been historically enriched by non-Western traditions. She laments the Euro-centric teaching in most school subjects including science, and states that while school history textbooks, for instance, meticulously record happenings in Europe during the Dark Ages (600 - 1600 CE), the scientific, technological and engineering advancements by non-Western peoples at that time are hardly acknowledged. Moreover, there is no mention that these latter movements paved the way for the Renaissance in Europe. As Khan explains, students are consistently informed only about the Western advancements in science:

Isaac Newton, Charles Darwin and Albert Einstein. The chances are that if you try to remember which scientists you were taught about at school, these
names will be on your list. But how many students will learn about scholars from non-Western civilisations, such as Ibn al-Haitham, a Muslim scholar of optics who first developed the laws of light reflection and invented the pinhole camera in the 11th century? Or Ibn Nafis, who first recorded observations on pulmonary blood circulation, a theory attributed to William Harvey 300 years later? How about Abbas ibn Firnas, who made the first attempt of human flight in the 9th century, using adjustable wings covered with feathers? And how many would know of Zeng He, the Chinese Muslim admiral who used refined technology to construct fleets of massive non-metal ship vessels five centuries ago? (http://www.scienceinschool.org/2006/issue3/missing)

Scholars believe that scientific traditions among African, South and Southeast Asian peoples are of equal historical significance when attempting to produce a complete and unbiased account of the history of science (see, for example, Needham, 1969; Razaullah Ansari, 2002; Van Sertima, 1983). There is contention, however, whether these sciences constitute science proper or if they are mere technologies. An example of this contention is highlighted by Mahroof (1998) who points out that a substandard view of medical practices of non-Western peoples had been maintained in British colonial records till as recently as the 19th Century. This, however, leaves room for a mistaken understanding that the empirical inquiries and intellectual pursuits of peoples from non-Western cultures do not constitute science, a term which Harding (1991) argues is used exclusively to describe North Atlantic scientific traditions:

These (non-Western) sources do not bring with them many footnotes of five centuries of testimony by Western scientists and observers of science as recorded in books, libraries, and doctoral dissertations – although they do bring a few. These sources definitely feel lighter in weight, more fragile, in evidential underpinnings. It is as if they veer off the road at some moment or other and then move off on newly visible paths into other worlds where our narrative has never ventured. (p.221)
It is not possible, however, to discern the science of a given age and location without understanding the values and practices of people therein (see, for example, Gilbert et al., 1999). Thus the empirical inquiries and intellectual pursuits of non-Western peoples, including the examples above, are reflections of their unique scientific spirits. Moreover, not unlike the West, these pursuits are utilitarian responses to challenges posed by the times in which they lived and also their geographical distribution (see Usher, 1954). Sarton (1948) claims, therefore, that it is impossible to discern a form of science which is more superior. Despite these arguments, some studies contend that Western science should enjoy a more elevated status:

A group may decide that their own cultural orientation is of overriding importance, and that they wish to give pre-eminence in education to their own cultural tradition… but as with all decision-making, it needs to be informed, and decisions need to be made with regard for the consequences. To make decisions on the basis that ethno-sciences are cognitively equivalent to Western science is a mistake. (Matthews, 1994, pp.197-8)

Keita, (1977) states that such views, which acknowledge Western science as the only credible form of science, are harmful. Such views advance the notion that science, as we see it today, was developed only in one culture (i.e. the West), despite the numerous empirical and intellectual traditions that have been fostered in other cultures. These distorted views advantage a Western ownership of science. Addressing such preconceived biases about science in Africa, Keita states that it is a popularly held belief that Egyptian and Greek sciences are more closely linked to Europe than to Africa. Inaccurate perceptions such as this one are schemes that have been devised to distinguish North Atlantic scientific traditions and disadvantage the scientific histories of Africa. Harding
(1991) states that such fragmented origins stories\textsuperscript{10} about science serve only to distinguish the Western scientific tradition as a more superior one:

In the Western story, Third World peoples appear as primitives, as children, as barbarians and savages, as outside of history and culture, with no redeeming cultural achievements. They are an obstacle to \textit{human progress} and a threat to the West unless they are supervised by Westerners. (p.237)

Other researchers state that a Western ownership of science is based solely on political and economic motives (see, for example, Goonatilake, 1987; Shiva, 1997). In order to ensure Western supremacy, these researchers argue that significant scientific and technological advances in the Third World need to be continuously absorbed into North Atlantic economies. In doing so, Goonatilake (1987) states, scientists in the Third World are trained to communicate exclusively with audiences that are predisposed towards Western beliefs and values. Even when science is communicated within non-North Atlantic cultures, he laments, it identifies predominantly with North Atlantic syntax and imagery:

Third World scientists are led to speak and write primarily to and for an audience of Western listeners and readers; the intellectual and technological world systems make it unreasonable for them to be primarily interested in Third World (\textit{i.e. their own}) audiences. (p.890, \textit{emphasis added})

These views are echoed by Hwang (2005). Based on a study of scientists and engineers in Korea, Hwang states that Korean scientists and engineers are led to believe that being able to communicate in English is crucial to their careers:

\ldots learning English is essential for their scientific activities, especially their need to acquire scientific knowledge and up-to-date information\ldots This becomes a social structural problem because the acquisition of English is a prerequisite for non-native English-speaking scientists and engineers.

\textsuperscript{10} Anthropological term used to describe ideologies associated with a particular race of people.
Furthermore, the rare use of English for knowledge production in the Korean setting causes severe difficulties for them in getting their scientific knowledge accepted and recognised at the international level. (p. 420)

As a consequence, Korean scientists and engineers perceive their position as peripheral to mainstream science and innovation by Western countries. This leads to a depreciated view and prejudice against their own culture. Hwang holds that this prejudice, which is triggered by the need to communicate to Western audiences, is the reason senior scientists and engineers from Korea opt for more junior positions in British laboratories.

Because the same tendencies to communicate exclusively with Western audiences permeate even the classroom, school science seems foreign to students who do not share these Western values and beliefs (see Aikenhead, 1996). As Waldrip, Timothy and Wilikai (2007) state:

Students conceptualise science as consisting of superior words and concepts but are often unable to relate these terms and concepts to their life experiences…While they might have a superior attitude to what science can do, they fail to internalise the real meaning and value of using science to understand their world. (p.120)

Hence learning science in school demands alteration of personal identities and belief structures from students who are not from North Atlantic cultures. Being confronted with such a challenge is an ordeal for some students as Palmer (1999) has described earlier (also see Larochelle, 2002). This may also explain the significantly low secondary science retention levels of Indigenous Australian students (i.e. 39.5% compared to 76.8%, non-indigenous Australian students: AESOC Senior Officials Working Party on Indigenous Education, 2006). It may also shed some light on the 2006 PISA (OECD, 2006) findings
which reported that only few students from non-English language backgrounds were able to obtain a proficiency level 2, in comparison to native English speakers, who performed significantly better.

Aikenhead (1996) points out, therefore, that establishing *personal meaningfulness* of school science content assumes entirely different dimensions of complexity in the case of non-Western students. Before they feel familiar enough to learn science, he states, these students first need to feel comfortable about the way science is communicated. Students from non-Western backgrounds need to feel at ease and need to be offered a flexible approach to navigate across cultural borders when learning science.

It is apparent, therefore, that the language of science and also the seeming Western ownership of science can contribute (like the three other features mentioned earlier; *viz.* transmissive pedagogy, decontextualized context and the unnecessary difficulty), to make school science unappealing to many students. As Stocklmayer (2001) states, it is only reasonable for many students to feel excluded because of the unfamiliar language and cultural non-identify they experience with mainstream science:

> All people, Western or not, seek relevance for their understandings. A discipline which holds abstractness and objectivity as high virtues becomes, for the ordinary person, irrelevant. When that same discipline cloaks its doctrines in mystical, inaccessible language it becomes remote and elitist. Small wonder, then, that the excitement of science, its potential for positive change and its power to describe the natural world remain the province of a privileged few. (p.18)
Summary: Part 2

Part 2 of this chapter examines several features that are endemic to middle school science teaching, which have been identified in the literature as reasons for students’ disengagement with science.

Teaching that directly transfers scientific information to students (i.e. transmissive pedagogy), school science content that lacks relevance to students’ daily life (i.e. decontextualized content), and the belief held by many, but not all, female students that science is difficult, are some of the features that have been criticized. It has also been identified from the literature that the impersonal and inaccessible language used to communicate science, and the apparent Western ownership of science can also be a confronting experience for students.
Chapter Summary

Chapter 3 reviewed the literature in the area of formal science education in middle school.

The first part of this chapter recounted the mounting level of dissatisfaction that has been directed at science teaching in middle school, and the attempts that have been underway internationally during the past two decades to counteract students’ disengagement from science. Part 1 described a key reform effort, viz. inquiry-based pedagogy, which is believed to make learning science more personally meaningful to students. Many international directives to reform science teaching in middle school have, therefore, called upon teachers to move away from hitherto used teacher-centered pedagogy, and to help students to construct personally meaningful understandings about science.

In spite of these efforts, Part 2 of this chapter describes several features that persist in middle school science teaching which discourage students from engaging with science. These features include transmissive pedagogy, decontextualized science content and the perception of school science being unnecessarily difficult. Two additional features have also been suggested in the literature. They are the language of science, which misrepresents the actual human agencies that are involved in science, and the overt Western representation of science, that disadvantages students from non-Western cultural backgrounds when learning science.

Having thus reviewed the processes by which middle school science fails to engage students, the next chapter looks at the bases that predispose science teachers to persist with this type of pedagogy.
Chapter 4: Science teacher education

Chapter Overview

Part 1: Teachers’ beliefs about teaching and learning
   Lack of awareness of genuine alternatives 105
   Influences of school culture and availability of resources 108
   Examination-oriented focus 112
   Perception that students have blank minds 113
   Uncertainty in constructivist classrooms 116
   Reliance on textbooks 118
   Lack of an adequate science background 121
   Summary 124

Part 2: Teacher education 126
   Teacher change 126
   Preservice training 128
   Inservice professional development 131
   Constructivist focus 134
   Short-term professional development 141
   Summary 146

Chapter Summary 148
Chapter 4: Science teacher education

When introducing science that promotes the development of scientific literacy one would expect to see changes to teaching and learning strategies in our classrooms... Some of these changes will require significant and sometimes fundamental changes in teachers’ practices, and their beliefs, it is not a simple matter of “fine tuning”.


Part 1: Teachers’ beliefs about teaching and learning

In their report to the Australian Council of Deans of Science, Harris, Jensz and Baldwin (2005) state that:

The quality of science teaching in Australian secondary schools is central to nurturing scientific understanding, inquiry and enthusiasm and to laying the foundations for the education and training of future generations of Australian scientists and researchers. The importance of well qualified, committed science teachers in motivating and inspiring students hardly needs reiterating…(p.1)

Statements such as this one echo sentiments across the literature that advocate that school science foster meaningful learning experiences to which students can relate not only in the classroom but also in later life. Science education reform efforts that promote such experiences are, however, hard-fought when teachers, particularly in middle school, adopt pedagogy which discourages students from actively engaging with science (see Chapter 3). In spite of the vast body of national and international literature, which informs teachers about inquiry-based pedagogy to teach science, Goodrum et al. (2001) state that the actual picture in most science classrooms seems to be otherwise:
The actual picture of science teaching and learning is one of great variability but, on average, the picture is disappointing. Although the curriculum statements in (Australian) States/Territories generally provide a framework for a science curriculum focussed on developing scientific literacy and helping students progress towards achieving the stated outcomes, the actual curriculum implemented in most schools is different from the intended curriculum. (p.viii)

Despite numerous efforts to promote active inquiry, it is evident that teachers are reluctant to move away from traditional models of pedagogy (see, for example, Brophy, 1989; Caprio, 1994). Yager (1991) states that “during the last three decades faith in objective scientific knowledge has served as the unquestioned basis for most of the teaching in K through 12 schools” (p.53). This view is shared by more recent scholars. As Tytler (2007) claims almost two decades later, very little has changed in terms of teaching science; i.e. “the broad shape of science education has remained relatively unchanged, at least in its official guise, for the last half-century at least, and this shape has been similar across the developed world” (p.3).

Researchers, including Porlán and Martín del Pozo (2004), continue to find that most teachers still teach science by directly transmitting scientific facts and that they base their lesson content on information that lacks relevance to their students (also see Hammrich, 1998; Lyons, 2006; Weiss, 1997). Needless to add, these practices are not conducive to inquiry-based active learning approaches. Several of these features that are endemic to middle school science teaching have already been described in the previous chapter. The negative perceptions about science that students retain as a consequence of these features have been blamed for students’ disenchantment with science (see, for example, Désautels, 1998; Levy et al., 1997; Sutton, 1996; Speering & Rennie, 1996). The significant decline in enrolments in science in post-compulsory years and the pronounced indifference to science
among youth in post-industrial societies have been linked as direct consequences of this afore disenchantment with middle school science. Luft and Patterson (2002) state that it is, therefore, paradoxical to find teachers in middle school “struggling to maintain teacher-centred environments when they are confronted with the mechanics of implementing student-centred inquiry” (p.267).

Research into teacher-beliefs have revealed, however, that the reason science teachers are reluctant to adopt inquiry-based approaches is not because they believe this type of pedagogy to be ineffective. As Crossley and Guthrie (1987) have stated “teachers are not generally irrational opponents of change but they rationally weigh alternatives according to the realities they perceive” (p.65). In fact studies report that teachers are aware of the benefits of inquiry-based teaching. Cox-Peterson (2001), for example, reported that as many as 27% of the teachers who participated in her study (in the US) agreed that inquiry-based instruction was a better approach towards teaching science. One teacher in particular remarked “students have a better attitude toward science and more motivation for science when inquiry-based instruction is being implemented” (p.112).

Another study in Israel similarly revealed that teachers were aware that student-centred approaches were more effective than traditional models of teaching (see Eylon, Berger & Bagno, 2008). In a study of Australian middle school science teachers’ beliefs about teaching and learning, Harris et al. (2005) also found that significantly more teachers agreed that inquiry-based teaching was a more effective form of instruction. In fact, almost all the teachers (98.6%) who were surveyed in this study agreed that student-centred teaching can improve their students’ scientific literacy.
There is an inconsistency between these findings and the teaching practices that were described in Chapter 3. It is, therefore, evident that although teachers are aware of the benefits of inquiry-based instruction, they are not convinced strongly enough to translate this awareness into their actual classroom practice. This would imply that pedagogical change involves more than simply adopting teaching methods that have been proven to be effective. As Hoban (2002) points out, “educational change is a complex process involving many interconnected elements that have a dynamic effect on one another” (p.29).

Bybee (1993) states that teachers’ reluctance to adopt pedagogy based on inquiry and their persistence with conventional forms of teaching is a manifestation of certain beliefs which are strongly held by teachers. These beliefs do not allow them to easily abandon one form of instruction and take up another. Haney et al. (2002) point out, therefore, that “there is a relationship between what teachers believe and what they do in the classroom (p.184). This view is shared by other researchers, like Van Driel, Beijaard and Verloop (2001), who claim that teachers’ “integrated set of knowledge, conceptions, beliefs and values” (p.141) have a direct impact on their teaching practices (also see Bandura, 1986; Riggs & Enochs, 1990). Van Driel et al. reason, therefore, that teachers’ beliefs which govern their classroom practices may also play an equally fundamental role in science education reform; i.e. “The beliefs that teachers hold regarding science reform ideas are truly at the core of educational change (p.171).

It has been established previously that teachers are fundamental to all attempts to reform science teaching. The literature strongly holds that it is futile to attempt educational change without the complete participation of teachers in those efforts (see, for example, Bybee, 1993; Rennie et al., 2001). Davis (2002) argues that it is, therefore, not possible to ignore these beliefs which predispose teachers to teach in a certain way. Hence it is of importance
to this thesis to spend some time to examine what has been documented in the literature and
to describe some of bases for these beliefs which influence teachers’ choice of pedagogy.

Lack of awareness of genuine alternatives

Among the teachers’ beliefs that are extensively documented in the literature, Porlán and
Martín del Pozo (2004) suggest that teachers “lack awareness of genuine alternatives”
(p.52) to teacher-centred traditional models of instruction. Because teachers have “suffered
and endured authoritarianism, rote learning and examinations” as students, the researchers
point out, note-copying, chalk-and-talk instruction and cookbook-type practical classes
remain the only feasible approach with which many teachers believe they have to teach
science.

The literature states that teachers acquire beliefs and attitudes about teaching through
numerous interactions and experiences with learning and teaching (see, for example,
Désautels, 1998; Hammrich, 1998; Levy et al., 1997). Among these, their own school
experiences are the most influential (see, for example, Bradmald, Hardman & Leat, 1995;
reference to the literature, that most teachers receive extensive apprenticeships in teacher-
centred learning cultures, which on average span a duration of almost two decades:

Teachers acquire behaviours and beliefs about teaching through
experiencing school for seventeen or more years in a 30,000-hour
apprenticeship-by-observation, which include twelve to thirteen years of a
mixture of passive listening, regurgitation and verification activities
followed by one to four years of the same at post-secondary level. (p.247)
Researchers concur, therefore, that it is only reasonable for teachers to view and practice their own science teaching based on personal convictions and ideas that were amassed through their schooling years (also see, for example, Ajzen, 1985; Bandura, 1986; Pajaras, 1992). This view is supported by other researchers, who also maintain that teachers bring to the classroom attitudes and beliefs about pedagogy which they themselves preferred as learners (see, for example, Connolly et al., 1985; Mellado, Blanco & Ruiz, 1998). As Melear, Goodlaxon, Warne and Hickok (2000) point out, to have to teach otherwise poses a significant challenge to teachers. The researchers explain that this is because many teachers, when they were students, “liked to achieve by following explicit directions and succeeded in traditional lecture-based and cookbook laboratory courses” (p.89). A statement by one of the teachers reported by these authors highlights this point:

*After so many years of structured classes, to be involved in this (i.e. student-centred inquiry) makes me feel lost. I really don’t know which way to go...I don’t quite know how to handle this science, over the years I have been conditioned to follow the lead of the teacher.* (p.83)

Thus for some teachers, teacher-centred pedagogy remains the only feasible approach to teach science (McDermott, 1991). As Rakow (1986) explains, having to move away from pedagogy to which they have grown accustomed as students is a significant challenge many teachers wish to avoid:

...teaching science as a process of inquiry requires behaviours and attitudes that for many teachers are contrary to the ways in which they traditionally have taught and contrary to the ways in which they have been taught as students. In fact, difficulty in changing teacher behaviour and attitudes has been a major impediment to the large-scale adaptation of an inquiry approach to teaching science. (p.15)
Quoting Lortie’s (1975) dictum: *teachers teach as they were taught*, Greenwood (2003) adds, therefore, that “teachers teach as they were taught while often reverting to ideas and beliefs that are familiar to their ideology of teaching” (p.217). This opinion is shared by contemporary researchers like Tytler (2007), for example, who states that “change has been resisted…by the silent choice of teachers for the status quo; one that supports and reflects their identities as knowledge experts. Science teachers tend to teach as they themselves were taught in school…” (p.57). Porlán and Martín del Pozo (2004) state, therefore, that it is disappointing to find that teachers’ beliefs about teaching range from “a predominant view based on the transmission–reception of knowledge to a minority constructivist view” (p.39).

The fact that teachers’ beliefs support teacher-centred, content-dominated, lecture-type, chalk and talk models of science teaching, compared to pedagogy based on inquiry, is overtly consistently reported across the literature (see, for example, Bradmald et al., 1995; Gallagher, 1993; Goodrum *et al.*, 2001; Porlán & Martín del Pozo, 2004; Smith & Neale, 1991). Studies that document science teachers’ beliefs about teaching have reported that almost 83% of middle school science teachers identify their objective in teaching science as to *teach* basic scientific concepts to their students (Weiss, 1997). Also, these teachers emphasized that it was important to teach scientific terms and facts to their students. These findings are consistent with those of Yager (1991), who reported that many teachers were convinced that, in order to learn science their students first needed to “learn its *special vocabulary* – often by rote” (p.55) (also see Black & Aitkin, 1996). As Kennedy (1991) has stated, these studies highlight the fact that “teachers almost universally have a limited view of their role as such, *believing* that learning involves assimilation, and teaching being telling what they know to the students and evaluating the students’ recall of this
knowledge” (p.55 emphasis added). Although teachers may be aware of pedagogy based on inquiry, they remain oblivious about how to actually implement it in their classrooms. Moreover, as the next section reveals, influences within the teachers’ school cultures and the limited availability of teaching resources offer minimal assistance to teach otherwise.

Influences of school culture and availability of resources

Lee and Krapfl (2002) claim that “adaptation to the traditional school culture, the job structure of the teaching profession” (p.57) may serve to further reinforce traditional models of science teaching. Having to conform to traditional school culture and other professional limitations, the researchers point out, obstructs teachers from implementing inquiry-based pedagogy. As Plummer and Barrow (1998) have further explained “teachers are frequently given large classes with unmotivated students and assigned to schools with high rates of teacher turnover, large numbers of inexperienced staff and apathetic parents” (p.293).

These views are shared by other researchers, including Baird, Prather, Finson and Oliver (1994). They report that teachers identify insufficient funds for supplies, lack of student interest in science and inadequate laboratory facilities, as their most pressing concerns when called to teach science through inquiry (p.55). Another study which surveyed members of the American Middle Level Science Teachers’ Association found that 60% of the respondents associated inadequate budget for supplies and materials as a deterrents to teaching science (see Koker, 1993). Similarly, Goodrum et al. (2001) state that many Australian secondary level science teachers’ report that the quality of their teaching is limited due to inadequate science budgets, large class-sizes and inadequate time for preparation, reflection and peer-collaboration (see Table 5). These studies conclude,
therefore, that implementing student-centred inquiry is hardly a priority for teachers who are confronted with limitations such as those described above.

Table 5: Factors limiting the quality of secondary science teaching (n=296)

<table>
<thead>
<tr>
<th>Factor</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Resources:</strong></td>
<td></td>
</tr>
<tr>
<td>Inadequate resources</td>
<td>24</td>
</tr>
<tr>
<td>Inadequate science budget</td>
<td>19</td>
</tr>
<tr>
<td>Poor access to laboratory for teaching science</td>
<td>13</td>
</tr>
<tr>
<td>Inadequate equipment</td>
<td>12</td>
</tr>
<tr>
<td>Poor access to computers</td>
<td>9</td>
</tr>
<tr>
<td><strong>School and Syllabus Constraints:</strong></td>
<td></td>
</tr>
<tr>
<td>Class size too large</td>
<td>19</td>
</tr>
<tr>
<td><strong>Student factors:</strong></td>
<td></td>
</tr>
<tr>
<td>Poor student behaviour, attitude or welfare problems</td>
<td>16</td>
</tr>
<tr>
<td><strong>Teacher Factors:</strong></td>
<td></td>
</tr>
<tr>
<td>Teachers have inadequate time for preparation, reflection and collaboration</td>
<td>21</td>
</tr>
<tr>
<td>Teachers lack the knowledge and skills to teach science or lack of professional development</td>
<td>15</td>
</tr>
<tr>
<td>Inadequate time for teaching science and/or too much content to cover in the available time</td>
<td>8</td>
</tr>
</tbody>
</table>

(Source: Rennie et al., 2001, p.482)\(^{11}\)

Morey (1990) points out that these limitations are especially likely to have an impact when teachers attempt to teach science through active inquiry (\(i.e.\) hands-on approaches). This claim by Morey is confirmed by Weiss’ (1997) findings, which revealed that hands-on science teaching is far less frequent in most classrooms, when compared to lecture and

---
\(^{11}\) Based on the summary of *Factors limiting the quality of secondary science teaching* reported in Goodrum *et al.*, 2001, p.104.
discussion-based models of instruction. Collaborating studies in the literature, such as the above two, support the fact that traditional methods of instruction are more appealing to teachers, who are faced with resource-limited teaching environments. As Rennie et al. (2001) have stated:

A teaching style that emphasises an inquiry-oriented, student-centred, outcomes-focused approach requires more sophisticated teaching skills than those associated with traditional didactic methods. To do this with large classes, poor resources and potentially disruptive students presents problems that many teachers find too difficult to overcome. It is easier to maintain the status quo. (p.488)

Researchers also point out that in order to facilitate recommended pedagogy teachers need to be freed from the influences of conventional teaching. Studies have shown, however, that several features endemic to school cultures obstruct teachers from implementing inquiry-based teaching. These include “lack of time for teacher planning and collaboration, difficult working conditions, and state testing mandates” (p.8, Davis, 2002). Davis states that these professional limitations can prevent teachers from attempting to make changes to their instructional approaches (also see, for example, Adey, 2000; Haury & Rillero, 1994; Hoban, 2002; Mayoh & Knutton, 1997; Volkman, 2000).

This is clear from findings in a study by Kahle and Boone (2000). In this study it was found that school teachers and principals did not share similar views about pedagogical processes. The teachers realised that equipment and supplies supported student inquiry “with the most promise of improving student learning” (p.98). However, the school principals correspondingly prioritized curriculum that focused on problem solving. Because the school principals identified themselves as “curricular and instructional leaders” (p.103), the
Researchers point out that they served to further reinforce content-focused, examination-oriented pedagogy.

Plummer and Barrow (1998) lament that it is unfortunate that “social stereotypes of education and the school” (p. 57) lead teachers to conform to content-dominated, assessment-oriented, teacher-centred models of instruction. Greenwood (2003) claims, moreover, that there is evidence to suggest that even when teachers “fully embrace contemporary epistemological and pedagogical perspectives” (p. 218), the school culture “gets in the way of its implementation”. She explains this further with reference to a teacher (i.e. “Judy”) who participated in her study. Greenwood observed that although Judy attempted to move away from teacher-centred traditional methods of instruction, “her creativity was restricted by her cooperating practitioner” (p. 220). The researcher notes that the cooperating practitioner, in this instance, was a veteran teacher of thirty years, who subscribed to more conventional models of science teaching.

Zeichner and Tabachnick (1981) use the term washing out to describe situations where teachers, under the influences of their school cultures, revert to traditional forms of instruction. The literature identifies that the strong focus many school cultures place on students’ success at standardized examinations play an important role in influencing teachers to wash out. The literature states that teachers’ preoccupation with teaching their students examination-specific science content serves consequently to strengthen their beliefs towards traditional forms of pedagogy.
Examination-oriented focus

Lappan (2000) stated that the fact that traditional forms of instruction (viz. teacher-centred content transmission) enable more coverage of content within a shorter period of time influences teachers against any reform of their pedagogy. This view is consistent with Koballa and Tippins’ (2000) reference to Block Scheduling in the US; where teachers are expected to cover large quantities of content in limited time periods. Parallels to this have been found by Goodrum et al. (2001) during secondary teacher focus groups in Australia. These teachers complained that they are perpetually rushed to cover assessment specific content with little time to reflect on what was being taught. Although teachers are aware that pedagogy based on inquiry is more effective in ensuring longer-term engagement with science, they (mistakenly) conclude that teacher-centred instruction is more efficient when confronting time constraints and content-overloaded science curricula (Harris et al., 2005).

Moreover, teacher-centred instruction is perceived by teachers to be a more effective form of pedagogy because information retained through rote learning allows students to perform better in standardised assessments (see, for example, Lappan, 2000). Although it has been established that information learnt by rote is non-substantive (see Ausubel, 1968; Marzano, Pickering & Pollock, 2001), Osborne and Collins (2001) states that passive-absorption of information and regurgitation allows students to perform better at examinations. This consequence of better grades and successful admission to tertiary education commends teachers to members of the school management and to the students’ parents.

Bandura (1997) states that experiencing success and observing success are two reasons which strengthen beliefs. Because teachers feel a greater sense of accomplishment by observing their students’ success at examinations, they conclude that teacher-centred
pedagogy has produced that outcome. These experiences serve to reinforce teachers’ beliefs that favour traditional forms of pedagogy. This problem was also identified by Rennie et al. (2001) who state that “most secondary science teachers are concerned about the final assessments for students… and they regard covering the content likely to be assessed as of paramount importance; the repercussions of which echo right down to early years of high school” (p.468). The researchers add, therefore, that “traditional assessment practices remain as one of the most significant barriers to educational reform in secondary schools where teachers are required to cover too much content to prepare students for the test” (p.477).

Because of the above emphasis on success at examinations, it is unfortunate that traditional forms of pedagogy fail to teach information that is relevant to students. Teaching students what teachers need to teach them, as opposed to what students want to learn, is not only influenced by this belief about students’ success at examinations. Teachers are also persuaded to teach in this way because many of them believe that students have blank minds.

Perception that students have blank minds

von Glasersfeld (1988) states that teachers have traditionally taken for granted the existence of ‘objective knowledge’ and that students readily ‘learn what is directly transmitted’. Also, as Geddis et al. (1998) point out, most teachers believe that scientific knowledge is “something that students have to learn” (p.277). Black and Aitkin (1996) agree that traditional assumptions predispose teachers to foster a limited view about the role of their students. In fact, the researchers state that many teachers believe that it is more effective to
teach students abstract facts and leave understanding about applications for later. Black and Aitkin list several such assumptions that are held by teachers about learning, which they believe disadvantage students in traditional models of instruction:

- ‘Knowing that’ must come before ‘knowing how’
- The effective sequence of learning is first to receive and memorize, then to use in routine exercises so as to develop familiarity and understanding, before attempting to apply.
- It is better to teach at the abstract level first and to leave the business of application in many different contexts to a later stage.
- Motivation is to be achieved by external pressure on the learner, not by change in the mode of learning or the presentation of subject.
- Difficulty or failure in learning by traditional routes arises from an innate lack of ability, or inadequate effort, rather than from any mismatch between the teacher’s preferred learning style and the student’s. (p.62)

Aguirre, Haggerty and Linder (1990) state, therefore, that the popular belief held by teachers, that students have blank minds, helps to reinforce traditional pedagogy. This has been described further by Porlán and Martín del Pozo. (2004) as follows:

The pupil’s mind is seen as a tabula rasa (i.e. a blank tablet) that receives information from the teacher and will capture its meaning as long as the pupil is attentive and suffers from no mental dysfunction. The communication of content is assumed to be a linear process in which the meanings undergo no alterations and each concept has a single meaning. (p.54)

There is little evidence to suggest that teachers acknowledge any preconceived notions, socio-cultural constructs or questions students bring to the classroom when they attempt to teach science through traditional pedagogy. Hence teachers remain oblivious to the fact that the difficulties students experience, when they learn science, stem from the preconceived
notions the students bring to the classroom (see Cavicchi, 2006). Instead teachers perceive these difficulties as a deficiency on the part of the student. This problem was also observed by Greenwood (2003), and is explained further with reference to a Year 10 physical science teacher (i.e. “John”) who participated in her study.

After two years of teaching, John’s science teaching orientation emphasizes retention and replication of scientific knowledge. He does not see science lessons as opportunities to explore possible explanations..., neither does he stress the application of scientific knowledge...John is consumed by the need to cover the science concepts so that the students receive the necessary information and get the right answers to be able to perform well on standardized tests...John does not elicit students’ prior knowledge, but includes within his lessons an explanation of commonly known misconceptions that he has read in the teacher’s guide accompanying the text he uses. (p.230)

Lortie (1975) has pointed out that teacher-centred pedagogy focuses on teachers’ own understandings of scientific concepts. As established previously, these understandings are based on teachers’ personal experiences and preferences (see, for example, Melear et al., 2000). Because of the highly transmissive role teachers play in teacher-centred classrooms, Kearney (1984) adds that it is possible for school science to become extensions of the worldviews held by the teacher. This may be particularly disadvantageous when teachers themselves are unsure of the principles underpinning abstract scientific concepts (see Koballa & Tippins 2000); and more so when teachers are prone to share alternative conceptions (or misconceptions) with their students (see, for example, Stocklmayer, 2001).

Transmitting teachers’ understandings about science directly to students can have another disadvantage. Because transmission-oriented learning environments do not offer students the opportunity to critically evaluate and actively construct new knowledge (see, for example, Osborne & Collins, 2001), Kearney (1984) points out that the understanding of
the teacher forms the basis of what is assumed and communicated as correct answers. Essentialist beliefs, such as this one, bestow an element of absolutism on the part of the teacher, as was described in Chapter 3. While such beliefs further predispose teachers to ignore students’ prior knowledge, they focus primarily on ensuring that students arrive at what is believed to be the correct answer. Hence as Geddis et al. (1998) point out, teaching becomes associated with fail-safe strategies, and the “anxiety about getting things right” (p.289). Bennett and Powell (1990) criticize such knowledge-centred beliefs about teaching. They describe teachers who foster such beliefs as ‘resisters’ to reform efforts which promote student-centred inquiry.

Epistemological absolutism as described above remains “the most powerful obstacle to the development of constructivist epistemology” (p.147, Southerland & Gess-Newsome, 1999). This is because constructivist pedagogy requires teachers to, conversely, relinquish their control over their students’ learning processes, and succumb to the uncertainty of the science classroom.

**Uncertainty of constructivist classrooms**

Shymansky et al., (1997) states that it is evident teachers are deterred by pedagogy based on constructivist principles, and that they are challenged by the puzzlement, uncertainty and confusion endemic to constructivist teaching. It is not unreasonable, he states, for teachers to find these features of constructivist pedagogy threatening to the comfort to which they have grown accustomed in teacher-centred classrooms. These sentiments are highlighted in a statement that was made by a teacher who participated in the study by Melear et al. (2000):
I think the whole class (of teachers) agrees with me on feeling a bit uncomfortable...we really don’t know if what we are doing or saying is the correct thing. I am a little frustrated because I’m not sure where this is going but I guess that is what science is all about. (p.83)

Tippins, Kemp and Ogura (2000) point out that teachers are prone to self-doubt when they are confronted with the uncertainty that is inherent to constructivist pedagogy. Not wishing to admit to this level of ambiguity, van den Berg (2001) explains, is the chief deterrent teachers have against implementing recommended pedagogy:

In terms of belief change, constructivism implies a radical change in the perception of learning: from viewing students as empty vessels to be filled with knowledge, to students actively constructing knowledge of science, where the role of the teacher should change from a transmitter of factual information to a facilitator and guide of student learning. (p.29)

van den Berg states, moreover, that constructivist classrooms cannot be regulated by safety-nets, such as textbooks, which otherwise guarantee teachers assurance against elements like uncertainty in more traditional teaching environments. She points out that “working towards constructivist science teaching can be perceived as a journey of discovery for teachers. Such a journey lacks a detailed road map to serve as a guide from the point of departure to the final destination” (p.41). In constructivist classrooms teachers need to be prepared to frequently alter their lesson plans (see Yager, 1991). In place of lesson plans dictated by textbooks or curriculum guides, Yager states, constructivist teaching is expected to “use student identification of problems with local interest and impact as organizers for the course” (p.56). This means that teachers need to constantly alter their lesson based on students’ ideas, experiences and interests. Teachers cannot merely rely on textbooks to direct the course of the lesson. As Wells (1994) states “teaching can never be a
matter of simply implementing packages developed by others (p.3 emphasis in original). However, as it is subsequently revealed, teachers are reluctant to set aside the textbook and take charge of their own teaching.

**Reliance on textbooks**

It has been found that teachers are more comfortable when they are in control of their students’ learning. In order to ensure that this control is maintained, many teachers rely heavily on curriculum guides and textbooks (see Anderson, 2002). Wong and Wong (1998), for instance, contend that these materials function as primary survival tools for many teachers. With their heavily structured lesson plans and answer indices, they serve as detailed maps for teachers. They navigate teachers through science lessons with no threat of uncertainty and ambiguity.

Anderson (2002) adds that the activities and quizzes in these materials rarely, or never, promote active reflection or critical thinking. Instead they employ reinforcement pedagogy to cement the scientific information that the readings present. As a consequence, textbooks and curriculum guides manipulate students’ thinking to arrive at preordained solutions, which are presented as correct answers or preferred forms of knowledge (often in the last pages of these books). As a consequence, Anderson points out, these materials provide an element of essentialism, which serves to reiterate the absolutist beliefs that school science promotes about knowledge (also see, for example, Geddis, et al., 1998).

In addition, their heavily structured lessons promote the idea that science is a logical sequential process (see Eltinge & Roberts, 1993; Wong & Wong, 1998). Thus, Rennie et
al. (2001) maintain that textbooks and curriculum guides conflict with science education reform efforts and obstruct recommended pedagogy. Based on telephone survey responses from secondary level science teachers, the researchers state that:

…textbooks supplemented by school developed curriculum materials is the almost universal approach to curriculum implementation. The concern here is that many of these texts embody traditional pedagogy, content and context, limiting teachers’ ability to implement curriculum frameworks as intended by their writers. (p.481)

Furthermore, Goodrum et al. (2001) point out that many textbooks and curriculum guides are strongly grounded in traditional scientific disciplines. These materials rarely explore beyond the conventional boundaries of biology, physics, chemistry and earth science. Such a compartmentalized perception of science makes it difficult to conceptualize contemporary scientific topics like biotechnology and global warming, for example. Black and Aitkin (1996) state that not being able to appreciate science in such broader contexts prevents students from experiencing the actual nature of science. The researchers add that devoid of such real life examples, it is unreasonable to expect students to make links between school science and their daily life.

Researchers have also pointed out that reliance on textbooks and curriculum guides offers teachers only marginal (if any) room for variation. As a consequence, Barnett and Hodson (2001) lament that science teachers are reduced to the mere “role of technicians” (p.428). In this limited role teachers are charged with executing prescribed science lessons and laboratory classes with neither ownership of their teaching nor allowance to modify lessons to suit students’ interests:
By these means, the teacher is reduced to the role of technician, whose job is merely to operationalize the plans of others, teach in a way prescribed by others, and assess students’ learning in a way that is designated by others. (p.428)

These lamentations are echoed by Darling-Hammond (1994) who claims that textbooks and curriculum guides are often designed to be “teacher proof” (p.7) (also see Howe & Stubbs, 1996). This means, the researcher adds, that the content in these materials allow for minimal input by teachers, and thereby prevents any harm that teachers might do by changing or adapting the materials to suit the needs and interests of their students:

The conditions for teaching for most teachers…are anti-professional. They continue to presume that teachers are semi-skilled workers who implement a curriculum designed by others, receiving knowledge that trickles down form the top of the system in the form of directives, memos, and teacher proof curriculum guides. (Darling-Hammond, 1994, p.7)

These views are shared by some teachers, who complain about the restricted role which is imposed on them. In a study by Barrett (2003), for example, one teacher states that she feels that school science treats teachers like “robots” (p.34), whose role is to scrupulously follow the directives of curriculum guides. Despite this diminished status many teachers continue to rely on these materials, in the comfort zone that preserves them from the enormous uncertainty that is endemic to student-centred inquiry-based pedagogy (see Fetters, Czerniak, Fish and Shawberry, 2002). This element of assurance is described in a teacher’s response from that study:

...many teachers feel their science background is insufficient to adequately understand, explain, and implement the concepts of the current science curriculum...Many, such as me, graduated from College over twenty years ago. I recall only one general science course and one science methods
As this teacher remarks, many teachers are not confident about their *science background*. They do not believe that they possess an adequate understanding about science that is required to facilitate inquiry-based pedagogy. This belief that is held by teachers questions the very foundations of pedagogy that is based on inquiry. The fact that teachers are not able to teach science through inquiry because they lack a deeper understanding about science requires pause for reflection.

**Lack of an adequate science background**

A primary reason for teachers’ resistance to inquiry-based pedagogy is their lack of an adequately developed understanding about science (see, for example, Barnett & Hodson, 2001; Bell & Gilbert, 1992; Birman, Desimone, Porter, & Garet, 2000; Borko & Putman, 1996; Darby, 2008; Dillon et al., 2000; Posnanski, 2002; Tytler et al., 2008; Williams, 2008; Yates & Goodrum, 1990). The fact that many teachers do not have sufficient tertiary level training in science serves to strengthen this resistance. Based on a survey of *Schools and Staffing in the US* in 1987/88, Haury and Rillero (1994) found that a significantly high proportion of middle school teachers did not have the necessary tertiary training to teach the subjects which they were allocated in upper middle schools. The researchers state that “fewer than half of all middle school teachers of biological sciences and only about one-fifth of teachers of physical sciences felt they were teaching the subject for which they were best qualified” (p.2). The fact that these teachers believed they did not have an
adequate knowledge base about the science subjects they taught indicated that they were not confident about their science teaching.

More than a decade later, Harris et al. (2005) found, not too dissimilarly, that as many as 50% of Australian teachers did not have formal tertiary level training in science (see Table 6). The researchers state that “12% of the middle school teachers had not studied any of the four science disciplines discussed (i.e. biology, chemistry, physics and geology) beyond first year at university, and nearly half of these teachers had not studied the subjects at university at all” (p.13). Across the (traditional) science subjects at university, geology registered the lowest uptake, with only 13% of teachers having studied the subject beyond first year. This was followed by physics, which was studied beyond first year by 28% of teachers.

Table 6: Disciplinary backgrounds of the middle school science teachers (n=701)

<table>
<thead>
<tr>
<th>Highest level of university study completed</th>
<th>University subject areas (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Biology</td>
</tr>
<tr>
<td>4th year or above</td>
<td>14.1</td>
</tr>
<tr>
<td>3rd year</td>
<td>34.1</td>
</tr>
<tr>
<td>2nd year</td>
<td>9.1</td>
</tr>
<tr>
<td>1st year</td>
<td>19.0</td>
</tr>
<tr>
<td>Nil</td>
<td>23.7</td>
</tr>
</tbody>
</table>

(Source: Harris et al., 2005, p.14)

The fact that teachers do not have an adequately developed understanding about science is reflected in their classroom practices. This is seen, for example, when teachers attempt to teach the nature of scientific experimentation. Yager (1997) states that few teachers have
practiced science in terms of experiencing “the richness and excitement of knowing about and understanding the natural world” (http://wolfweb.unr.edu/homepage/jcannon/ejse/yager.html). He points out that many teachers lack an understanding about the true experimental nature of science, and are, therefore, unable to convey this excitement and appreciation to their students. Findings based on a study of science teacher candidates support this view (see Williams, 2008). Williams states that many teacher candidates lack an “understanding of what scientific theories and laws are” (p.29). For instance, he found that 76%, of teacher candidates equated scientific fact with the terms truth and proven. Some of them defined a hypothesis in terms of “a theory based on knowledge”, or “a theory proven by experiment”.

An inadequate understanding about science also predisposes teachers to promote alternative conceptions (or misconceptions) along with their teaching (see Stocklmayer, 2001). Gilbert, Boulter and Rutherford (1998) state that it particularly disadvantages teachers when they attempt to use models or analogies to explain abstract scientific concepts to their students. It is highly probable, the researchers state, that these models could be scientifically inaccurate. The literature offers examples of studies that examine the prevalence of such alternative conceptions in specific scientific topics (see, for example, Osborne & Gilbert (1980) for alternative conceptions about electric currents; Trumper & Gorsky (1993) for alternative conceptions about energy; Koballa & Tippins (2000) for alternative conceptions about atomic models).

The literature holds that it is precisely this lack of an adequate scientific understanding that leads teachers to rely overtly on textbooks and curriculum guides (see, for example, Anderson, 2002). Teachers remain trapped within the boundaries set by these materials fearful of venturing into pedagogy based on enquiry. Because these efficacy beliefs
influence teachers’ choice of pedagogy (see Bandura, 1997), it is claimed that inadequate understandings about science promote traditional models of instruction and discourage inquiry-based pedagogy (see, for example, Rennie et al., 2001; Southerland & Gess-Newsome., 1999; Tytler, 2007). These sentiments are also echoed by the Australian Senate Standing Committee on Employment Workplace Relations and Education (2007), which states according to Tytler et al., (2008) that:

A deep understanding frees you (i.e. the teacher) up to use good pedagogy, to discuss ideas, to relax, to open up the discussion, to throw away the textbook and to throw away the work sheets because you are interested, you understand the ideas and you know how to promote those ideas and that discussion. (p.108)

It is maintained, therefore, that the confidence with which teachers view their scientific background is the cornerstone of inquiry-based pedagogy. As Borko (2004) states, “to foster students’ conceptual understandings, teachers must have a rich and flexible knowledge of the subject that they teach” (p.5). This means that teachers should be able to construct scientific understandings confidently in order to teach science through inquiry.

Summary: Part 1

Teachers are crucial to science education reform efforts which attempt to make science more meaningful to students and purposeful to their daily life. It is stated, however, that these efforts are unlikely to succeed when teachers are reluctant to adopt inquiry-based pedagogy to teach science. Despite evidence to suggest that teachers are aware of the benefits of inquiry-based pedagogy, studies continue to reveal that teachers are strongly
predisposed towards traditional models of instruction (i.e. note-copying, chalk-and-talk lecturing and cookbook-type practical classes). The literature suggests that teachers continue to teach in this manner because of beliefs they hold about teaching and learning.

Part 1 of this chapter describes the bases for several such teacher-beliefs. They include teachers’ lack of awareness about alternatives to traditional forms of pedagogy, the influences wielded by teachers’ school cultures, including the emphasis placed on preparing students for standardised assessments, and the limited availability of teaching resources in most schools. Teachers’ wishes to remain oblivious to preconceived notions their students bring to the classroom, their fear of the uncertainty associated with constructivist teaching, and their dependence on textbooks are also reasons for teachers to foster beliefs that promote traditional forms of teaching. Most importantly, the literature identifies that many teachers lack an adequate understanding about science which is necessary to teach science through inquiry. It is important, therefore, to devote the next part of this chapter to examine the measures that are proposed in the literature to address this problem.
Part 2: Teacher education

Teacher change

The literature is consistent in the view that teaching science through inquiry needs to recognise the pivotal role teachers play in affecting curriculum reform. Goodrum and his colleagues (2001) state, for example, that “teacher change is the basis of educational innovation, reform and improvement” (p.168). The same researchers add elsewhere that “change imposed without teacher engagement and ownership of the change brings little effective improvement in the longer term” (p.487, Rennie et al., 2001). These views are consistent with those of Bybee (1993), who stated much earlier that “the decisive component in reforming science education is the classroom teacher”; and “unless classroom teachers move beyond the status quo in science teaching, the reform will falter and eventually fail” (p.144). Others like Duschl and Wright (1989), for example, have also maintained that science teachers should be agents of change and the essence of education reform efforts (also see Fullan & Miles, 1992). Clarke and Hollingsworth (2002) define teacher change as “change as growth or learning”, in which “teachers change inevitably through professional activities and are themselves learners who work in a learning community” (p.948). These researchers state, moreover, that change should be “a natural and expected component of the professional activity”.

As stated in the previous section, teacher-beliefs are deeply entrenched. Moreover, it has been shown that these beliefs predispose teachers to pedagogical models that are inconsistent with science education reform. Changing to accommodate recommended pedagogy would, therefore, also require teachers to change their beliefs. As Black and
Aitkin (1996) point out, such changes make far reaching demands on teachers’ “personality, confidence and intellectual powers” (p.64):

Ideally, teachers will be trying to offer their students...a deeper mutual transaction of learning...to achieve it, teachers will have to change almost every aspect of their professional equipment. They will have to reconsider themselves entirely: not only the structures of their material and their classroom techniques, but even their fundamental beliefs and attitudes concerning learning. (p.63)

The literature does not refute the fact that teachers need support to accommodate these changes. In fact it strongly endorses the need for teachers to have training opportunities to equip them to teach science through student-centred inquiry-based approaches (see, for example, Fensham, 2007; Lumpe, 2004). However, as Rennie et al. (2001) state in the opening quote in this chapter, the training that is offered to teachers needs special attention. They point out that the fundamental and significant nature of teacher change that is required to facilitate inquiry demands support which must extend beyond mere fine tuning of teachers’ pedagogy. This statement echoes sentiments by Shulman (1990), who argued that pedagogical change involves much more than informing teachers about a new set of teaching skills:

Educating a teacher is not a matter of inculcating a knowledge base in the form of a specific set of teaching skills and competencies. Rather, to educate a teacher is to influence the premises on which a teacher bases practical reasoning about teaching in specific situations. (p.80)

Tytler (2007) concurs that efforts to support teacher change cannot merely address superficial elements of pedagogy. As he points out, the support teachers receive needs to probe deeper to address personal convictions:
The scale of the challenge in moving to a system which is focused on a very specific view of science content, and with many teachers long used to a transmissive pedagogy, should not be underestimated. What is required in order for many teachers to make the change is a new set of beliefs about the nature and purposes of science education. Also required is a new set of teaching and learning skills that give more agency to students, and open up the possibility of new knowledges being produced, rather than simply rehearsals of well-known knowledge elements. These are significant changes, beyond the reach of simple content delivery models of professional development. (p.60)

There is, however, concern whether teacher training programs genuinely encourage teachers to move away from their preconceived predispositions. As the subsequent section reveals, researchers question whether the training teachers currently receive is consistent with the expectations placed on them for recommended reform outcomes (see, for example, Barnett & Hodson, 2000; Howe and Stubbs, 1996).

Preservice training

In Australia, secondary (including middle school) teachers are qualified to teach science through university-based graduate diplomas courses in education, or more intensive bachelor’s degree programs that may require them to major in a particular science subject (see Goodrum et al., 2001). Researchers worldwide point out, however, that there is little relevance between the preservice training teachers receive and the actual practices that the profession involves (see, for example, Duschl, 1983; Lortie, 1975; Melear et al., 2000; Smylie, 1988). Rodriguez (1993) states, for example, that if teacher candidates are to make proper sense of the training they receive they need to have opportunities to experience intended theoretical orientations (such as inquiry-based active teaching) through practice. Unfortunately, Rodriguez states, “teacher education programs may be inadvertently
widening the gap between theory and practice” (p.221). This view is broadly consistent across the literature. Yore (2001), for example, agrees and adds that it is doubtful whether transmission models of instruction, that are used in preservice education, could accurately transfer elements of inquiry to teacher candidates:

It is essential that on-campus components of teacher education programs present an internally consistent rationale for and expectations of inquiry science teaching. Lecturing about the nature of science and constructivist science teaching lacks internal consistency. Likewise, embedding inquiry-oriented science education in a context of traditional chalk-n-talk academic science courses with verification laboratories has little impact on preservice teachers’ views of science as inquiry and a tentative, speculative process… (http://wolfweb.unr.edu/homepage/crowther/ejse/yore.html)

Studies that have investigated preservice training programs have confirmed these doubts. In a study in the USA by Tobias (1990), for example, a teacher candidate remarked that learning to teach physics was “like cooking, where someone follows the recipe” (p.21). All that was required to pass the course, the candidate further explained, involved mimicking the examples outlined in the prescribed texts. Lee and Krapfl (2002) claim, therefore, that models of preservice education, which are based on transmission and reinforcement, may in fact serve to strengthen beliefs that predispose teachers to traditional pedagogy. Geddis et al. (1998) concur that such pedagogical models can cause “confusion about how to approach learning to teach” (p.272). They also believe that these models in preservice education may serve to reproduce teacher-centred content delivery:

Undergraduate science introduction typically promotes a learning orientation that assumes something like the following – there are right answers; science has reliable problem-solving algorithms for yielding those answers; science learners need to master these algorithms. Unfortunately, this learning orientation has limited utility for learning to teach science in schools. (p.271)
Moreover, Geddis and his colleagues add that preservice training of this type does very little to inform teacher candidates about how students learn:

Epistemological underpinnings of science are seldom addressed in undergraduate instruction...Consequently, science teacher candidates, while they may have had considerable experience in solving subject matter problems, have likely had little experience in thinking about how they solve such problems or, even more broadly, how they think in their subject field. Like the proverbial fish who is unaware of the water, undergraduate science teachers have little awareness of how they think or that there might be alternative ways of thinking. Such habits of mind are freely transferred to their thinking about the classroom where they focus on finding solutions in the same technical-rationalist manner in which they would go about solving their weekly set of physics problems. Unfortunately, precious few of the real world problems of the classroom yield to such strategies. (p.278)

Anderson and Michener (1994) agree that preservice education, which teachers traditionally receive at tertiary level, although crucial, is hardly likely to provide science teachers with the necessary training that would help them reform their classroom practice. Several reasons, that include mainly (but not exclusively) inadequate funding and resource allocation are used to justify the inadequacies of preservice training (see, for example, Dobson & Calderon, 1999). Reviewing the present situation in Australian preservice education programs, Rennie et al. (2001) state:

Reduced budgets and staffing levels have forced education faculties to reduce the hours of class contact provided to students, and to adopt low cost, mass lecture and tutorial methods which are failing to produce the much higher standards of professional knowledge and skills, and capacity for educational leadership, that are required by modern innovative schools. (p.484)
Disquiet about the inadequacies of preservice training, in terms of addressing reform efforts, has also been voiced at government level. The *Australian Senate Employment, Education and Training Reference Committee Report* (1998) has stated, for instance:

If we are serious about enhancing the status of teachers we must ensure that new teachers are adequately prepared for the complex and demanding task ahead of them. High quality, appropriate pre-service training is essential...Without increased funding it is unlikely that the quality of teacher training will improve. Indeed it is likely to deteriorate. (p.200)

It is, however, not the aim of this thesis to address arguments about preservice training. Suffice to mention that much needs to be deliberated before preservice education is capable of effecting (desired) teacher change. This thesis investigates, more importantly, the role of inservice professional development for science teachers. The remaining sections of this chapter are devoted to that topic.

**Inservice / professional development**

In a recent high level document (*viz. Reaching All Australians*) Garnett (2003) has reported on behalf of the National Reference Group that “there is insufficient support for those who inspire our children to study science” (p.ix), and that “teachers need ongoing professional development to help them to teach science”. This statement acknowledges the external interventions (as opposed to preservice training) which have been remedially sought to support science teachers professionally in the form of inservice training for more than three decades (see, for example, Anderson & Michener, 1994; Council for Science and Technology, 2000; Hackling *et al.*, 2005, Loucks-Horsley *et al.*, 1998).
Inservice training, otherwise more recently termed *professional development*, was identified from the early 1970s to be more effective than preservice training at improving teachers’ pedagogical practices. Since then teachers have embraced these interventions in the hope that they would assist in teaching science within the expectations of science education reforms (see, for example, Kahle & Boone, 2000). As Fensham (2007) states, it is an indisputable fact that teachers require professional development. It is important, he points out however, to discern the *form* such support should assume:

It is quite unrealistic to think that preservice education alone can equip...teachers for teaching science that has quality and character that is called for in the rhetoric of so many reports and curriculum documents. In order to interest students of all ages school science must reflect some of the richness of science. This involves teachers having an awareness and access to some of the exciting questions that scientists are asking as they explore the natural world and try to tackle the issues that arise at the interfaces between science and technology and society. Hence, professional development in science and how to find ways to teach it are absolutely essential features of science teachers, both primary and secondary. The issue is not whether such professional development is necessary. Rather it is how should it occur? (p.10)

Numerous professional development efforts for science teachers have been extensively documented in the literature (see, for example, Borko & Putman, 1996; Reys, Reys, Barnes, Beem, & Papik, 1997; Smylie, 1988). There has been a tendency among earlier efforts, especially those in the post-depression era, to *top-up* teachers’ science content knowledge, on the premise that it would better enhance teachers’ pedagogy (see Howey & Vaughan, 1983). Orlich (1983) has described one such intervention in the US as follows:

Most school districts simple adopt a textbook series, provide three and a half hours of inservice education, and call the result a science program. Needless to say, this strategy does not serve the best interest of our nation or provide the best education for our children. (p.10)
Professional development efforts based on this historic model of addressing teachers’ knowledge deficits have been widely criticized in the literature (see, for example, Clarke & Hollingsworth 2002; Guskey, 1986; Loucks-Horsley et al., 1989; Howey & Vaughan, 1983; Smylie & Conyers, 1991). As Jackson (1974) has stated, professional development needs to do more than “just repair a personal inadequacy as a teacher, but to seek greater fulfilment as a practitioner of the art” (p.26). Posnanski (2002) adds, moreover, that “the critical need for content must go beyond merely conveying science content or topics during professional development programs” (p.191). These efforts are also criticised for the minimal input they allow teachers and the technician-like role to which teachers are reduced as a consequence (see, for example, Barnett & Hodson, 2001; Darling-Hammond, 1994; Howe & Stubbs, 1996). Miles (1995) states that professional development of this type, which imposes information upon teachers and denies them the ownership of their learning process is “everything that a learning environment shouldn’t be” (p.vii).

Moreover, Porlán and Martín del Pozo (2004) state that although this type of professional development may seem to better equip teachers by adding to their science content knowledge, they are in fact “defending an alternative model” (p.54) which serves to reproduce traditional models of teaching. Models of professional development that only address teachers’ knowledge deficits operate similarly to transmissive models of instruction which equip students with scientific facts. It was mentioned in the previous chapter that scientific knowledge that is advanced in this way is not useful to students. Similarly, Goodrum et al. (2001) state, although teachers are better informed about science content as a result of these programs they “often cannot make meaningful links between discipline knowledge and its applications in the world outside the classroom” (p.173). Hence both groups of researchers (viz. Goodrum et al., 2001; Porlán & Martín del Pozo, 2004) are
consistent in their claims that professional development which only focuses on conveying science content does not necessarily provide teachers with the expertise to convey to students how they are supposed to make sense of that knowledge meaningfully. Professional development programs of this type defeat the expectations placed on teaching science through inquiry. Hence it is important to examine the focus of professional development programs if they are to offer teachers the necessary support needed to teach science in this way.

**Constructivist focus**

Contemporary professional development needs to focus on ways to address the challenges that confront teachers when teaching science through inquiry (see, for example, AbuSharbain, 2002; Lumpe, 2004). Goodrum and his colleagues (2001) state that current models of professional development should assist teachers to “teach science in ways that promote improved learning outcomes” (p.172) by “providing science learning experiences that promote the development of scientific literacy” (p.173). This would mean helping teachers to move away from familiar models of traditional pedagogy, which manipulate student thinking, towards pedagogy based on inquiry, where teachers can confidently facilitate investigative exploration without being threatened by the uncertainties that are endemic to constructivist classrooms.

Desired pedagogical characteristics, such as the ones listed above, can only be achieved when teachers are able to construct scientific understandings confidently (see, for example, Borko, 2004). A model of professional development that aims merely to repair teachers’ knowledge deficits is, however, as the reviews earlier in this section criticise, not suitable for this purpose. Instead, it requires a professional development model which provides
teachers with understandings about science which they could confidently share with their students (see Holt-Reynolds, 1999). As Kennedy (1998) concludes, based on a review of effective professional development programs for science and mathematics teachers in the US:

Programs whose content focused mainly on teachers’ behaviours demonstrated smaller influences on student learning than did programs whose content focused on teachers’ knowledge of the subject, on the curriculum, or on how students learn the subject. (p.18)

Feldman (2000) states, therefore, that teachers need to make sense of scientific knowledge in ways that are personally meaningful to them. This means that scientific information should seem “reasonable” in terms of being “understandable, sensible, beneficial…and be in tune with the teacher’s goals” (p.612). When teachers perceive science content knowledge to be relevant to their own interests, it becomes easier for them to “negotiate meaning within the learning community, make connections with past personal understandings, (and) modify prior conceptions if they are inaccurate” (p.2, Anderson & Michener, 1994).

Communicating science in this way resembles the PAST model that was described by Stocklmayer and Gilbert (2002) earlier. This model emphasises the need to actively engage with previous experiences in order to advance (or change) one’s personal awareness about a particular scientific concept (p.853). Stocklmayer (2001) has stated elsewhere that “the challenge for science communication is to provide those contextual experiences, to provide for the link with the target to be clearly delineated and to encourage further interactions” (p.147). This implies that professional development should inform teachers’ understandings by linking experiences that evoke in teachers earlier awareness about relevant scientific
concepts. These views are also broadly consistent with the Constructivist Learning Model described by Yager (1991). The following characteristics describe professional development that is based on the Constructivist Learning Model:

- Inservice education that matters involves conceptual change on the part of teachers;
- When the thrust of the inservice program is towards constructivist perspectives on teaching and student learning, the change involves teachers’ conceptions of learning and teaching;
- Conceptual change in teachers is most helpfully considered in terms of whether or not new ideas are intelligible, plausible, fruitful, and feasible;
- The conceptions held by teachers on entering an inservice program will sometimes include ideas and beliefs about the focus of the program that are in conflict with the ideas and beliefs of those running the program;
- Inservice, whenever possible, must model but not mimic the strategies and ideas being advanced;
- Different groups will enter inservice programs with different levels of relevant knowledge and experience; and
- Those conducting the inservice program must be sensitive to their own needs to undergo conceptual change. (p.57)

These recommendations for teacher professional development closely resemble the recommendations made earlier in the literature for students. Researchers agree, therefore, that teacher professional development should promote learning experiences that are similar to the ones recommended for students. As Taitelbaum et al. (2008) point out, “teachers need to undergo…professional development so that they will experience the same skills, knowledge, and thinking habits as their own students” (p.595). This shift in focus of science teacher professional development has been supported by the National Research Council (1996) in the US. The Council states that, given the “substantive change in how science is taught” (p.56), it is reasonable to expect changes in teachers’ professional development practices. Many researchers have also confirmed that teacher professional
development could equally benefit from the principles that inform science education reform. Yager (1991) has stated, for instance, that “as we learn more about how students learn, it seems we should utilize these same techniques in programs… designed for inservice teachers” (p.57).

This view is reiterated by recent researchers, like Posnanski (2002), who states that “as contemporary ideas of both science teaching and learning change, so too must teachers have opportunities to study and engage in the theories and research that drive these reformative changes” (p.189). Consequently, Posnanski adds, these changes have started to reflect constructivist approaches in professional development for science teachers; i.e. “More contemporary views of staff development promote a constructivist approach in the delivery of professional development programs” (p.190). Other researchers (see, for example, Anderson & Michener, 1994; Carter, 1990; Windschitl, 2002) also agree that teachers, like students, could benefit from constructivist learning experiences. As Hammrich (1998) reasons, “if students are to be taught in a way that helps them construct their own knowledge, then teachers need to learn science in the same manner” (p.183) (also see McBride et al., 2004). Posnanski (2002) points out, furthermore, that “under a constructivist method of professional development teachers learn about science and science teaching with the same methods and strategies as students should learn science in schools” (p.190).

Loucks-Horsley and her colleagues (1998) hold the same opinion. Because constructivist learning involves “collegiality and collaboration…experimentation and risk taking…drawing content form available knowledge bases…involving participants in decision making…providing time to participate, reflect and practice what is learned,” (p.36), professional development based on constructivist principles “parallel(s) those of
effective learning experiences for students”. Loucks-Horsley et al. claim, therefore, that such an approach to “building new understandings through active engagement in a variety of experiences…with others in supportive learning environments, is as necessary for adults as it is for young people” (p.36). In summary, therefore, the researchers agree that professional development based on constructivist principles would enable teachers to teach for recommended outcomes. Adopting such a model for professional development, the researchers point out, would better equip teachers to teach science through inquiry, having experienced similar learning approaches themselves.

Professional development that is modelled on constructivist epistemology promotes several features that are conducive to teaching through inquiry. It is strongly believed that this type of professional development can help teachers to construct personally meaningful scientific understandings on which they can confidently draw to facilitate recommended pedagogy (see, for example, Davis, 2002; Joyce & Showers, 1988). This is possible because constructivist principles acknowledge learners’ existing knowledge constructs. This means, essentially, that professional development which is based on constructivist principles “begins with teachers’ knowledge, beliefs, and skills” (p.27, Davis, 2002). Researchers claim that scientific understandings which are constructed with attention to learners’ existing knowledge structures, beliefs and experiences have greater meaning and personal relevance (see, for example, Bybee, 1993; Hargreaves, 1994; Hall & Hord; 2001; Hurd, 1992). Dillon et al. (2000) point out that teachers who learn science in this way are able to take charge of their own learning; i.e. “teachers will no longer depend on external sources for the solution of their problems but will come to rely on their own knowledge, experience, and expertise” (p.168, Howe & Stubbs, 1996). Davis (2002) states, therefore, that professional development efforts which are based on constructivist principles are able
to offer teachers much desired ownership of their learning (and teaching), and, by doing so, empower teachers to rise above their otherwise technician-like role to teaching.

Researchers also agree that professional development which is based on constructivist principles can promote other features that advantage inquiry-based pedagogy. Borko (2004) states that professional development which is based on active inquiry would necessarily involve teachers in experiences such as scientific experiments, hands-on investigations and other practical aspects of science. It is anticipated that employing such strategies would enable teachers to reflect upon the actual nature of scientific inquiry. More importantly, quoting Bruner (1961) earlier, such an approach to professional development would prepare teachers better to teach science through inquiry; *i.e.* “I have never seen anybody improve in the art and technique of inquiry by any means other than engaging in inquiry” (p.31). As McBride *et al.* (2004) describe, more recently:

> Teachers are taught inquiry teaching strategies by engaging in inquiry science activities and extending their understanding of the science concepts that they teach. As the teachers understand the process of science as inquiry, the teachers more eagerly teach the process to their students in much the same way… (p.434)

Another beneficial feature of professional development based on constructivist principles is that it provides teachers the opportunity to learn collaboratively from one another (see Dillon *et al.*, 2000). Davis (2002) states that offering teachers the opportunity to actively contribute and be part of a learning community fosters a sense of assurance: that it is all right to learn from one another. These views are also consistent with studies by other researchers (see, for example, Harrison, Hofstein, Elyon & Simon, 2008), who confirm that collaboration and professional interaction in professional development are important for
teachers to “recognise good practice within a domain, make sense of its complexities and understand the effects and synergies of various aspects of practice as they come to find their own ways in establishing such practice” (p.589). Harrison and her colleagues add that “the trusting environment of like-minded colleagues enables teachers to overcome their own institutional hurdles to change”.

In addition, Lieberman and Miller (1992) claim that by framing professional development within constructivist epistemology, science teachers would have the opportunity to learn about and experiment with science pedagogy “through continuous inquiry into their practice” (p.106). By developing such an outlook to science, the researchers point out, teachers would begin to feel comfortable with the uncertainty and ambiguity that would otherwise discourage them when called to teach through student-centred inquiry.

Researchers agree, therefore, that professional development based on constructivist principles can offer teachers the necessary support to teach science through inquiry. It can be summarised from the literature above that professional development programs which have a constructivist focus can help teachers to build meaningful and confident understandings about their scientific knowledge. They also offer teachers the opportunity to experience inquiry in practice, learn collaboratively from each other and get accustomed to the uncertainties of student-centred pedagogy. Loucks-Horsley and her colleagues (1998) state, therefore, that:

First, by becoming a learner of the content, teachers broaden their own understanding and knowledge of the content they are addressing with their students. Second, by learning through inquiry…and experiencing the process for themselves, teachers are better prepared to implement the practices in their classrooms. (p.49)
Having thus established, from the literature, that professional development based on constructivist principles can help teachers to achieve recommended reform, it is relevant to explore what the literature states about modelling short-term professional development on constructivist principles. The remaining pages of this chapter consider this issue.

**Short-term professional development**

It was highlighted by Fensham (2007) earlier that there is contention about the manner in which professional development should be implemented. Most recommendations in the literature favour professional development programs which are continuous or long-term (see, for example, Goodrum *et al.*, 2001; Loucks-Horsley *et al.*, 1998,). Researchers like Wayne, Yoon, Zhu, Cronen and Garet (2008), believe that the basis for this bias is grounded in an earlier study by Carpenter, Fennema, Peterson, Chaing and Loef (1989). Carpenter *et al.* showed that students taught by teachers who received an 80-hour cognitively guided professional development program scored better in the achievement measures for mathematics that were later examined. Long-term professional development programs, such as the cognitively guided professional development program above, often assume the form of summer schools or more costly longer-term interventions that sometimes span a period of several years. The *Eisenhower Professional Development Program* in the US, for example, cost the Federal Government US$335 million in 1999 alone (Borko, 2004). Birman, Le Floch, Klekotka, Ludwig, Taylor and Walters (2007) report more recently that approximately US$1.5 billion was invested by the US Federal Government into teacher professional development during 2004-2005. Wayne *et al.* (2008) state, however, that there is insufficient evidence to warrant this level of investment; *i.e.*
“This level of investment – plus the investments made by states and school districts – necessitates a strong base of research to guide policy and practice” (p.469).

Moreover, there are reports which suggest that long-term professional development focuses mainly on aspects of science teaching, such as classroom practice and related student activities. For example, Fensham (2007), who also stresses that effective professional development “needs to be over an extended period of time” (p.10), states that such efforts should focus “on one aspect of science teaching”. More importantly, it is stated that long-term professional development programs rarely appreciate individual teacher’s beliefs, and that they do not address teachers’ understandings about science at a deeper level (i.e. “do not take into account what we know about how teachers learn” p.3, Borko, 2004). A recent study by Lee and Witz (2008) states that these programs “may not sufficiently achieve the aims enough to change teachers’ teaching practices toward the reforms” (p.28).

There is also debate about short-term professional development, or otherwise known as one-shot programs. Although these programs are regarded as the most popular form of science teacher professional development, as Fensham (2007) points out, they are also the most widely criticized:

Many modes of p.d. (i.e. professional development) exist, but by far the commonest one is to bring teachers together for a rare pupil-free day, or for a few hours after school or to a conference in a vacation. On these occasions they (i.e. teachers) are usually offered a range of workshops on all sorts of aspects of science teaching, as well as lectures by leading edge scientists, etc.. They are like a smorgasbord type feast…This commonest mode of p.d. is also the mode of p.d. that research has been shown to be the least effective. (p.10)
Short-term professional development programs, that attempt to promote teacher change based on a single intervention, are criticised in the literature as being *ad hoc* and piecemeal in nature (see, for example, Anderson & Michener, 1994; Guskey, 1986; Hoban, 2002; Senate Employment, Education and Training Reference Committee Report, 1998). Scholars, like Fensham (2007) quoted earlier, are doubtful of the success of such efforts to genuinely equip teachers to teach science based on inquiry. They remain sceptical about the capability of such single interventions to significantly encourage teachers actually to alter their practice. Goodrum *et al.* (2001) state that “the single, stand-alone workshop or seminar seems to have the least impact in improving teaching practice” (p.70). The researchers conclude, therefore, that short-term professional development minimally influences recommended pedagogical change. Some researchers even argue that short-term professional development may in fact simply perpetuate deficit models of professional development (see Clarke & Hollingsworth, 2002).

It was established in Part 2 of this chapter that professional development based on remedying teachers’ knowledge deficits is hardly likely to promote pedagogical change, as it fails to inform teachers’ understandings about science. Programs that are based on deficit models of professional development are criticised for the non-sustainable learning experiences they offer to teachers (see, for example, Porlán & Martín del Pozo, 2004). It has also been established previously in the literature that fostering inquiry-based pedagogy is best achieved when professional development for science teachers is modelled on constructivist principles. However, the literature lacks studies which investigate the possibility of short-term professional development that has been modelled to include such a constructivist focus. There is essentially a dearth of studies which explicitly investigates the possibility of informing middle school teachers’ understandings about science through
short-term professional development based on constructivist principles. Only a few studies make some reference in this regard, but even these are not explicit in their findings.

In one such study, that investigated professional development for elementary science teachers in the US, Posnanski (2002) mentions that it should be possible to further explore short-term professional development in an attempt to guide teachers towards recommended pedagogy. The researcher states that “one-day workshops, infrequent in-service sessions and/or planning days need to be elaborated upon if teachers are to partake in professional development programs guided by the national standards” (p.189). While Posnanski confirms previous claims in the literature that “professional development programs should use a constructivist approach with participant experimentation with instructional strategies and curricular/ activity design” (p.215), he nevertheless recommends that “professional development programs should be long-term”. Posnanski does not explore the possibility of including a constructivist focus for short-term professional development.

An important study is that of van den Berg (2001). This researcher states that there is “ample opportunity to practice and reflect on ideas advocated in short-term professional development programs” (p.42). van den Berg states that, while short-term programs have been widely criticised, there is the possibility, “under certain conditions” (p.29), that these programs “may have a long-term impact and serve as an important factor in systematic reform efforts”. Practice-oriented approaches based on constructivist principles need to be at the forefront of such short-term professional development programs. She also emphasises that, like student-centred learning, professional development “should be attuned to the particular needs of teachers” (p.42). This is crucial because teachers differ widely in the support they require. She adds that an open individual cycle (see Huberman, 12 i.e. US National Science Education Standards (NRC, 1996).
1995) can also help teachers to address individual needs by consulting peer networks. van
den Berg states that it is possible through such an approach to motivate individual teachers
to change their practice. There might also be evidence to suggest that such short-term
programs can have what the researcher terms a *propelling effect*:

…it may be asserted that the dissatisfaction with relatively short inservice
education programs would call for some nuancing. Although an inservice
education program in itself may not yield a dramatic effect,…even an
*introductory program* may cause lasting effects. This might be labelled as
the *propelling effect* of inservice education. (p.42 *emphasis added*)

van den Berg’s findings imply, therefore, that it may be possible for a one-off introductory
intervention to motivate teachers to teach science based on inquiry. Like the study by
Posnanski (2002), this possibility was not, however, explored fully by van den Berg.
Moreover, van den Berg’s study also focuses on professional development for elementary
science teachers. Hence it does not provide evidence for the possibility of a *propelling
effect* in short-term professional development for middle school teachers.

The above views by Posnanski and van den Berg are supported by a recent study by
Taitelbaum *et al.* (2008). These researchers state that professional development which
could even *trigger minor changes* in teachers’ pedagogy “can influence teachers’ self
confidence” (p.613). The researchers explain that “once the teachers have acquired this
knowledge, they could use it explicitly while they guide and provide support for their
students, and thus make their guidance effective and meaningful”. While this study
supports the minority view; that it might be possible to promote desired change through
short-term professional development, it focuses exclusively on Israeli elementary school
teachers and, like Posnanski (2002), makes recommendations for long-term professional development.

These three studies (i.e. Posnanski, 2002; Taitelbaum et al., 2008; van den Berg, 2001) indicate that short-term professional development could offer teachers the support they require to teach science based on inquiry. These studies did not, however, investigate the possibility of including constructivist principles in short-term professional development.

**Summary: Part 2**

In order to encourage teachers to change their pedagogy, it is necessary to address teacher beliefs which were described in Part 1 of this chapter. The support teachers receive to effect these changes are described in Part 2.

There is wide agreement in the literature that tertiary level preservice training is unable to equip teacher candidates to teach science based on inquiry. This is because, it is believed, pedagogical models used in preservice training may reinforce traditional models of teaching. Inservice professional development is recognised, instead, as a more effective means to effect teacher change. While earlier inservice attempts that aimed to address teachers’ knowledge deficits are strongly condemned in the literature, researchers concede that professional development which is modelled on constructivist principles can offer teachers the necessary support to teach for inquiry. It is believed that by involving a constructivist focus, teachers will be able to develop personally meaningful understandings about science and confidently draw upon those understandings to facilitate student inquiry in the classroom. Professional development based on constructivist principles also offers
teachers opportunities to experience active hands-on exploration, collaborative peer learning, and familiarity with student-centred pedagogy. There is, however, debate about how such programs should be implemented. Studies are particularly critical of short-term programs, on the grounds that they perpetuate deficit models of professional development.

There are, however, a few studies which suggest that short-term professional development programs might have the potential to motivate teachers to teach science based on recommended pedagogy. These studies have not investigated the possibility of including constructivist principles in short-term programs, and are, therefore, unable to offer confirmatory evidence.
Chapter Summary

Chapter 4 reviewed studies which have examined teachers’ beliefs about pedagogy and the support that is offered to teachers to implement inquiry-based approaches.

Part 1 of this chapter described the bases for several beliefs that discourage teachers from implementing inquiry-based pedagogy. The literature holds that teachers continue to foster traditional models of instruction mainly because they lack a deep understanding of scientific knowledge. As a consequence, teachers are not confident to engage in inquiry-based pedagogy, and prefer to remain confined to teacher-centred models of instruction under the protection of textbooks and curriculum guides.

Part 2 of this chapter examined means to induce teacher change. The literature suggests that professional development based on constructivist principles could offer teachers the support they require to implement inquiry in their classrooms. Professional development of this type would enable teachers to construct personally meaningful understandings about science. It is believed that when teachers have ownership of their learning they would be more confident to facilitate student learning in the classroom.

There are only a few studies which indicate that short-term programs may have the possibility to motivate teachers to teach for inquiry. However, these studies do not fully explore that possibility. It is, therefore, the aim of subsequent chapters in this thesis to explore the possibility of including constructivist principles in short-term professional development for middle school science teachers.

The next chapter describes the research methods that are used in this study.
Research methods
## Chapter 5: Research methods

### Chapter Overview

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Creative science teaching using simple materials</td>
<td>152</td>
</tr>
<tr>
<td>Research methods</td>
<td>156</td>
</tr>
<tr>
<td>First supplementary research question</td>
<td>161</td>
</tr>
<tr>
<td>Second supplementary research question</td>
<td>164</td>
</tr>
<tr>
<td>Third supplementary research question</td>
<td>171</td>
</tr>
<tr>
<td>Ethical considerations</td>
<td>176</td>
</tr>
<tr>
<td>Research procedures</td>
<td>178</td>
</tr>
<tr>
<td>Chapter Summary</td>
<td>180</td>
</tr>
</tbody>
</table>
Chapter 5: Research methods

Creative science teaching using simple materials

Professional development modelled on constructivist principles should offer science teachers the necessary support they require to effect recommended pedagogical reform (see Chapter 4). This would be achieved, the literature maintains, by enabling teachers to construct meaningful understandings about science, on which they could confidently draw to teach science through inquiry. Some studies with elementary science teachers have suggested that short-term professional development needs to be explored to include a constructivist focus. None of these studies has, however, actually investigated this possibility. There is, therefore, no experimental evidence to confirm that short-term professional development which is based on constructivist principles has the potential to offer teachers the support they require to implement inquiry-based pedagogy. In particular, no studies have investigated short-term professional development for science teachers in middle school. It is, therefore, the aim of this thesis to address this problem by exploring short-term professional development for middle school science teachers. This sequence of reasoning, which forms the underlying argument to this thesis, is shown in the form of a flow chart (Figure 5).
Education reform efforts recommend that *inquiry* should be the basis for science teaching in middle school.

Science teachers require *support* to implement inquiry-based pedagogy in their classrooms.

This support should enable teachers to develop personally meaningful *understandings* about scientific knowledge.

The support is most effectively provided through professional development modelled on *constructivist principles*.

It remains to be investigated whether *short-term professional development* can offer such support.

Figure 5: Flowchart outlining the underlying argument of the present study
In order to investigate whether short-term professional development could enable teachers to construct personally meaningful understandings about science, the present research study examined the one-day workshops offered to middle school science teachers by the Centre for the Public Awareness of Science (CPAS) at the Australian National University (Canberra, Australia). As shown in Figure 6, these workshops are entitled *Creative Science Teaching Using Simple Materials*:

These workshops, known more popularly as *Creative Science Teaching Using Simple Materials*, take the Questacon tradition into classrooms in Australia and internationally, through the use of simple, familiar and easily obtained materials. The workshops give teachers the opportunity to experience creative science teaching through hands-on activities.
The CPAS workshops\textsuperscript{13} have a duration of one or two days, and are offered mainly to secondary level science teachers, both in Australia and abroad. Feedback from a workshop participant claims in Figure 6, that the CPAS workshops have expanded that teacher’s knowledge and encouraged her/him to teach science more creatively:

\begin{quote}
\textit{The hands-on activities expanded my knowledge and encouraged me to search for simple methods and materials when teaching science.} (Workshop participant, 2007)
\end{quote}

There has not been, however, a formal study of the CPAS workshops to determine their efficacy. Therefore, in order to explore fully the potential for short-term professional development programs to include a constructivist focus, the CPAS workshops have been investigated in this thesis with regard to the following research question:

\begin{quote}
\textbf{Do short-term workshops that are based on constructivist principles enable teachers to construct personally meaningful understandings about science?}
\end{quote}

This overarching research question informs the underlying argument of this thesis. In order to fully explore the presence of constructivist principles in the CPAS workshops and their ability to inform the teachers’ scientific understandings three supplementary research questions have been developed based on this overarching research question. The bases on which the three supplementary research questions were developed, the research methods by which they were investigated, and lastly how the three supplementary research questions inform the overarching research question are discussed in the subsequent sections.

\footnote{\textsuperscript{13} For purposes of this thesis, the \textit{Creative Science Teaching Using Simple Materials} workshops that are conducted by the Centre for the Public Awareness of Science (CPAS) will be referred to as “CPAS workshops”\textsuperscript{155}.}
Research methods

The present research study used qualitative research methods in its attempts to answer the overarching research question. Qualitative research involves research procedures that do not rely on statistical methods to reach their findings. This type of research primarily uses observation techniques and interviews to gather data. As Strauss and Corbin (1990) have explained:

By the term qualitative research we mean any kind of research that produces findings not arrived at by means of statistical procedures or other means of quantification. It can refer to research about personas’ lives, stories, behaviour, but also about organizational functioning, social movements, or interactional relationships...researchers gather data by means of interview and observation – techniques normally associated with qualitative methods. (p.17-18)

When qualitative methods are employed in research, the literature recommends that more than one source of data should be used to increase the validity of the research findings (see, for example, Jick, 1983; Miles et al., 1984). Research methodology describes this strategy as Triangulation. As Willms and Johnson (1996) state:

Triangulation is a strategy for ensuring that a study’s findings are not the artefact of a single method, a single source, or a single investigator’s biases. It is, therefore, a means of increasing confidence in the validity or authenticity of the data and its interpretation. (p.5)

Other researchers, like Mathison (1988) for example, agree that “good research practice obligates the researcher to triangulate” (p.13), and that by using multiple methods and data sources it is possible to increase the validity of researcher’s findings. Ball (1997) explains that by having access to different kinds of data, the researcher is in a position to cross-
examine (i.e. to triangulate) findings from one method against another. As a consequence, triangulation allows the researcher “a way of minimizing the distortions inherent in any one kind of data collection” (p.312).

Some of these researchers have, however, questioned the claim that triangulation, by itself, increases the validity of research findings. They argue that results from different qualitative methods would not necessarily converge to produce a single valid position. If there is a determined focus on converging the findings that are produced from separate research methods, as Mathison (1988) explains, it is possible for a researcher to ignore the full richness that is offered by each of the findings; (i.e. “Because of the predominance of the assumption that triangulation will result in a single valid position we look for the convergence of evidence and miss what I see as the greater value in triangulating” (p.15).)

Instead Mathison states, with reference to Miles et al. (1984), that triangulating evidence from multiple sources should enable the researcher to obtain a “rich and complex picture of some social phenomenon being studied” (p.15). Denzin, who advanced the strategy of triangulation, himself later (in 1989) agreed that “in depth understanding, not validity, is sought in any interpretative study” (p.246). Contemporary literature on research methods is, therefore, consistent in the opinion that “triangulation in itself should not be viewed as a guarantee of the validity or truthfulness of a study” (p.255, Rice & Ezzy, 1999). Instead, Fielding and Fielding (1986) state that “triangulation puts the researcher in a frame of mind to regard his or her own material critically, to test it, to identify its weaknesses, to identify where to test further doing something different” (p.24).

From the different types of triangulation that were originally identified by Denzin (1978), methodological triangulation, more precisely between-methods triangulation, was used in
the present study. This means that more than one research method was used to investigate
the overarching research question. Denzin describes this strategy as follows:

The rationale for this strategy is that the flaws of one method are often the
strengths of another: and by combining methods, observers can achieve the
best of each while overcoming their unique deficiencies. (p.302)

Between-methods triangulation was decided as the most suitable triangulation strategy
based on the premise advance by Ball (1997) that “questions raised or left unanswered by
one method…may be answered by another” (p.312). This means that different research
methods could be employed to answer separate research questions; or more specifically,
supplementary research questions that inform an overarching research question.
Researchers, including Smith and Kleine (1986) agree that supplementary research
questions offer “different images of understanding” (p.331). By investigating the
overarching research question from these different perspectives, Eisner (1979) states, it
enables to “eventually create a whole that is supported by the bits of evidence” (p.215).

Based on this premise, three supplementary research questions were devised to help answer
the overarching research question that is argued in this thesis. By using three
supplementary research questions it was expected to investigate the constructivist nature of
the CPAS workshops from three different perspectives based on three separate research
methods. It was intended, as a result of this strategy, to obtain a better understanding about
the CPAS workshops in terms of supporting teachers to teach for recommended reform.
The three supplementary research questions are, therefore, as follows:
1. Are constructivist principles used to design the CPAS workshops?

2. Are constructivist principles used to deliver the CPAS workshops?

3. Do the teachers who attend these workshops construct personally meaningful understandings about science?

It was intended for the supplementary research questions to offer means by which to obtain (literally) three different images of understating (as Smith & Kleine (1986) mention earlier) of the CPAS workshops. This has been illustrated in Figure 7, which shows that the overarching research question was approached from three different perspectives, each determined by one of the supplementary research questions. The first supplementary research question, which investigated elements of the CPAS workshops’ design, advanced a progressive perspective from which to approach the overarching research question. The second supplementary research question offered a contemporary perspective to the overarching research question by exploring the CPAS workshops in-progress. The last supplementary research question, which examined the effects of the workshops after they had taken place, offered a retrospective view to the overarching research question.

Based on Denzin’s (1978) rationale for methodological triangulation, separate research methods were used to investigate the three supplementary research questions. These methods are described in the following sections. Miles et al.’s (1984) parameters for data collection (viz. setting, actors, events and process) were considered in the development of these methods. It should also be mentioned here that the investigations for the three supplementary research questions did not proceed in the order in which they have been
listed above. In attempts to minimize bias, as explained later in this chapter, investigations commenced with the second supplementary research question.

Figure 7: Different perspectives of the overarching research question as viewed by the three supplementary research questions.
First supplementary research question

Are constructivist principles used to design the CPAS workshops?

The first supplementary research question investigated the influence of constructivist principles on the workshops’ design. The Creative Science Teaching Using Simple Materials workshops are designed (and facilitated) by staff from the Centre for the Public Awareness of Science at the Australian National University. They are, therefore, the most informed about the CPAS workshops’ design, particularly the influence of constructivist principles therein. Because of their specialized knowledge, the CPAS staff who design the workshops constitute what research methodology identifies as a select group of informants or key informants (see Gall et al., 1996). Interviews with the CPAS workshop facilitators are, therefore, described as key informant interviews; i.e. “Data collected from individuals who have special knowledge or perceptions that would not otherwise be available to the researcher” (p.306).

Key informant interviews with two main workshop facilitators were used to obtain information about the CPAS workshops’ design. While other facilitators were present in some of the CPAS workshops mentioned here, the two facilitators who were interviewed were present in all the CPAS workshops in this study. These two workshop facilitators were interviewed individually, in the last phase of the research. They were asked to comment about the content for the workshops; i.e. the scientific concepts that were covered by the workshops, the workshop activities that were used to illustrate those concepts, and the features and bases of those activities. The facilitators were also asked to elaborate on their understandings of Constructivism, and whether they thought constructivist principles
influenced the design of these workshops. If they believed this was the case, they were asked to describe examples from the workshops’ activities, which illustrated constructivist learning experiences for the teachers. The interviews concluded by asking the facilitators what improvements they envisaged for the workshops.

The above key informant interviews were based on a General interview guide approach format (Gall et al., 1996):

The general interview guide approach involves outlining a set of topics to be explored with each respondent. The order in which the topics are explored and the wording of the questions are not predetermined. They can be decided by the interviewer as the situation evolves. (p.309)

This meant that the facilitators were not asked fixed questions. Instead the interviews covered a series of topics that have been listed in Figure 8. This flowchart outlines how the information that was gathered from the interviews informed the first supplementary research question.

In terms of the structure of the interview, an interview topic may have been left aside for some time and (if appropriate) revisited later during the course of the interview. While doing so, it was also anticipated (and later noted) that a facilitator could offer more than a single response a particular question. Educational research methods refer to such an interview structure as a Branching structure with feedback loops:

Both interviewer and respondent move freely from one aspect to another. They may return to the questions asked much earlier in the interview, attend to some aspects of the response to probe these, take up the other aspects when each is fully explored, and use each other’s questions and responses to pose further questions or qualify earlier responses. (p.308, Keats, 1997)
Interviews with workshop facilitators

Interview topics:
- Scientific concepts covered by the workshops
- Activities that were used to illustrate various scientific concepts
- Features and bases of workshop activities
- Facilitators’ understanding of Constructivism
- Examples of workshop activities that illustrate constructivist principles
- Envisaged improvements for the workshops

There is, however, a possibility of bias with the above interview structure. Branching structure with feedback loops could influence the direction of the interview. Given the specialised nature of the information that is sought, Keats (1997) states, it is possible that the interview could branch in directions that are partial to both the interviewer and the respondent. He offers the following recommendations to reduce possible bias in the interviews, while ensuring that informants are not restricted in their responses:

The researcher needs to be alert for responses that do not fit preconceptions of theoretical parameters, and for the possible biasing effects of the affective interpersonal relations that develop in the interview. One of the most challenging tasks for the interviewer is to remain unbiased in the presence of biases in the respondents’ replies. (p.309)
Second supplementary research question

Are constructivist principles used to deliver the CPAS workshops?

The second supplementary research question investigated the presence of constructivist principles during the actual delivery of the CPAS workshops. This was achieved by observing the different ways in which science was communicated to the teachers by the workshop facilitators. Education research methods describe this technique as participant observation (sometimes known as direct observation). As Gall et al. (1996) explain, participant observation yields more accurate data when attempting to answer a research question, such as the second supplementary research question in the present study.

Even when bias is not present in self-report data, observational methods may yield more accurate data. For example, educators have noted that teachers dominate classroom talk at the expense of student participation. But what are the actual percentages of teacher and student talk in classrooms? Self-reports by teachers or students are unlikely to yield an accurate answer to this question, but an analysis of observations...could do so. (p.328)

Participant observation involves, as Lofland and Lofland (1984) describe “the interweaving of looking and listening” (p.13). Marshall and Rossman (1989) add that this research method allows the researcher to immerse in the settings and “hear, see and begin to experience reality as the participants do” (p.79). Hence Wolcott (1988) points out, depending on the purposes of the study, the role of the observer could assume that of an active participant to a limited observer. For the purposes of the present study, the author assumed the latter role (i.e. a complete observer). This meant that the author “observed without participating” (p.150, Creswell, 2003) in the CPAS workshops.
Observations of the CPAS workshops involved recording verbal and visual communications by the workshop facilitators. This was accomplished by recoding frequency-counts of descriptive observational variables (see Gall et al., 1996).

In frequency-count recording the observer records each time a target behaviour occurs. A tally sheet typically is used for this purpose. Frequency counts are most useful in recoding behaviours of short duration and behaviours whose duration is not important. (p.333)

*Descriptive observational variables* are variables that require little inference on the part of the observer. They sometimes are called low-inference variables for this reason. One of their major advantages is that they generally yield reliable data. (p.332)

A specific set of descriptive observational variables, based on *Flanders interaction analysis system*, was developed to categorise and record the different types of observations in the CPAS workshops. Flanders interaction analysis system is a model used in education research to analyse teacher behaviour (see Flanders, 1970). This model uses a series of ten broadly descriptive variables to categorise direct communications between a teacher and students. These categories describe communications which are used to elicit, inform and facilitate classroom discourse. Table 7 presents a summary of these communications as categorised by Flanders.
Table 7: Flanders interaction analysis system

<table>
<thead>
<tr>
<th>Observational category</th>
<th>Variable description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category 1</td>
<td>Teacher accepts feelings</td>
</tr>
<tr>
<td>Category 2</td>
<td>Teacher encourages students</td>
</tr>
<tr>
<td>Category 3</td>
<td>Teacher uses ideas of students</td>
</tr>
<tr>
<td>Category 4</td>
<td>Teacher asks question</td>
</tr>
<tr>
<td>Category 5</td>
<td>Teacher lectures</td>
</tr>
<tr>
<td>Category 6</td>
<td>Teacher gives directions</td>
</tr>
<tr>
<td>Category 7</td>
<td>Teacher criticizes student</td>
</tr>
<tr>
<td>Category 8</td>
<td>Student responds</td>
</tr>
<tr>
<td>Category 9</td>
<td>Student talks</td>
</tr>
<tr>
<td>Category 10</td>
<td>Silence or confusion</td>
</tr>
</tbody>
</table>

(Source: Adapted from Gall et al., 1996, p.331)

For the purposes of the present study, Flanders’ categories of observational variables were tested against the protocol of a prototype observation of a CPAS workshop in Cessnock (NSW) (See Appendix 2 for Cessnock workshop observation report). Based on this prototype study, six categories of observational variables were developed. These have been listed in Table 8.
Table 8: List of observational variables (based on prototype observation of CPAS workshop)

| Category 1: Facilitator makes a statement / asks a question that causes teachers to reflect about their existing awareness of a particular scientific concept |
| Category 2: Facilitator informs teachers about the scientific accuracy of their understanding |
| Category 3: Facilitator provides a reference that informs teachers’ understanding about a particular scientific concept |
| Category 4: Facilitator offers an activity that informs teachers’ understanding about a particular scientific concept |
| Category 5: Facilitator provides a reference to scaffold teachers’ new level of awareness about a particular scientific concept |
| Category 6: Facilitator offers an experience to scaffold teachers’ new level of awareness of a particular scientific concept |

The communications in the subsequent CPAS workshops were described by these six categories of observational variables, and the frequencies at which these communications occurred were recorded in those six categories. Six CPAS workshops were observed based on this technique. Figure 9 outlines the steps by which the six categories of observational variables were derived and how they served to inform the second supplementary research question.
Frequency counts of the above observational variables were recorded in six CPAS workshops. Recordings commenced at the start of each workshop (usually 9am) and concluded when feedback forms were distributed to the teachers at the end (usually 3pm).
The first four workshops were conducted in the Queensland towns of Ayr and Charters Towers; and in Hobart and Launceston in Tasmania (Australia). They were attended by middle school science teachers in those areas. The last two workshops were offered to science teachers from outside Australia. These two workshops formed the basis for the cross-cultural perspectives that are mentioned in this study. One of these workshops was conducted in Colombo (Sri Lanka), while the other was attended by science teachers visiting from Indonesia. In order to accurately record communications from these two workshops, it was necessary to have an understanding of those teachers’ mother tongues. In the workshop in Sri Lanka, this was managed by the author’s familiarity with the languages in that country. When observing the workshop for Indonesian science teachers, the author required the assistance of a colleague, who was fluent in those teachers’ mother-tongue. Observations, including descriptions and numbers of participants, from the six CPAS workshops are described in the next chapter.

The literature points out that the primary device in participant observation is the researcher. It adds, therefore, that observational data can be influenced by observer effects. Observer effects include the effect of the observer on the observed. This means that the presence of the observer during direct observation may unintentionally result in changing the situation being observed. Another such observer effect is the researcher’s personal bias when recording observations. It is claimed, therefore, that the researcher may have a negative impact when attempting to directly record observations (see Everton & Green, 1986). However, Gall and her colleagues (1996) justify observational data on the basis that “any observations made by human beings will contain some personal bias because all of us are influenced by our experiences and beliefs” (p.340). A similar argument is put forward by Morgan (1986). Morgan argues from a post-modern perspective that “our seeing and
understanding of the world is always seeing as, rather than seeing as is” (p.382). Salvia and Mersel (1980) equally point out, however, that researchers are often influenced by socioeconomic and ethnographic stereotypes. Consequently, they add, a researcher may neglect to record certain observations or may be unable to maintain a neutral perspective.

The literature offers several means of overcoming observer effects (see, for example, pp.329, 340 & 352, Gall et al., 1996). These include creating a contrived setting for the observations to take place and efforts to maintain objectivity on the part of the observer. In compliance with these recommendations the following strategies were employed in the present study. To remedy the effect of the observer on the observed, the teachers and the CPAS facilitators in each of the workshops were informed in advance that they would be observed during the workshops. Since “everyone involved was aware of what is happening” (p.329) this created a contrived setting for the observations to take place. To ensure that the workshop observations were not influenced by biases and preconceived notions, the author observed the CPAS workshops before conducting interviews with CPAS workshop facilitators and the teachers who participated. The author was able, therefore, to observe uninfluenced and from an unvested perspective the communications that transpired during the workshops. In addition, during the CPAS workshop for Indonesian teachers, observation notes were compared with those of a colleague. This colleague observed the workshops through a personal interest. His notes offered, therefore, an unbiased perspective.
Third supplementary research question

Do the teachers who attend these workshops construct personally meaningful understandings about science?

The third supplementary research question investigated whether the teachers who participated in the CPAS workshops believed, in retrospect, that the workshops enabled them to construct personally meaningful understandings about science. The teachers who participated in the CPAS workshops were interviewed in order to investigate their perceptions of the CPAS workshops they attended. The literature recommends self-reporting based on interviews, for this purpose, because of their adaptability and ability to yield more informative data (see Legacy & Bennett, 1979). Moreover, in order to encourage respondents to express their ideas in non-restricted terms, the literature states that it is customary to use open-ended interviews in qualitative research (see Patton, 1990). The interviews with teachers in the present study also followed this principle. These interviews were, however, standardized (i.e. standardized open-ended interviews) in order to ensure consistency. Gall et al. (1996) also point out that standardized open-ended interviews help to reduce bias:

The standardized open-ended interview involves a predetermined sequence and wording of the same set of questions to be asked of each respondent in order to minimize the possibility of bias. This approach is particularly appropriate when several interviews are used to collect data. (p.310)

The teachers were interviewed after they had participated in the CPAS workshops. They were asked if they believed the workshops had informed their understandings about science; i.e. Did the workshop help you to know more about science? If this was the case,
the teachers were then asked to describe how they believed the workshops achieved this aim; \textit{i.e.} How do you think this was done by the workshop? Finally, the teachers’ suggestions to improve the workshops were given; \textit{i.e.} What would you suggest to improve the workshops? Thus a three-part format was used to standardize the interviews with the teachers; \textit{i.e.} first if the teachers believed that workshops informed their understandings about science; next they were asked how they perceived this was managed by the workshops; and lastly whether they had any recommendations to improve future workshops. However, if the teachers indicated a negative response to the first part of the sequence; \textit{i.e.} they did not believe that the workshops advanced their scientific understandings, the interview protocol provided for them to proceed to the third part of the sequence; \textit{i.e.} their suggestions to improve the workshops accordingly. Particular attention would be paid to any suggestions that recommended constructivist principles, since these would imply that the teachers had not perceived such elements in the workshops.

A list of open-ended questions that was used to interview the teachers, based on the above three-part format, has been included in Table 9. It will be noticed that apart form the three main interview questions (that have been indicated in \textbf{bold} type) other questions were also used alternatively to obtain information from the teachers. It should be noted, however, that it was not necessary to ask the teachers all the questions that were listed in Table 9 if their responses to the main interview questions were sufficient. In Figure 10 a flowchart outlines the means by which this information which was obtained from the teachers was used to inform the third supplementary research question in the present study.

Also, questions in Table 9 which formed the main body of the interviews were preceded and followed by informal conversations with the teachers. The literature states that such introductions and conclusions to interviews are necessary to establish rapport and to gain
the respondents’ trust. Keats (1997) has described these three phases (viz. introduction, main content and conclusion) of an *effectively structured interview* as follows:

The effectively structured interview has three main phases. The interview begins with an introductory phase in which the credentials of the interviewer are established and accepted, rapport between interviewer and respondent is developed, and an appropriate language style adopted. This phase is often used to obtain basic nonthreatening background information. In the second phase the main content of the interview is developed. In general, less threatening content will be addressed first, followed by the more detailed exploration of the topic, characterized by probing and elaboration of the interview structure. The third and final phase is denouement, in which the interviewer concludes the interview and releases the respondent. (p.307)

Table 9: Questions used in the interviews with teachers

<table>
<thead>
<tr>
<th>Part 1:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Did the workshop help you to know more about science?</strong></td>
</tr>
<tr>
<td>Do you think the CPAS workshop you attended helped you in anyway?</td>
</tr>
<tr>
<td>Do you think the workshop was relevant to your needs?</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Part 2:</strong></td>
</tr>
<tr>
<td><strong>How do you think this was done by the workshop?</strong></td>
</tr>
<tr>
<td>What science topics did the workshop help you to know more about?</td>
</tr>
<tr>
<td>How did the workshop help you to know more about those topics?</td>
</tr>
<tr>
<td>Would you like to explain what you mean by using an example?</td>
</tr>
<tr>
<td>What do you remember most from the workshop you attended?</td>
</tr>
<tr>
<td>What was it that interested you in that particular workshop component?</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Part 3:</strong></td>
</tr>
<tr>
<td><strong>What would you suggest to improve the workshops?</strong></td>
</tr>
<tr>
<td>Do you think the workshop could be improved?</td>
</tr>
<tr>
<td>How do you think the workshops could be improved?</td>
</tr>
</tbody>
</table>
The interviews were conducted individually as well as in groups. Individual interviews involved one-on-one questions and responses between the interviewer and respondent. These interviews lasted approximately 30 minutes. Depending on teachers’ availability and access (geographically) individual interviews were sometimes conducted over the telephone (i.e. “school personnel are easier to reach by telephone”: p.311, Gall et al., 1996). Group interviews lasted between 45 minutes to one hour. They were always conducted in person. This was necessary to maintain the dynamics of group interviewing, as Krueger (1988) describes below:

A carefully planned discussion designed to obtain perceptions on a defined area of interest in a permissive, nonthreatening environment. It is conducted with approximately seven to ten people by a skilled interviewer. The discussion is relaxed, comfortable, and often enjoyable for participants as
they share their ideas and perceptions. Group members influence each other by responding to ideas and comments in the discussion. (p.18)

Teachers for the interviews were selected by *purposeful random sampling*. This was achieved by randomly selecting a sample of teachers, from each of the CPAS workshops, who consented to be part of the study. Based on this sampling method a total of 38 teachers who participated in the CPAS workshops were interviewed. These respondents included teachers from schools in Tasmania and Queensland (Australia); and also teachers who participated in the workshop in Sri Lanka. The group of Indonesian teachers were interviewed together with the assistance of an interpreter.

Purposeful random sampling was used to reduce sampling bias, which may have resulted if simple random sampling were used (see Creswell, 2003). Moreover, because the interviews do not only report success stories of the phenomenon being investigated, Gall *et al.* (1996) state that this sampling method offers greater credibility to the findings:

*Purposeful random sampling* involves selecting a random sample using the methods of quantitative research. Nevertheless, the purpose of the random sample is not to represent a population, which would be its purpose in quantitative research. Rather, the purpose is to establish that the sampling procedure is not biased. For example, if a researcher is evaluating a program for which some constituencies are critical, the researcher can gain more credibility for the findings by selecting cases at random rather than looking for “success stories” to report. (p.235)
Ethical considerations

Research that is designed with the use of qualitative methods should address the importance of ethical considerations (see, for example, Marshall & Rossman, 1989). This is essential, the literature dictates, because methods like participant observation can be intrusive, while interviews may require participants to divulge sensitive information. The following safeguards have been suggested, therefore, in order to protect the participants in qualitative research:

1. The research objectives will be articulated verbally and in writing so that they are clearly understood by the informant (including a description of how data will be used),
2. Written permission to proceed with the study as articulated will be received from the informant,
3. A research acceptation form will be filed with the (respective) instructional review board
4. The informant will be informed of all data collections devices and activities
5. Verbatim transcriptions and written interpretations and reports will be made available to the informant
6. The informant’s rights, interests and wishes will be considered first when choices are made regarding reporting the data, and
7. The final decision regarding informant anonymity will rest with the informant. (Creswell, 2003, pp. 165-6)

Based on the above recommendations and the Research Award Rules of the Australian National University, an application seeking approval for the present study was submitted to the Human Research Ethics Committee (ANU)^14. The Committee approved the present research study on 09 May 2005. The Committee endorsed the author’s arrangements to

^14 See Appendix 3 for a copy of the application that was submitted to the Human Research Ethics Committee (ANU) including samples of consent forms.
seek prior permission in writing from the CPAS workshop facilitators and teachers before interacting with them for purposes of this study.

All interviews proceeded after signed consent was obtained from the respondents. The interviews were conducted at a time, date and place that were convenient to each respondent. The respondents were given the option of discontinuing the interview at anytime they chose to so do. Audio recordings and transcripts of the interviews are currently being stored in a locked office space. Copies of the interview transcripts were returned to the respondents and were checked for inaccuracies in their statements presented therein. The identities of the respondents have not been revealed when presenting the results of this study.

The committee further recommended that permission had to be sought from all teachers participating in a given CPAS workshop before arrangements were made by the author to observe that workshop. This recommendation was consistent with the research methods described earlier, in terms of creating a contrived setting for observations of the CPAS workshops to take place (see Gall et al., 1996). The co-ordinator for each workshop was advised, therefore, to inform teachers, when they enrolled for the workshop, that they would be observed as part of this study. Since none of the teachers expressed disagreement, all the workshops presented in this thesis were observed in accordance with recommendations by the Human Research Ethics Committee.
Research procedures

The three supplementary research questions were investigated independently. As mentioned previously, these investigations did not proceed in the order in which the supplementary research questions have been listed. Investigations commenced with the second supplementary research question. This meant that the CPAS workshops were observed, before interviews were conducted with the workshop facilitators and participants. This was necessary to reduce possible observer bias, which may have resulted from interview data influencing observation recordings.

Consistent with the third supplementary research question, the teachers who participated in the CPAS workshops were interviewed next. It was necessary for logistical reasons for these interviews with the teachers to precede interviews with the workshop facilitators. The teachers who agreed to be interviewed were distributed over a vast geographic area (viz. regional Australia, Indonesia and Sri Lanka). Many of them could not guarantee regular communication by e-mail or telephone. Hence it seemed practical to interview these teachers soon after they had attended the workshops. The teachers within Australia were interviewed within three months after they attended the workshops. In the case of the Sri Lankan and Indonesian teachers these interviews were managed a few days to one week after they attended the workshops.

The CPAS workshop facilitators were more easily accessible and their interviews, with which it was intended to answer the first supplementary research question, were conducted last. By conducting these interviews as the final investigational stage it was possible to be more objective with the two earlier investigations (i.e. workshop observations and interviews with teachers), and to be more explorative with the questions to the workshop
facilitators. Figure 11 illustrates the order of the research procedures and how they subsequently informed the overarching research question. It should be noted that Figure 11 is a composite of the Figures 8, 9 and 10, which were used respectively to describe the investigative processes involved in the three supplementary research questions.

1. Observations of CPAS workshop

2. Interviews with workshop participants

3. Interviews with workshop facilitators

Figure 11: Research procedures informing overarching research question
Chapter Summary

Chapter 5 described the research methods that have been used to investigate the research questions explored by this thesis.

Studies suggest that professional development that is based on constructivist principles could promote recommended pedagogy by enabling teachers to construct personally meaningful understandings about science. However, the literature does not contain sufficient studies that have investigated this claim with regard to short-term professional development for middle school science teachers. This thesis attempted to address this problem by investigating the one-day science teacher workshops by the Centre for the Public Awareness of Science (ANU). Qualitative methods have been used to investigate the CPAS workshops based on three supplementary research questions.

In the first investigative stage, frequencies of specific observational variables were used to explore the presence of constructivist principles during the workshops. These findings informed the second supplementary research question (i.e. Are constructivist principles used to deliver the CPAS workshops?). Next the teachers who participated in the workshops were interviewed in order to investigate if they believed the workshops had informed their understandings about science. Results from these interviews were used to inform the third supplementary research question (i.e. Do the teachers who attend these workshops construct personally meaningful understandings about science?). Finally the workshop facilitators were interviewed to investigate the presence of constructivist principles in the workshops’ design. Data from these interviews were used to inform the first supplementary research question (i.e. Are constructivist principles used to design the CPAS workshops?). Data from these three sources were triangulated using the strategy of
between-methods triangulation to obtain an in-depth understanding from which to answer the overarching research question that is argued in this thesis (*i.e.* Do short-term workshops that are based on constructivist principles enable teachers to construct personally meaningful understandings about science?). Approval to carry out investigations for this study was obtained from the Human Research Ethics Committee (ANU). The explorations in the present study have been consistent with the recommendations by that Committee.

Findings that were obtained based on the above research methods are presented and discussed in the preceding chapters. The next chapter describes the observations which were recorded in the CPAS workshops.
Results and discussion
Chapter 6: Observations

Chapter Overview

Observations of CPAS workshops 184

Category 1 189
Category 2 192
Category 3 200
Category 4 207
Category 5 and Category 6 220
Cross-cultural perspectives 229

Chapter Summary 242
Chapter 6: Observations

Observations of CPAS workshops

This chapter describes the observations that were recorded during the CPAS workshops. Data based on observations of six workshops were used to answer the second supplementary research question (i.e. Are constructivist principles used to deliver the CPAS workshops?). This data comprised frequencies of the six categories of observational variables, which have been described earlier in Table 8 (see Chapter 5).

The six CPAS workshops which were observed were broadly consistent in their structure and content. They each spanned a duration of one-day (9am to 3pm), and involved a balance of discussions, activities, breaks for refreshment and finally time for teachers to give feedback (see Table 10).

Table 10: A typical one-day CPAS workshop program

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>09.00 am</td>
<td>Introduction</td>
</tr>
<tr>
<td>09.05am</td>
<td>Teaching in context - Discussion</td>
</tr>
<tr>
<td>09.45am</td>
<td>Hands-on activities (Part 1)</td>
</tr>
<tr>
<td>10.40am</td>
<td>Morning tea</td>
</tr>
<tr>
<td>11.00am</td>
<td>Hands-on activities (Part 2)</td>
</tr>
<tr>
<td>11.45am</td>
<td>The background to understanding - Discussion</td>
</tr>
<tr>
<td>12.45pm</td>
<td>Lunch</td>
</tr>
<tr>
<td>01.30pm</td>
<td>Problem solving and misconceptions - Discussion</td>
</tr>
<tr>
<td>02.30pm</td>
<td>Hands-on activities (Part 3)</td>
</tr>
<tr>
<td>03.00pm</td>
<td>Evaluations and Close</td>
</tr>
</tbody>
</table>

The discussions involved one-on-one communications between the teachers and facilitators as well as discourses among teachers and the facilitators. These discussions explored the
teachers’ scientific background and the constraints they encountered in the classroom. In doing so, the discussions attempted to establish elements that underpinned the teachers’ classroom pedagogy and to locate the subsequent workshop activities in the teachers’ own world and the world of their classrooms. The discussion also exposed the teachers to deeper understandings of the concepts which underpinned inquiry-based pedagogy, such as Constructivism and Multiple Intelligence Theory. Activities that informed the teachers’ meta-cognition were used in these discussions to emphasise alternative ways of understanding and the basis for misconceptions. For instance, the teachers were asked to construct mind-maps on a specific scientific topic, wherein they were expected to link the different concepts they believed related to that topic. They were then asked to compare their mind-maps and take notice of the different ways each of them viewed similar scientific concepts.

The workshop activities which complemented and followed the above discussions consisted of learning experiences that were drawn primarily from physics. They included, however, some topics from chemistry and biology. Table 11 lists a sample set of these activities which comprised a typical one-day CPAS workshop. While detailed explanations of these activities are included in Appendix 5, many of these activities (and some others) are described subsequently in the context of the workshop observations and the teachers’ interviews. The workshops adjourned twice for refreshments (i.e. morning tea and lunch). The facilitators distributed evaluation forms at the close of each workshop to obtain the teachers’ feedback.
Table 11: A sample set of activities in a typical one-day CPAS workshop

<table>
<thead>
<tr>
<th>Activity</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Eureka! Archimedes</strong></td>
<td>An object will only float in a fluid providing that it displaces an amount of fluid equal to its own weight.</td>
</tr>
<tr>
<td><strong>Cartesian Diver</strong></td>
<td>An object floats when it displaces a sufficient mass of water to produce a buoyant force that balances the object’s weight.</td>
</tr>
<tr>
<td><strong>Buoyancy Seesaw</strong></td>
<td>Pressure in a fluid increases with depth.</td>
</tr>
<tr>
<td><strong>Guesstimation</strong></td>
<td>Surface tension is a strong force.</td>
</tr>
<tr>
<td><strong>Making a Cloud</strong></td>
<td>An increase in pressure can reduce temperature sufficiently to cause water vapour to condense as a mist.</td>
</tr>
<tr>
<td><strong>Film Can Rocket</strong></td>
<td>The reaction between bicarbonate of soda and vinegar produces carbon dioxide gas.</td>
</tr>
<tr>
<td><strong>Unexpected Heat</strong></td>
<td>Sodium thiosulphate is one of a few substances which can dissolve in its own water of crystallization, and remains in a liquid state at room temperature.</td>
</tr>
<tr>
<td><strong>Hot and Cold nails</strong></td>
<td>The skin has different sensors for different experiences.</td>
</tr>
<tr>
<td><strong>Reaction Timer</strong></td>
<td>Reaction time is the time between the eyes seeing something and the brain and limbs responding to it.</td>
</tr>
<tr>
<td><strong>Symmetry</strong></td>
<td>The human body is aligned symmetrically about a vertical axis.</td>
</tr>
<tr>
<td><strong>Corner Reflector</strong></td>
<td>A beam of light makes a reflection in each of the three mirrors arranged to form a corner and is reflected back to the source.</td>
</tr>
<tr>
<td><strong>Clucking Cup</strong></td>
<td>Sound is made whenever vibrations are set up.</td>
</tr>
<tr>
<td><strong>Musical Straws</strong></td>
<td>The frequency of a note depends on the length of a pipe.</td>
</tr>
<tr>
<td><strong>Coat Hanger Bells</strong></td>
<td>Sound vibrations travel best through solids and least through air.</td>
</tr>
</tbody>
</table>

(Source: Based on creative science teaching using simple materials © Gore, Bryant & Stocklmayer, 2004)

The six CPAS workshops varied in terms of their locations and the numbers of teachers who participated. The first four of these CPAS workshops were conducted for middle
school science teachers in Australia. These workshops were conducted in the Queensland
towns of Ayr and Charters Towers; and in Launceston and Hobart in Tasmania. There
was some variation in the numbers of teachers who participated in these workshops. For
instance, 30 teachers attended the workshop in Hobart and 18 teachers attended the
workshop in Launceston. There were fewer but similar numbers of teachers in the
workshops in Queensland. Based on the fact that the CPAS workshops were advertised
regionally, this variation in numbers could be explained in terms of regional populations
in those areas. Regional statistics from the Australian Bureau of Statistics (2008) state,
for example, that the population in Hobart is significantly greater than that of Launceston.
Hence it would be reasonable to extrapolate that more teachers would have attended the
workshop in Hobart. A similar pattern emerged when the number of teachers who
participated in the CPAS workshops in Charters Towers and Ayr were compared to the
regional populations in those areas (see Table 12).

Table 12: Numbers of teacher-participants in CPAS workshops in Australia

<table>
<thead>
<tr>
<th>Workshop locations</th>
<th>Number of teachers</th>
<th>Regional populations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Launceston, Tasmania</td>
<td>18</td>
<td>103200</td>
</tr>
<tr>
<td>Hobart, Tasmania</td>
<td>30</td>
<td>494520</td>
</tr>
<tr>
<td>Ayr, Queensland</td>
<td>12</td>
<td>8334</td>
</tr>
<tr>
<td>Charters Towers, Queensland</td>
<td>11</td>
<td>8846</td>
</tr>
</tbody>
</table>

The last two CPAS workshops were offered to science teachers from outside Australia; viz.
Sri Lanka and Indonesia. The workshop in Sri Lanka was conducted at the National
Science Foundation in Colombo. It was intended as part of Sri Lanka’s *National Science*
Week program for that year. It was attended by 66 teachers who taught science from Years 7 through 11 in Sri Lankan schools. This workshop was also one day’s duration and involved a similar balance of hands-on activities and discussions to the workshops for middle school science teachers in Australia.

The workshop for Indonesian science teachers was conducted as a component of a week-long residential professional development program in Australia (based in Canberra). The participants comprised a group of nine science teachers, who taught secondary level science in schools across Indonesia. This CPAS workshop was not entirely similar in structure because it formed part of a larger professional development program, where the teachers were informed about formal and informal science education in Australia. It was, however, broadly consistent in terms of its science content with the other CPAS workshops that have been described in this section.

Workshop communications that were recorded in the six categories of observational variables are now discussed separately. A table is used, when discussing each of these categories, to present the frequency of that category alongside the total frequencies (i.e. frequencies of all six categories of communications) that were recorded in each workshop. In addition, the observations from the last two workshops revealed some elements that were not seen previously in the workshops for science teachers in Australia. These observations, which featured cross-cultural perspectives from the Sri Lankan and Indonesian teachers, are discussed later in this section.
Category 1

Facilitator makes a statement / asks a question that causes teachers to reflect about their existing awareness of a particular scientific concept

Workshop communications that were described in the above terms were recorded in Category 1. These communications comprised 20% (on average) of the total workshop communications. The frequencies of Category 1 communications in the six workshops that were observed is given in the table below.

Table 13: Frequencies of Category 1 communications in the six CPAS workshops

<table>
<thead>
<tr>
<th>CPAS workshop for teachers in:</th>
<th>Frequencies of Category 1 communications</th>
<th>Total frequencies (All categories)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Launceston</td>
<td>29</td>
<td>142</td>
</tr>
<tr>
<td>Hobart</td>
<td>22</td>
<td>122</td>
</tr>
<tr>
<td>Ayr</td>
<td>20</td>
<td>131</td>
</tr>
<tr>
<td>Charters Towers</td>
<td>30</td>
<td>146</td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>42</td>
<td>198</td>
</tr>
<tr>
<td>Indonesia</td>
<td>49</td>
<td>219</td>
</tr>
</tbody>
</table>

Category 1 communications featured, essentially, at the onset of a workshop component that was devoted to a specific scientific concept. Before introducing optics and heat, for instance, a facilitator asked the teachers:

Have you thought about why you see lightning before you hear thunder?
A similar question that was asked by a facilitator before commencing discussions about buoyancy was:

Why do you think some objects float and others don’t?

These questions were sometimes structured to present a statement. With reference to the previous topic of buoyancy, for instance, the facilitator stated:

We know that a ship which weighs several tons floats in water, but a pebble weighing far less would sink.

By examining the vocabulary which was used to phrase these communications, it was revealed that the facilitators emphasised particular actions; i.e. “Why do you think…”; “Have you thought…”; and “We know…”. The action words (i.e. verbs) that were used in these examples delineate actions that require active thinking and reflection. By structuring questions and statements in this way, it allowed the facilitators to invite the teachers to actively reflect about their awareness of a particular scientific concept.

Active reflection (i.e. self-analysis) is promoted in the literature as a feature of good science teacher professional development. Schön (1983) points out that by using reflection critically and analytically it is possible to ensure teacher change through professional development. Hunsacker and Johnston (1992) support this view. They add that it is critical to have opportunities for reflection in professional development programs, if these programs genuinely wish to promote a climate of active inquiry in classrooms. Calderhead and Gates (1993) point out that active reflection “enables teachers to analyze, discuss and evaluate their own practice…encourages teachers to take responsibility for professional
growth…and empowers them to influence future directions of education” (pp.3-4). Other researchers, including Connelly and Clandinin (1988), concur that reflection helps teachers to clarify their thinking and anticipate decisions for future actions. This implies that teachers need opportunities to actively reflect not only on their practice, but also on their own awareness of science. By having such opportunities to actively reflect, they would be more prepared to face the challenges that confront them in student-centred constructivist classrooms.

Inviting teachers to actively reflect about their awareness of a particular scientific concept is, however, insufficient to obtain a complete picture of their understandings about that scientific concept. Since teachers’ understandings about science form the basis for their scientific awareness (see Burns et al., 2003), it is also essential to examine the accuracy with which teachers construct those understandings. This is important because teachers hold alternative conceptions (or misconceptions) about scientific concepts (see, for example, Gilbert et al., 1998; Stocklmayer, 2001). There is agreement among these researchers that teachers promote alternative conceptions because they lack a deeper understanding about their scientific knowledge. Moreover, based on the earlier premise that teachers’ existing scientific knowledge and understandings forms the basis for the construction of subsequent knowledge (see Watson & Manning, 2008), it is critical for professional development to inform teachers about the scientific accuracy of their understandings. It was necessary to observe whether communications in the CPAS workshops also attempted to inform teachers in this way. Observations of these communications are described in Category 2.
Category 2

*Facilitator informs teachers about the scientific accuracy of their understanding*

Workshop communications that were described in the above terms were recorded in Category 2. These communications comprised 11% (on average) of the total workshop communications. The frequencies of Category 2 communications in the six workshops that were observed is given in the table below.

Table 14: Frequencies of Category 2 communications in the six CPAS workshops

<table>
<thead>
<tr>
<th>CPAS workshop for teachers in:</th>
<th>Frequencies of Category 2 communications</th>
<th>Total frequencies (All categories)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Launceston</td>
<td>14</td>
<td>142</td>
</tr>
<tr>
<td>Hobart</td>
<td>14</td>
<td>122</td>
</tr>
<tr>
<td>Ayr</td>
<td>16</td>
<td>131</td>
</tr>
<tr>
<td>Charters Towers</td>
<td>19</td>
<td>146</td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>19</td>
<td>198</td>
</tr>
<tr>
<td>Indonesia</td>
<td>23</td>
<td>219</td>
</tr>
</tbody>
</table>

Category 2 communications attempted to inform teachers about the accuracy with which they understood scientific concepts. These communications featured attempts to address alternative conceptions that were held by the teachers. Addressing teachers’ alternative conceptions can, however, be challenging and sometimes even confrontational, as Greenwood (2003) explained with reference to the teachers in her study. Challenging preferential forms of knowledge can be seen as a threatening experience by some teachers.
Such experiences contradict earlier recommendations in the literature which strongly advocate that professional development should promote non-threatening learning environments for teachers (see, for example, Harrison et al., 2008). Moreover, it is not possible for professional development to simply inform teachers about correct forms of knowledge, since the literature also vehemently condemns teacher education that perpetuates canonical perceptions about scientific knowledge (see, for example, Porlán & Martín del Pozo, 2004). Communications in professional development should, therefore, be circumspect when attempts are made to address teachers’ alternative conceptions.

It was observed that several methods were used in the CPAS workshops to address the teachers’ alternative conceptions. One of these methods involved inquiring from teachers what they knew about different scientific concepts. This was achieved by asking the teachers to individually record (anonymously) their agreement, disagreement and ambiguity (i.e. true, false and not sure), to a series of statements relating to different scientific facts. The statements which were used in one such quiz were derived from the national surveys conducted in 1988 to examine the British and American publics’ understandings about science (see Durant et al., 1989). These included statements about the structure and components of atoms, the chemical composition of everyday substances and the Earth’s atmosphere (see Figure 12). The teachers were informed about the findings made by the above surveys in an attempt to show them that alternative conceptions were widespread. They were informed, for instance, that 69% of the UK and US publics did not know that electrons are smaller than atoms; and that 36% of those surveyed believed that common salt was made from calcium carbonate. It was observed, however, that the teachers had more accurate understandings about these scientific facts.

Another quiz was used in some of the workshops for the same purposes. The statements in that quiz are included in Appendix 4.
Figure 12: A quiz used in some of the CPAS workshops to examine teachers’ alternative conceptions.

What do you think?

<table>
<thead>
<tr>
<th></th>
<th>True</th>
<th>False</th>
<th>Unsure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. An object at rest has no energy</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Heat is a transfer of energy</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. If an object is at rest, no forces are acting on it</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Light travels faster than sound</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. When an object runs out of force, it stops moving</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Friction always hinders motion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Heat rises</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Energy is used up in a torch bulb</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Metal is naturally cooler than plastic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Heat is a substance contained in a body</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. If a pen is dropped on the moon, it will fall to the surface of the moon</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. Pressure and force are not the same thing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. A golf ball sinks because it is heavier than water</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14. Stored energy is energy contained in an object: for example, in a battery</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15. A more massive pendulum bob on a 50cm string will swing faster than a less massive one</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(Source: Based on creative science teaching using simple materials © Gore, Bryant & Stocklmayer, 2004)
Nevertheless, the teachers were challenged when they were asked to comment about statements like “all the oxygen we breathe comes from plants”. Many teachers were uncertain about the source of the oxygen we breathe, and were doubtful whether all of that oxygen originated from plants. Some teachers believed that there were sources of oxygen other than plants. During the discussion that followed the teachers stated that a large percentage of the oxygen is produced by oceanic algae and blue-green algae (viz. Cyanobacteria). They were, however, reluctant to agree that these forms of algae were actually plants, since they believed that plants grew on land. This example illustrates that the teachers lacked a deeper understanding about scientific knowledge constructs, which in this instance led them to understand that the term plants only meant terrestrial forms. Hence (like 40% of Durant et al.’s respondents), the teachers were also not sure whether all the oxygen we breathe came from plants.

In another attempt to address the teachers’ alternative conceptions, the facilitators showed part of a video called A Private Universe (Science Media Group, 1989). In this video, newly graduated students from Harvard University (Massachusetts, USA) were asked to explain the reason for seasonal change. Many of the graduates who were interviewed, including those who had specialized in science, explained that the Earth’s elliptical orbit, as opposed to the tilt in its axis, was responsible for the change in seasons. They believed that winter was a consequence of the Earth travelling to the end of the orbit away from the Sun and, conversely, that summer was when the Earth arrived at the other end of the orbit which was nearer to the Sun. It may have been possible that the teachers in the workshops also held this alternative conception. However, the facilitators did not directly inform the teachers of this possibility. Instead it was observed that the facilitators implied to the
teachers that *their students* might hold this alternative conception about the reason for changing seasons:

*Your students might also believe that summer changes to winter because the Earth is travelling away from the Sun.*

While informing the teachers that the Earth’s axial tilt was more accurately the reason for seasonal change, the facilitators pointed out, with reference to the video, that it was possible for anyone to hold alternative conceptions, irrespective of their level of scientific training.

The workshop also addressed alternative conceptions which are promoted through textbooks. For example, the facilitators showed the teachers a diagram of the burning candle experiment (similar to the one illustrated in Figure 13), and asked them what was demonstrated by that experiment. This experiment has been extensively used in science teaching to demonstrate that oxygen comprises 20% of the atmosphere. The teachers explained that when the candle underneath the jar is extinguished, after having used up the oxygen, the water level within the jar rises by one-fifth. This apparently demonstrates that one-fifth of the atmosphere consists of oxygen. The teachers arrived at this conclusion based on the alternative conception that has been advanced through science textbooks: *i.e.* the water in the jar rises to occupy that space which was previously occupied by oxygen.

The subsequent dialogue that issued between a facilitator and some of the teachers from the CPAS workshop in Launceston is given below.
Facilitator: I’m sure you are familiar with this diagram from your science textbooks. What do you think this experiment is trying to show?

Teacher 1: Isn’t it something to do with oxygen?...isn’t the candle supposed to go out or something like that when the oxygen finishes?

Facilitator: Yes, that’s right, it does have something to do with oxygen. (Looking at another teacher) Yes, you were going to say something?

Teacher 2: I’m not quite sure, but if I remember right, the water level in the jar rises up when the candle goes out.

Teacher 1: That’s it, I remember now...the water level goes up in the jar by one-fifth...or something like that, doesn’t it?

Facilitator: All right. Okay, the candle goes out the water level in the jar rises by one-fifth. Any other thoughts on this?

(Looking around the room and noting nods of agreement from other teachers the Facilitator continues) Okay, but why by one-fifth?

Teacher 3: Oxygen makes up 20% of the atmosphere, so 20% is one-fifth.

Facilitator: That’s correct, but what do you think happens to the oxygen in the jar while the candle is burning?

Teacher 3: Combustion requires oxygen, so when the oxygen in the jar is over the candle goes out, because there is no more oxygen left to burn. That’s why the water rises.

Teacher 1: Exactly, the water takes the place of oxygen in the jar.
Facilitator: *Okay I understand. So, the oxygen completely vanishes when it gets burnt. That is why the water level rises to replace it. But doesn’t oxygen get converted into carbon dioxide?*

Teacher 1: *(Thinks for sometime) Yes, that can happen…but (looks confusedly at Teacher 3)*

Teacher 3: *Hmm...I agree, oxygen gets converted into carbon dioxide while burning (but looks confused). What are you trying to get at?*

Facilitator: *So what happens to that carbon dioxide? It would also occupy some space in the jar, wouldn’t it?*

Teachers: *(Silence)*

In order to address the alternative conception surrounding the burning candle experiment, that has been advanced through textbooks, the facilitator pointed out to the teachers that the carbon dioxide which was formed as a result of combustion would replace the space in the jar that was previously occupied by oxygen. This meant that it was not possible for the water level in the jar to rise to occupy that space. Several teachers commented at this stage that they had actually seen the water level in the jar rise. They asked the facilitator how this observation was explained.

Teacher 4: *But I’ve actually seen the water go up when the candle goes out. I did the experiment with my students. Are you saying the experiment is wrong? I’m sure..., one student even measured the water level height and we calculated it. It was one fifth. (Looks around at other teachers who nod in agreement).*

The reason for the rising water level, the facilitator explained further, was due to initial expansion and subsequent contraction of the air in the jar. While the air expanded initially due to the heat from the candle, it contracted upon cooling when the candle was extinguished. Because the air in the jar now occupied less space than it did before, the water level rose to claim the space. Hence the facilitator pointed out to the teachers that the
rise in the level of water in the jar was not indicative of the percentage of oxygen in the atmosphere.

The facilitators were confronted with greater resistance when they attempted to address alternative conceptions that were held by teachers from outside Australia. It was observed that these teachers were more challenged than their Australian counterparts, when the facilitators informed them about possible inaccuracies in their scientific understandings. The Sri Lankan teachers, in particular, were not prepared to accept that textbooks could perpetuate alternative conceptions in this way. These discourses were marked more strongly by cross-cultural elements of communication and are discussed later in this section.

The literature maintains that teachers’ understandings about science (even understandings which advanced alternative conceptions as described previously), are based on strongly held beliefs (see, for example, Bybee, 1993). New forms of understanding are necessary to change those beliefs. The literature also holds that teachers “modify prior conceptions if they are inaccurate” (p.2, Anderson & Michener, 1994) only when they perceive alternative forms of understanding to be relevant to their own interests. It was necessary, therefore, to observe whether the CPAS workshops also offered the teachers similar opportunities to experience new forms of understanding. How these workshops attempted to offer such experiences are discussed in Category 3.
Category 3

Facilitator provides a reference that informs teachers’ understanding about a particular scientific concept

Workshop communications that were described in the above terms were recorded in Category 3. These communications comprised 18% (on average) of the total workshop communications. The frequencies of Category 3 communications in the six workshops that were observed is given in the table below.

Table 15: Frequencies of Category 3 communications in the six CPAS workshops

<table>
<thead>
<tr>
<th>CPAS workshop for teachers in:</th>
<th>Frequencies of Category 3 communications</th>
<th>Total frequencies (All categories)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Launceston</td>
<td>22</td>
<td>142</td>
</tr>
<tr>
<td>Hobart</td>
<td>23</td>
<td>122</td>
</tr>
<tr>
<td>Ayr</td>
<td>20</td>
<td>131</td>
</tr>
<tr>
<td>Charters Towers</td>
<td>24</td>
<td>146</td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>42</td>
<td>198</td>
</tr>
<tr>
<td>Indonesia</td>
<td>40</td>
<td>219</td>
</tr>
</tbody>
</table>

Category 3 communications informed the teachers’ scientific understandings by using references that were socio-culturally meaningful to them. These communications used historic, contemporary, and linguistic references as bases for teachers to link their scientific knowledge to new forms of understanding.
Historic references were presented in the form of narratives. One such example was the story of King Hieron’s crown (based on accounts by the Roman writer and engineer Vitruvius (80-15 BCE), which was used in the context of workshop discussions about the principle of fluid displacement. In this story, King Hieron asked Archimedes to find out if his crown was made of pure gold. One of the facilitators created a vivid image of how Archimedes, while in his bath, contemplated the King’s request. The facilitator narrated how Archimedes chanced upon an experience that revealed to him that when an object was submerged it displaced an equal weight of water. The facilitator concluded the story by telling the teachers how Archimedes, after having thus discovered the principle of fluid displacement, ran down the streets of Syracuse in excitement shouting the famous words *Eureka Eureka*.

An important feature that emerged from this communication was the characterization of human elements that were involved in Archimedes’ investigations. For example, the facilitator drew to the teachers’ attention, the frustrations Archimedes might have encountered when trust by King Hieron to find out if the crown was made of pure gold. Also elements of fear, humiliation and perhaps even anxiety about the safety of his own life, that might have troubled Archimedes, if he failed to provide the King with this information, were emphasised through this narrative. Moreover, the elements of chance, speculation and excitement, which characterized Archimedes’ scientific investigation, also become apparent in this communication.

It has been recommended in the literature that the actual human agencies which are involved in scientific investigations should be presented when scientific information is communicated. For instance, it has been pointed out by Sutton (1996) that “a mixture of personal, figurative analogy and tentativeness” (pp.3-4) needs to be employed when
science is communicated for “persuasion and counter-persuasion”. Science historians, like Sarton (1948), have also stated that presenting scientific information together with its actual human agents allows for an unsynthetical view about science. It is argued that presenting science in this way enables learners to relate to those experiences more closely, and in doing so offers them more meaningful learning experiences. It is claimed, therefore, that science which is communicated together with its human spirit promotes pedagogy that is conducive to recommended science education reform (see Fensham, 2007).

Also the fact that the above narrative described how Archimedes chanced upon an experience which led him to discover the scientific concept of fluid displacement highlights recommendations in the literature to teach students the actual nature of science. By managing the communication in the way it was done, the facilitator was able to lead the teachers to understand that science does not necessarily constitute a series of logical processes that pave the way for the discovery of pre-existing scientific truths (see Brush, 1989). This was especially highlighted in the facilitators’ account of the historic events that led to the invention of Wilson’s Cloud Chamber. The teachers were surprised to learn from the facilitators that this invention for which the Scottish physicist Charles Wilson was awarded the Nobel Prize for Physics in 1927 was serendipitously aided by wayward X-Ray particles from a laboratory adjacent to that of Wilson’s at Cambridge. By communicating the historic and social events which surrounded scientific discoveries in this way, the facilitators were able to inform the teachers that science is not a sequential logical process of discoveries as presented in many textbooks and curriculum guides (see Eltinge & Roberts., 1993).

Contemporary references that were used during the CPAS workshops were also recorded. For example, the teachers were shown a roadside corner-reflector (also referred to as a
**roadside safety marker** (see Figure 14), which is a contemporary feature along most highways in Australia. These devices are red or white-coloured discs and are comprised of many small corner-shaped indentations. Corner-reflectors have the unique property of reflecting light back to its source, and are used to alert motorists, as safety markings on the middle and sides of roads. The facilitators used this contemporary reference in the context of the workshops’ discussions about reflection properties of light. The facilitators explained and demonstrated that when a beam of light is projected on to three mirrors, that are arranged to form a corner (*i.e.* like in a corner-reflector), the light-beam is reflected back to its source.

![Figure 14: Photograph showing a (white) roadside safety marker. The minute dot-like markings on its surface are in fact many minute corner-reflectors.](image)

In another example of a contemporary reference, the facilitators spoke about the Australian Olympic swimmer Ian Thorpe, with particular attention to his fast reflexes. They used
anecdotal evidence to inform the teachers about the short time between a gunshot being fired and the swimmer diving into a pool at the start of a race. The facilitators used this contemporary reference in the context of workshop discussions about motor responses by the human body to various environmental stimuli. Using the above contemporary reference, the facilitators informed the teachers about the time required by the human brain to initiate motor responses to sound stimuli (i.e. auditory-motor responses).

It is maintained in the literature that incorporating cultural, social and historic perspectives into scientific understanding is consistent with constructivist epistemology (see, for example, Shymansky et al., 1997). Researchers hold that learning experiences that are grounded on obvious social and personal insights enable for more meaningful construction of knowledge (see Bybee, 1997). The ways in which language constructs are used to convey scientific concepts holds, therefore, special significance (see Sutton, 1996). Like historic and contemporary references that have been mentioned earlier, linguistic references can also inform the ways by which learners make sense of everyday experiences.

The use of linguistic references in teacher education also serves a pedagogical purpose. The literature has pointed out that, when teaching science, teachers are more prone to use unfamiliar scientific terminology and conventional language structures; i.e. the mystery of scientific discourse (see Hanrahan, 2003). Despite the fact that students are challenged by such unfamiliar use of language (see Palmer, 1999), researchers like Larochelle (2002) hold that teachers continue to teach science using conventional terminology because their scientific training has equipped them to teach science in this way. Teachers have had few opportunities to experience how language, which is familiar to their students, could be used to teach science. It is agreed, therefore, by researchers that teachers need to learn by
observing alternative means of communicating science if they are expected to change to their pedagogy (see, for example, Harrison et al., 2008).

Communications in Category 2 also recorded such linguistic references which drew on language constructs that were familiar to the teachers. In the workshops in Tasmania, for instance, the facilitators used the popular maritime term *ship’s displacement* (which is used to describe a ship’s mass), as a linguistic reference to discuss the principle of fluid displacement. It was assumed by the facilitators that the teachers would be familiar with this phrase, due to their geographic location and hence their familiarity with ships and nautical information. It was observed that the teachers did appreciate the use of this phrase in the context of the discussions that followed. It was seen, for instance, that the teachers were more forthcoming with their information. Some teachers even informed the facilitators and other teachers about ships that had sunk off the Tasmanian coastline.

The term *soft-brakes* was another example of a linguistic reference that was used by the facilitators to explain the difference between compression properties of gases and liquids. This reference was, however, not received with the same familiarity as the previous example (*i.e.* *ship’s displacement*). The facilitators assumed that the teachers would be familiar with the term soft-brakes, that is used to describe the phenomenon which is experienced when air gets trapped in the hydraulic brake-system of an automobile. This causes the driver to exert more force when applying the brakes. However, the teachers indicated that they were not familiar with this term. It was also observed that they were somewhat ambivalent to the information that was communicated subsequently on that topic. Hence the facilitators were required to explain what was meant by that term.
This second example illustrates a linguistic reference that was based on assuming too much about the teachers’ background. The facilitators may have assumed, since many teachers drove cars they would be familiar with the term soft-brakes. The teachers were, however, not familiar with that term. This did not mean, however, that the teachers were unfamiliar with the phenomenon. It was observed, from their subsequent discussions with the facilitators, that many teachers had experienced the phenomenon of air getting trapped in a car’s hydraulic brake-system. It was apparent that although the teachers were familiar with this phenomenon they did not use the term soft-brakes to describe it. (It may be possible that they used another term for it.) Irrespective of the reasons for the teachers’ confusion, this example reveals possible dangers of using linguistic references based on extrapolated assumptions about the audience.

This example also illustrates a situation where the teachers found that the linguistic reference, which was offered to inform their scientific understandings, was not intelligible to them. The literature has pointed out that conceptual change is made possible when new forms of understanding are “intelligible, plausible, fruitful, and feasible” (p.57) to teachers (Yager, 1991). It was observed, subsequently, that the facilitators had to use alternative means to inform the teachers about compression properties of different fluids.

The literature holds that is important to offer learners more than one means to inform their understandings about a particular scientific concept; i.e. “the diverse ways in which scientists study the natural world” (p.2, Anderson, 2002). Active learning experiences that involve minds-on and hands-on approaches feature predominantly in these claims. Researchers agree that experiences which allow learners to actively construct their scientific knowledge enables for more effective and long-lasting understandings about science (see, for example, Goodrum et al., 2001). It was necessary, therefore, to observe
whether active experiences, that went beyond informing teachers’ understandings based on socio-cultural references, were also part of the CPAS workshops’ communications. These observations are discussed in Category 4.

Category 4

Facilitator offers an activity that informs teachers’ understanding about a particular scientific concept

Workshop communications that were described in the above terms were recorded in Category 4. These communications comprised 34% (on average) of the total workshop communications, and featured as the single major component of the CPAS workshops. The frequencies of Category 4 communications in the six workshops that were observed is given in the table below.

Table 16: Frequencies of Category 4 communications in the six CPAS workshops

<table>
<thead>
<tr>
<th>CPAS workshop for teachers in:</th>
<th>Frequencies of Category 4 communications</th>
<th>Total frequencies (All categories)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Launceston</td>
<td>52</td>
<td>142</td>
</tr>
<tr>
<td>Hobart</td>
<td>41</td>
<td>122</td>
</tr>
<tr>
<td>Ayr</td>
<td>49</td>
<td>131</td>
</tr>
<tr>
<td>Charters Towers</td>
<td>49</td>
<td>146</td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>60</td>
<td>198</td>
</tr>
<tr>
<td>Indonesia</td>
<td>67</td>
<td>219</td>
</tr>
</tbody>
</table>
Category 4 communications attempted to inform the teachers’ scientific understandings by offering the teachers activities that were based in different scientific concepts. It was possible to discern two distinct forms of activities that were used to affect this purpose: minds-on and hands-on activities.

When minds-on activities were used, the teachers were asked to perform experiments in non-tactile terms, (i.e. the opposite of hands-on activities). This meant that teachers had to use their imagination to critically investigate specific experiences. An example of one such minds-on activity was the *Gedanken experiment*. This involved playing out contrived imaginary scenarios to reach outcomes that would have been achieved if the actions were performed actually. For instance, the teachers were asked about the comparative levels of difficulty they thought they would experience if they tried to submerge different sizes and types of balls in a swimming pool. Using this Gedanken experiment a facilitator attempted to inform the teachers’ understandings about fluid displacement; essentially that larger objects displaced a greater volume of water. The dialogue that transpired between the facilitator and some of the teachers from the CPAS workshop in Ayr during that Gedanken experiment is given below.

Facilitator: *Now, what I want you to do is to try and picture yourself standing in a swimming pool on a hot summer’s day. I’m going to give you in your imagination a ping-pong ball, like this one (shows the teachers a white ping-pong (i.e. table tennis) ball. Imagine that you are holding it in your right hand."

Teacher 1: *Can I use my left hand instead? I’m more comfortable with my left hand*

Facilitator: *Sure. Use either your left or right hand. What ever you are comfortable with. Now try and take your hand under the water. While you are doing that, imagine that you are also pushing the ping-pong ball below the surface of the water (mimes). Are you okay with that?*

Teachers: *(Nod)*
Facilitator: Alright. So, did you find that hard?
Teacher 2: Hmm... not that hard.
Teacher 1: No, not really.
Facilitator: All right, now let it go.
Teachers: (Indicate with their hands the ping pong ball rising up to the surface)
Facilitator: Next I want you to imagine trying to push a tennis ball like this one (shows the teachers a yellow tennis ball) below the surface of the water (mimes again). (After a few seconds) Was it the same as last time?
Teacher 3: Not as easy as pushing the ping-pong ball. But still, wasn’t hard (looks around at the other teachers enquiringly).
Teacher 1: Yes, I won’t call it hard. I felt the same as well.
Teacher 4: It was harder than pushing the ping-pong.
Facilitator: Okay, let it go. And tell me what you think will happen.
Teacher 2: It will come up to the surface (mimes action).
Facilitator: That’s right... Now I’m sure you’ve seen one of these at the beach or around a swimming pool (shows the teachers an inflatable beach-ball about 30cm in diameter). Try to do the same with one of these.
Teachers: (Laugh and gesture with their hands that the ball would rise up to the surface of the pool)
Facilitator: Why?
Teacher 5: That’ll be pretty hard to do.

Through the above dialogue the facilitator attempted to create a mindscape based on the teachers’ earlier (and familiar) experiences. The teachers were guided through different scenarios of actual events that were similar to the ones which were presented in the Gedanken experiment. Using what they remembered from those actual events the teachers deduced outcomes for the contrived imaginary scenarios in the Gedanken experiment. The facilitator then offered a further imaginary scenario that was unparalleled in reality. Next, the facilitator asked the teachers to visualize a very large beach-ball (i.e. “one that you would need to open both your arms wide to catch it”), and to imagine pushing it into the
swimming pool. Based on the links that the teachers established through the previous
minds-on experiences, they replied that it would be nearly impossible to push a ball of such
dimensions under water by themselves. As their responses quoted below indicate, this last
task would be more difficult than the ones they did before.

Teacher 1: *(Laughing) Might need to jump on it (mimes throwing entire body over the ball). Can’t see myself pushing it.*

Teacher 4: *Yes, jumping on the ball might work. It’s definitely harder than the other ones.*

Another example of a minds-on activity that was used in the CPAS workshops as called *Guesstimation.* It incorporated a sequential process of *predicting, observing and evaluating,* which is referred to as a *POE* approach in educational methods. The first part of this sequence (*i.e.* prediction) was used to offer the teachers a minds-on activity. For this, the teachers were provided with a set of information based on which they were expected to arrive at a reasonable prediction. In order to make this prediction, the teachers had to use their knowledge of previous experiences, that resembled the information they were provided, together with their understandings of relevant scientific concepts.

For example, the facilitators gave each group of teachers a small plastic bottle that was filled with blue-coloured water (which was placed on a white picnic-ware plate). The water was coloured in order to draw the teachers’ attention to the surface of the liquid that formed a convex surface (*i.e.* the meniscus) at the mouth of the bottle. A facilitator then held a metal paperclip over the mouth of one of the bottles (as featured in Figure 15), and asked the teachers how many such paper clips could be dropped into the bottle before the water spilt over. The teachers were asked to predict, by discussing in their groups, how many paperclips they thought would be needed before the water in the bottle ran over. In order to
make this prediction, the teachers had to use what they remembered from similar previous experiences. They also had to examine their understandings about surface tension; *i.e.* surface tension causes the surface of most liquids to occupy a minimum space, which causes the meniscus of most liquids to be convex.

![Image](image.png)

Figure 15: Photograph showing the introduction to the *Guesstimation* minds-on activity, where a paperclip is being held over the mouth of a bottle filled with blue-coloured water

The above minds-on activities embodied elements of the PAST model described by Stocklmayer and Gilbert (2002) earlier. The researchers have used this model to explain that learners’ scientific awareness is advanced to a new level through learning experiences that remind and thereby inform their existing level of scientific awareness. It was seen that, in both the Gedanken experiment and the Guesstimation exercise, the teachers had to revisit their awareness of the relevant scientific concepts. They then had to examine their understandings of those concepts in order to make well reasoned deductions (*i.e.*
predictions or guesses, depending on the activity). This meant that the teachers had to advance their awareness of the relevant scientific concepts when they made those deductions. These elements from the PAST model were not unique to the workshops’ minds-on activities alone. The hands-on activities, that are discussed now, also reveal that the teachers had to revisit and reason within their constructs of scientific knowledge, in order to conceptualise what they experienced.

Hands-on activities that were featured in the workshops, (as opposed to minds-on activities), offered teachers opportunities to inform their scientific understandings through practical exploration. In one such activity, the teachers used household compounds to explore the properties of gases. It was established, earlier in the workshops, that the teachers were aware that certain chemical reactions produced gases. The teachers knew, for example, that sodium bicarbonate (NaHCO₃) reacted with vinegar (i.e. ethanoic acid; CH₃COOH) to produce carbon dioxide (CO₂). The teachers were even familiar with the following chemical equation that represented that reaction:

\[
\text{Na}^+ \text{HCO}_3^- + \text{CH}_3\text{COO}^- \text{H}^+ \rightarrow \text{CO}_2(\text{gas}) + \text{H}_2\text{O} + \text{CH}_3\text{COONa}
\]

The teachers also knew, from their knowledge of Gas Laws, that the pressure exerted by a gas was inversely proportional to the volume of that gas (i.e. Boyle’s Law: \(P_1 V_1 = P_2 V_2\)). They were, however, not all aware that the carbon dioxide gas, which was formed through the above chemical reaction, would occupy a large volume. Moreover, they lacked an understanding of the pressure that is exerted by such a large volume of gas.
The facilitators used a hands-on activity called the *Film can rocket* to enable teachers to conceptualize this relationship between the pressure and volume of a gas. For this activity, the facilitators asked the teachers to tightly pack sodium bicarbonate into the lid of a film-can (as featured in Figure 16), and to clasp it shut tightly over the bottom half of the film-can. The bottom half of the film-can already contained a small quantity of vinegar. The teachers were then asked to quickly invert the closed film-can and observe what took place.

Figure 16: Photograph showing a teacher packing sodium bicarbonate into the film can lid in the hands-on activity titled *Film can rocket*.

The teachers saw that the inverted film-can separated from its lid (accompanied by a *popping* sound) and propelled into the air (like a *rocket*). They also saw that the chemical compounds (*i.e.* sodium bicarbonate and vinegar) had reacted to produce a foaming residue that was collected in the lid of the film-can. The teachers were able to infer, therefore, that carbon dioxide gas, which was produced from the chemical reaction within the film-can,
occupied a large space which could not have been contained within the can itself. The pressure exerted by the gas caused the bottom half of the film-can to separate from the lid. This was emphasized by the can popping open (to release the gas that was accumulated inside) and propelling the bottom half of the can into the air.

The facilitators demonstrated the relationship between pressure and temperature of a given volume of air using another hands-on activity called *Making a cloud*. In this activity the teachers were asked to drop a lighted match into a large clear PET bottle, which contained a small quantity of water (approximately 5ml). Once the match was doused, the teachers were asked to screw the cap on and rapidly squeeze and release the sides of the PET bottle (Figure 17). When the teachers released their pressure on bottle, it was observed that the air inside the bottle became cloudy.

Figure 17: Photograph showing a teacher applying pressure to a PET bottle in the hands-on activity titled *Making a cloud*
The facilitators informed the teachers that the phenomenon they were then observing could be explained by the Combined Gas Law (i.e. $P_1 V_1 / T_1 = P_2 V_2 / T_2$). The teachers knew about the Combined Gas Law, from their formal scientific training. They knew that pressure (P) and volume (V) were inversely related, which meant that an increase in volume resulted in a decrease in pressure, of a closed system. Based on that Law, they also knew that an increase in pressure resulted in an increase in temperature (T). They were, however, not able to make the link between the increase and decrease in pressure within the PET bottle, which corresponded with the actions of squeezing and releasing the bottle. When the teachers were informed of this relationship they were able to understand that the reduced pressure, which was created when the bottle was released, allowed for the temperature in the bottle to decrease. The reduced temperature caused the water vapour inside the PET bottle to condense. This made the air inside the bottle to appear cloudy.

Some hands-on activities were managed by minimal use of supporting materials by the teachers themselves. In one such activity the teachers were asked to observe the temperature of their breath when they blew onto their hands with their mouths open wide, and alternatively with their lips slightly apart. The teachers noticed that their breath felt much cooler when they blew with their lips slightly apart. The facilitators used this experience to explain how cooling was caused in refrigerators.

In another activity which demonstrated the asymmetrical behaviour of the human body, the facilitators asked the teachers to perform the following actions:

- Fold arms across chest
- Clasp hands as if in prayer
- Cross one leg over the other
- Applaud by clapping palms together
When performing each of these actions the teachers were asked to note which corresponding part of their body (i.e. left or right) superimposed itself on the other. The teachers were informed that the corresponding part of their body which superimposed itself, in each of the given situations, was called the *dominant* one. When they folded their arms across the chest, for example, the arm that was sitting over the other arm and positioned further away from the chest was the *dominant arm*. To advance the teachers’ understandings about asymmetrical behaviour in the human body they were asked to work in pairs and perform the following actions:

*Speak softly in your partner’s ear*

*Wink at your partner*

The teachers were asked to observe which ear and eye (i.e. left or right) was used by their partner to perform each of these actions. That ear and eye, the teachers were informed, was their partner’s dominant ear and dominant eye. While the teachers knew that the human body appeared to be structured symmetrically around a middle vertical axis, they were not all aware that the human body performed functions asymmetrically (as demonstrated above). This awareness was then used to inform the teachers’ understanding of *Parallax*.

Parallax is a concept in astronomy that is used to describe the displacement when an object is viewed from two different lines of sight. To illustrate this concept, the facilitators asked the teachers to look at a distant object in the room. Next the teachers were asked to stretch out their arms and, with both eyes open, let the tip of their index finger coincide with that object (as featured in Figure 18). The teachers were then asked to look at that object with only one eye, while the other eye remained closed. The teachers noted that the object was *truly* aligned only with their dominant eye, which they had previously identified. This
hands-on activity was followed by a historical anecdote which described events from studies in astronomy used to measure the distance between the Earth and the Sun.

![Figure 18: Photograph showing teachers experimenting with Parallax during the CPAS workshop in Sri Lanka](image)

An important feature that emerged from Category 4 communications was that the teachers applied different ways of knowing when they engaged in minds-on and hands-on activities. For example, the teachers had to think critically in order to predict the number of paperclips in the Guesstimation activity. They also needed to reason logically to deduce the varying degrees of difficulty when they hypothetically submerged different balls in a swimming pool, that were described in the Gedanken experiment. Gardener (1983) has described these different forms of knowing as *intelligences*. Based on Gardener’s *Theory of Multiple Intelligences*, the teachers would have had to apply *Logical intelligence* with both the Guesstimation activity and the Gedanken experiment. The teachers also had to apply
practical ways of knowing when they attempted to assemble the film can rocket and when they squeezed and released the sides of the PET bottle. This would mean that the teachers had to use *Kinaesthetic intelligence*. It was also highlighted that the workshops’ activities required the teachers to work with their colleagues. For instance, when they made predictions about the number of paperclips in the Guesstimation activity and when they explored different asymmetrical behaviours in the human body, the teachers had to work in groups and pairs. This meant that they would have had to apply *Inter-personal intelligence*.

It was a consistent feature of the workshops to encourage the teachers to work in groups or pairs when they carried out minds-on and hands-on activities. It has been established in the literature that group-work, which allows teachers to collaboratively learn from one another, has several benefits. For one, collaborative learning experiences offer teachers a sense of assurance (see, for example, Dillon *et al.*, 2000). In the Guesstimation activity, for example, when teachers were called upon as groups, rather than individually, to predict the number of paperclips, they felt less threatened about their answers not being *correct*. This fostered a collegial and non-threatening learning atmosphere. It was even observed that the atmosphere in the workshop, during this activity, took the form of a friendly game, where groups of teachers vied for the facilitators’ attention to state their groups’ predictions.

Also, as Harrison *et al.* (2008) have pointed out earlier, collaborative learning experiences allow teachers to recognise and emulate good practice within their learning community. This was observed in the Film can rocket hands-on activity. When the teachers assembled their film can rockets, they were observed to consult with peers whose film-cans had propelled much higher than their own. The teachers discussed among themselves about the technicalities of packing sodium bicarbonate into the lid of the film-can and strategies to quickly invert the bottom half of the can for best propelling effects.
The literature also offers two compelling reasons for professional development to include minds-on and hands-on activities. The first states that, because these activities offer teachers opportunities to critically explore their scientific understandings, they promote experiences that closely resemble actual scientific inquiry. There is wide agreement in the literature that when scientific understandings are advanced through experiences, similar to those of actual scientists, they promote a better appreciation for science (see, for example, Bencze, 2004; Rennie et al., 2001).

The second reason is more pedagogically relevant. It points out that while hands-on and minds-on activities are an integral component of inquiry-based science teaching, teachers have limited opportunities to experience science teaching that is based on such approaches (see, for example, Lee & Krapfl, 2002). As a consequence, teachers are not fully aware of how to assist their students to make sense of scientific information through inquiry-based pedagogy (also see Mortimer & Scott, 2003; Weiss, 1997). Researchers have recommended, therefore, that professional development needs to offer teachers opportunities to experience how to teach science through inquiry (see, for example, Borko, 2004).

The literature has recommended, furthermore, that teaching for inquiry should not culminate by only offering students meaningful learning experiences (see, for example, Hackling et al., 2005). Teaching science for continued engagement needs to go beyond informing students’ understandings about scientific concepts. It also needs to offer opportunities to scaffold these new ideas (see van der Valk & de Jong, 2008). This, the literature holds, constructs a climate of scientific awareness through which everyday experiences may be viewed more richly (see Tytler, 2007). Based on the conclusions drawn by researchers like Loucks-Horsley et al. (1998), that teachers should also “learn about science and science teaching with the same methods and strategies as students” (p. 190), it
is only reasonable that professional development should also scaffold teachers’ scientific awareness in the same way. This means that, in addition to informing teachers about new ways by which they could make sense of their scientific knowledge, professional development should also scaffold teachers’ scientific awareness which is manifested as a result of these new understandings. It was, necessary to observe, therefore, if the CPAS workshops also offered teachers opportunities to scaffold their newly developed scientific awareness in the broader context of everyday experiences. These observations are discussed with attention to the remaining two categories of observational variables.

Category 5 and Category 6

Communications in Categories 5 and 6 featured proximately during the CPAS workshops. They are, therefore, discussed together to accurately represent the information that was meant by these communications.

**Category 5: Facilitator provides a reference to scaffold teachers’ new level of awareness about a particular scientific concept**

Workshop communications that were described in the above terms were recorded in Category 5. These communications comprised 10% (on average) of the total workshop communications. The frequencies of Category 5 communications in the six workshops that were observed is given in the table below.
Table 17: Frequencies of Category 5 communications in the six CPAS workshops

<table>
<thead>
<tr>
<th>CPAS workshop for teachers in:</th>
<th>Frequencies of Category 5 communications</th>
<th>Total frequencies (All categories)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Launceston</td>
<td>14</td>
<td>142</td>
</tr>
<tr>
<td>Hobart</td>
<td>15</td>
<td>122</td>
</tr>
<tr>
<td>Ayr</td>
<td>17</td>
<td>131</td>
</tr>
<tr>
<td>Charters Towers</td>
<td>15</td>
<td>146</td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>15</td>
<td>198</td>
</tr>
<tr>
<td>Indonesia</td>
<td>20</td>
<td>219</td>
</tr>
</tbody>
</table>

**Category 6: Facilitator offers an experience to scaffold teachers’ new level of awareness of a particular scientific concept**

Workshop communications that were described in the above terms were recorded in Categories 6. These communications comprised 8% (on average) of the total workshop communications. The frequencies of Category 6 communications in the six workshops that were observed is given in the table below.
Table 18: Frequencies of Category 6 communications in the six CPAS workshops

<table>
<thead>
<tr>
<th>CPAS workshop for teachers in:</th>
<th>Frequencies of Category 6 communications</th>
<th>Total frequencies (All categories)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Launceston</td>
<td>11</td>
<td>142</td>
</tr>
<tr>
<td>Hobart</td>
<td>7</td>
<td>122</td>
</tr>
<tr>
<td>Ayr</td>
<td>9</td>
<td>131</td>
</tr>
<tr>
<td>Charters Towers</td>
<td>9</td>
<td>146</td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>20</td>
<td>198</td>
</tr>
<tr>
<td>Indonesia</td>
<td>20</td>
<td>219</td>
</tr>
</tbody>
</table>

Category 5 and Category 6 communications attempted to scaffold teachers’ scientific awareness in the context of familiar everyday constructs. It should be noted here that the teachers’ scientific awareness that was regarded in this instance was not the initial level of scientific awareness that was examined by communications previously described in Category 1 (i.e. Facilitator makes a statement / asks a question that evokes teachers to reflect about their awareness of a particular scientific concept). Instead, it was the new level of awareness, which was an outcome of the workshops’ earlier attempts to inform the teachers’ scientific understandings (see Category 3 and Category 4 above). Hence the observations that were recorded in Category 5 and Category 6 were workshop communications that offered the teachers perspectives from their daily life to scaffold this new level of scientific awareness.

Communications described by Category 5 used references from commonplace experiences to scaffold the teachers’ new level of scientific awareness. These references were often offered in the context of previous workshop communications, particularly Category 4.
communications (i.e. hands-on activities). For example, it was mentioned earlier that a hands-on activity called the Film can rocket was used to inform the teachers’ understandings about the magnitude of pressure which was exerted by an expanding volume of gas. After the teachers had experimented with their film can rockets, the facilitators informed the teachers that fire-extinguishers, like the ones that were fixed in the room in which the workshop was conducted, also operated on a similar principle. The chemical reaction that took place when a fire-extinguisher was activated was similar to the chemical reaction the teachers had used to propel their film can rockets. This reaction also produced a large volume of carbon dioxide gas, which was used to stifle the flames of electrical fires. The facilitators also mentioned that the large volume of carbon dioxide gas was expelled under pressure from the fire-extinguisher-hose based on the same scientific concept which the teachers had experienced when the bottom half of their film-cans were propelled into the air.

A similar attempt to scaffold the teachers’ scientific awareness was used after the workshops’ discussions about corner reflectors. It was mentioned earlier that roadside safety markers were used to inform the teachers about how a beam of light was reflected back to its source by three mirrors which were arranged to form a corner (i.e. a corner reflector). Pursuant to this, the teachers were informed of other commonplace uses for corner reflectors. One of these examples mentioned corner reflector strips that were used on the spokes of bicycle wheels to alert on-coming traffic. Another example mentioned how corner reflectors were used to set off chimes when customers entered a shop. In this instance, when a customer passing through the doorway of a shop interrupted a laser beam projected onto a corner reflector, an electronic device that was installed in the doorway set off a chime. The facilitators also spoke about the Lunar corner reflector, as another device
which also reflected light back to its source. This large disc, which has been placed on the moon, consists of many precise corner reflectors. The teachers were told that scientists use the Lunar corner reflector to reflect laser beams back to laboratories on Earth for experimental purposes.

It was observed that many Category 5 communications complemented communications that were described by Category 6. This meant that the observations recorded in Category 6 were seldom communicated exclusively. Instead they followed from the references that were described earlier by Category 5. Communications that were recorded in Category 6 described those which offered further hands-on experiences. Based on these experiences, the facilitators attempted to scaffold the teachers’ new level of scientific awareness.

Moreover, the hands-on experiences that were described by Category 6, extended beyond the hands-on activities that were described previously by Category 4. Also Category 6 communications were less activity-based and more experiential. This meant that the teachers were not asked to experiment as actively in Category 6 communications as they did in Category 4. In order to differentiate these two levels of hands-on exposure, the communications in Category 4 were described as hands-on activities, while Category 6 communications were described as hands-on experiences.

The following example illustrates a hands-on experience described by Category 6. It followed from a hands-on activity called the Clucking cup (i.e. a Category 4 communication). Also, as explained below, this Category 6 communication was complemented by a Category 5 communication, which referred to string instruments in an orchestra. In the Clucking cup hands-on activity the teachers used a Styrofoam cup with a piece of string attached to its base from the inside (as featured in Figure 19). The teachers
were asked to tug on the piece of string with a wet piece of cloth and observe that a *clucking* sound emitted from the cup. Using this hands-on activity, the facilitators attempted to inform the teachers that *sound* was produced from vibrations. (Because this was a hands-on activity that attempted to inform the teachers’ scientific understandings this communication was recorded in Category 4.)

![Figure 19: Photograph showing a *Clucking cup*: a Styrofoam cup with a piece of string attached to its base from the inside](image)

Next the teachers were informed that the Styrofoam cup acted as a resonance chamber. This meant that it amplified the sound vibrations that were produced. In an attempt to scaffold this new level of awareness, the facilitators referred to string instruments in an orchestra. They informed the teachers that instruments like violins, cellos and double basses had different-sized resonance chambers. (Because this reference attempted to scaffold the teachers’ new level of awareness in the context of an everyday experience it was recorded in Category 5.) Due to these different-sized resonance chambers, the
facilitators added, different string instruments produced sounds that were uniquely different to each other. The facilitators used an extended hands-on experience to illustrate this concept. Since this was a hands-on experience that attempted to scaffold the teachers’ new level of awareness, it was recorded as a Category 6 communication. This hands-on experience is described as follows.

A facilitator showed the teachers a plastic ice-cream container, to which a piece of string was attached from the inside of its base. The facilitator tugged at the piece of string with a wet piece of cloth to produce a sound. It was observed that this sound was louder than the sound which was produced earlier by the clucking cups. Next the facilitator showed the teachers a plastic bucket, to which a piece of string was attached in the same way. This bucket was larger than the ice-cream container. The facilitator tugged on the piece of string and the bucket produced a much louder sound. Then the facilitator used an analogy to compare the clucking cups to violins and asked the teachers to compare the ice-cream container and the bucket to other string instruments in an orchestra. The teachers pointed out that the ice-cream container could be compared to a cello, while the bucket could be compared to a double bass.

Making sense by being able to contextualise scientific concepts within the framework of one’s everyday experiences is strongly advocated as an integral feature of constructivist learning. It has been stated by researchers like Davies (2006), for example, that scientific information needs to be woven into “cultural, social, historic, legal and ethical perspectives” (p.57) to facilitate meaningful learning. It is argued that when learners are able to view science in a way that is relevant to their daily experiences they are in a better position to construct knowledge meaningfully (see, for example, Lyons, 2006). Moreover, meaningful learning experiences enable learners to engage with science on an everyday
level (see, for example, Bennett et al., 2005). Therefore, by scaffolding scientific information to construct a climate of awareness, Tytler (2007) states, learners are able to engage with everyday experiences more richly.

In addition, van der Valk and de Jong (2008) state that demonstrating to teachers the means of scaffolding offer a professional development trajectory; i.e. “the coach (i.e. the professional developer) uses them for scaffolding the teachers and the teachers can use them for scaffolding their students’ open-inquiry” (p.19). Professional development of this type emulates the practice of learning by doing, which is consistent with the recommendations made by McBride et al. (2004), who van der Valk and de Jong (2008) quote “stress the importance of engaging teachers in inquiry-based science in such a way that they can bring their new insights to their classrooms and implement the best ideas in their teaching” (p.20).

Efforts that aim to engage the public with science by offering them experiences which bear significance to their “personal, social and economic life” (p.18, Gilbert et al., 1999) are akin to principles of science communication. In fact, efforts to foster longer-term engagement with science lie at the core of endeavours that aim to increase the public’s awareness of science (Burns et al., 2003). It is believed that by offering the public a sense of ownership of scientific knowledge, in this way, it is possible to create a climate where people are confident in their understandings about science. Moreover, they would be more prepared to share those understandings with young learners in their community (Stocklmayer & Gilbert, 2002). Hence it is possible to say that the efforts which were featured in the CPAS workshops closely resembled science communication practices.
For example, in the early stages of the different workshop discourses the facilitators used communications to familiarise themselves with the audience. It was observed that the facilitators used different non-threatening ways to examine the teachers’ existing scientific awareness. This practice of science communication is consistent with Lawrence Bragg’s advice for the *first ten minutes of a lecture*; i.e. “…the first ten minutes, this is the time to establish the foundations, to remind the audience of things they *half know already*” (The Royal Institution, 1986, *emphasis added*). Examples from familiar experiences were used thereafter to establish rapport between the facilitators and teachers. This enabled a platform on which subsequent communications that informed the teachers scientific understandings could take place. An important characteristic of these communications was the use of well developed simple activities that helped the teachers to conceptualise scientific ideas (i.e. “audiences love simple experiments…” Bragg, quoted in The Royal Institution, 1986).

The way in which the workshop communications were managed, therefore, offered the teachers opportunities to not only enjoy those science-based activities, but more importantly to foster an interest and form opinions about those experiences. These features are consistent with the aspects of *Enjoyment, Interest* and *Opinion forming* in Burns et al.’s (2004) AEIOU vowel definition for science communication in the context of science presentations. It is safe to conclude, therefore, that principles of constructivist learning which were apparent in the workshops’ delivery were assisted by science communication practices. While the full bearing of these observations are discussed in Chapter 8, it remains to be investigated if the above science communication practices could also play a part in developing scientific awareness and understanding in the teachers.
Cross-cultural perspectives

It has been mentioned earlier that the two CPAS workshops for science teachers in Sri Lanka and Indonesia featured cross-cultural perspectives that were not previously observed in the workshops for science teachers in Australia. These perspectives did not, however, constitute separate categories of observational variables. Instead they featured alongside the communications that were described by the six earlier categories, and were, therefore, recorded as extensions to those communications. Some of these cross-cultural perspectives are discussed in this section.

During the communications in Category 1 (i.e. Facilitator makes a statement / asks a question that evokes teachers to reflect about their existing awareness of a particular scientific concept), it was observed that the Sri Lankan and Indonesian teachers did not respond immediately to the questions that were asked by the facilitators. It was, therefore, sometimes observed that the facilitators attempted to encourage the teachers to respond. For instance they used supporting information, such as diagrams, to complement their questions. (The teachers anticipated the supporting information that was presented by the facilitators, as if they wished to have surety before they committed themselves to an answer.) When the teachers did respond after some time, it was noticed that they did so using precise statements. These responses were different to the spontaneous, open-ended replies by Australian teachers that were observed in previous CPAS workshops. In addition these replies relied on technical and scientific vocabulary and attempted to answer the facilitators’ questions as correctly as possible. Also, it was noticed that not all the teachers responded to the facilitators’ questions. Many of the teachers in both Sri Lanka and Indonesia were seen to rely on more vocal peers to be their spokesperson during the workshops.
The above features which characterised Category 1 communications in the CPAS workshops for science teachers in Sri Lanka and Indonesia could be explained from cross-cultural perspectives that are advanced through the literature. It has been stated that learning science creates cultural-frontiers for learners from non-Western backgrounds (see, for example, Aikenhead, 1996). As in the cases of the science teachers from Sri Lanka and Indonesia, these cultural-frontiers were represented in the general workshop discourse that accompanied Category 1 communications. Phelan et al. (1991) have pointed out earlier that it is not possible for learners to always negotiate cultural-frontiers smoothly. One reason that is offered for this difficulty of passage is that (Western) scientific content is foreign to non-Western learners (see, for example, Costa, 1995).

However, this was not the case with the Sri Lankan and Indonesian science teachers in the present study. Irrespective of the fact that these teachers’ had non-Western cultural backgrounds, they were familiar with Western scientific knowledge as a result of their formal science training. Hence the reasons offered by the literature to explain non-Western learners’ apathy to Western science could not be used to explain the present teachers’ reluctance to respond to questions in Category 1 communications. Instead, these observations could be explained more accurately in terms of the dissimilarity between Western cultural values and the values associated with the present teachers’ cultural backgrounds. Aikenhead (2001b) has stated that cultural-frontiers also challenge non-Western learners’ “world-views, identities, and mother tongues” (p.338). Although the teachers were familiar with Western scientific knowledge, it is likely that the workshop communications themselves presented Western values that conflicted with their non-Western cultural backgrounds.
It has been stated in the literature that asking questions to elicit information subscribes to Western values of competitiveness and self-confidence (see Johnson, 2007). These values are not necessarily appreciated by non-Western learners. It is possible, therefore, that the Sri Lankan and Indonesian teachers were intimidated by the style of questions that were asked by the facilitators. This may explain why the teachers were not prepared to respond initially. They may have needed time to feel comfortable with these Western values before they responded to those questions. Hence, although the teachers were able to manage crossing over the cultural-frontier that confronted them in Category 1 communications, it was not a smooth transition. As Aikenhead (2001a) explains further, with reference to Phelan et al.’s (1991) categories of border crossing:

It is when people begin to feel a degree of psychological discomfort with another subculture that border crossing becomes less smooth, and needs to be managed. Contributing to their discomfort may be some sense of disquiet with cultural differences or their unwillingness to engage in risk-taking social behaviour…When the self-esteem of people is in jeopardy… border crossing could easily be hazardous. (p.26)

It was pointed out earlier that not all the Sri Lankan and Indonesian teachers responded to the questions that were asked by the facilitators. Instead they relied on their peers to communicate their ideas to the facilitators. It may be that the teachers who did not respond found the cultural-frontier less manageable (i.e. a hazardous border crossing). These teachers would have felt, that by answering the facilitators’ questions on their own, they would be putting their self-esteem at risk. It is possible that this anxiety caused them to seek the assistance of their peers to act as their spokesperson, since to express their ideas through an intermediate might have been seen by them to be less threatening. This was, however, not the only reason why some teachers relied on their peers to communicate with
the facilitators. As it is explained later, this observation could also be explained with reference to English not being these teachers’ first language.

The teachers also relied on the supporting information given by the facilitators to answer the questions during Category 1 communications. Aikenhead (2001a) states that such visual and auditory cues assist during border crossing by moving “back and forth between the culture of Western science and the cultures of the audience” (p.39). However, Western science was not an unfamiliar construct to the present science teachers. Therefore, the supporting information by the facilitators did not help by moving between the culture of Western science and Sri Lankan or Indonesian cultures. Instead, if these devices did assist in border crossing, they did so by moving between the culture of Western science and the teachers’ perception of that culture. This cross-cultural perspective was highlighted in the workshop communications in Category 2.

The facilitators used Category 2 communications to inform the teachers about the accuracy of their scientific understandings. The Sri Lankan and Indonesian teachers were more resistant than their Australian counterparts to the facilitators’ attempts to address inaccuracies in their understandings, particularly alternative conceptions that formed part of their understandings. The teachers in Sri Lanka, in particular, were not prepared to accept that textbooks could perpetuate alternative conceptions. During one such example, the facilitators attempted to point out to the teachers that the diagram used in most science textbooks, to illustrate how pressure in a fluid increases progressively with depth, was an inaccurate representation of that scientific concept. They showed the teachers four different diagrams, each showing different possibilities for water being projected from holes on the side of a container. They asked the teachers which of the drawings was scientifically accurate. The teachers selected the drawing similar to the one illustrated in Figure 20,
which shows that water was projected further away from the vessel as the holes on its side increased in depth.

Figure 20: A diagram which apparently shows that pressure increases progressively with depth

The facilitators agreed with the teachers that, that diagram was used in many textbooks to apparently show that pressure in a fluid increased progressively with its depth. However, they informed the teachers that this diagram advanced a misconception. The facilitators pointed out that the water which was projected from the hole closest to the base of the vessel (viz. C) did not reach as far as this diagram illustrated. In fact, they told the teachers, the distance projected by hole C was similar to the distance projected by hole B. The teachers did not, however, accept the facilitators’ explanation, and stated that it was not possible for textbooks to promote such an alternative conception. They pointed out, using fluid pressure laws, that a fluid contained in a vessel exerted the greatest pressure at the base of that vessel. The teachers reasoned, along the same lines as the textbook, that the
hole closest to the base of the vessel should project water the furthest, because greater
pressure was exerted on water at that level.

Based on these observations, it was evident that the Sri Lankan teachers felt threatened by
the facilitators’ attempts to address their alternative conceptions. These observations serve
to confirm Palmer’s (1999) claims earlier that learning science can be confrontational for
learners from non-Western cultures. As Palmer pointed out, the discourse of science
teaching can be perceived to threaten these learners’ world views. However, it must be
clarified again that the scientific discourse in this particular instance was not one which
challenged non-Western world views; i.e. the teachers were not threatened by the scientific
concept which in this particular instance stated that the pressure in a fluid increased with
the depth of that fluid. Instead the teachers were confronted by the fact that their
perceptions of Western scientific concepts were seen to be inaccurate; more precisely that
textbooks could possibly be wrong.

This revelation highlights two important elements that have been visited previously in the
literature. The first is that teachers, including those from non-Western backgrounds, rely
heavily on textbooks. The literature maintains that textbooks serve as a primary survival
tool for many teachers (see, for example, Wong & Wong, 1998). Moreover, many teachers
believe that textbooks are a source of correct forms of scientific understanding, and they
rely on this information to direct their classroom teaching. This explains why many
teachers turn to textbooks when confronted with uncertainty (see Anderson, 2002). It also
explains why they are compliant when asked to reproduce science lessons from textbooks
in technician-like fashion, with minimal input or ownership to their teaching (see Barnett &
Hodson, 2001). Teachers who are used to teaching in this way would be reasonably
alarmed if they are informed that textbooks promote alternative conceptions.
Secondly, the Western characterization of science is an important factor. The discourse of science teaching as Palmer (1999) has pointed out, is strongly Western in nature. This means that, as science historians like Mason (1953) have stated, Western science prides itself on being highly contestable. Researchers agree that the language used to frame scientific understanding also promotes this characteristic of Western science. As Sutton (1996) has pointed out earlier, questioning and scepticism are features endemic to science. He has stated that curiosity, tentativeness and being open to alternative interpretations are features that have characterised the progression of science. However, as historians have pointed out in the literature, these features characterise Western predispositions towards knowledge that have come to be regarded as characteristic of modern science (see, for example, Sarton, 1948). Harding (1991) has reasoned that the same values are not shared by non-Western cultures. Non-Western cultures may not necessarily be predisposed, like their Western counterparts, to view scientific knowledge with similar scepticism. This may explain why the Sri Lankan teachers were not comfortable with the attempts by the facilitators to inform them about alternative conceptions.

Moreover, as Aikenhead (1996) has pointed out, constructing meaningful scientific knowledge assumes entirely different dimensions of complexity with non-Western learners. Hence, the Sri Lankan science teachers, like other non-Western learners, would have had to feel comfortable with the ideas advanced through Western scientific knowledge before they felt familiar with that knowledge. Given the fact they went on to promote Western science through their classroom teaching, it would be reasonable to say that they were confident with their understandings of Western scientific concepts. Therefore, they were not challenged by Western scientific knowledge impinging on their non-Western world views. Instead, the author believes, the Sri Lankan teachers were challenged by the fact that the
comfort with which they had grown accustomed to Western scientific knowledge was being questioned by Category 2 communications.

Another important cross-cultural perspective which was observed was that the Sri Lankan and Indonesian teachers depended on their respective mother tongues to communicate during the workshops. The teachers in Sri Lanka (based on their ethnic origins) used either Sinhalese or Tamil as their first language. All the Indonesian teachers spoke Bahaasa, which is that country’s national language. The CPAS workshops for these teachers were, however, conducted in English. It was noted that the teachers refused offers to formally translate the workshop communications, saying that they had sufficient comprehension of the English language to understand what was said by the facilitators. This claim by the teachers was supported by the fact that many of them copied notes in their respective mother tongues while listening to what the facilitators said in English. This observation indicated, however, that the teachers relied on their mother tongues to make sense of the workshop communications; essentially by translating what was said in English into Sinhalese, Tamil or Bahaasa. When the teachers were confronted with an unfamiliar use of the English language, the most popular means by which they handled those translations was through their peers; *i.e.* the teachers turned to one or more of their peers who volunteered to translate the information that was communicated by the facilitators. This was, however, not managed continuously throughout the workshops. These teachers who volunteered to translate only intervened as and when their colleagues indicated that translations were necessary.

Although remedial, this strategy had some limitations. For instance, when the facilitators said something about which the teachers were unclear, one of the teachers volunteered this information in the teachers’ mother-tongues. In doing so, that teacher used language
constructs which were familiar to her/him, and assumed that the other teachers were familiar with those language constructs. This assumption may have been incorrect. It is possible that a teacher may have used a construct from that teacher’s mother-tongue which was not necessarily familiar to the other teachers, despite the fact that they spoke the same first language. This element manifested itself differently in the two workshops. In the workshop for Indonesian teachers it was noted that there were different region-specific uses of Bahasa in the different islands of Indonesia. In Sri Lanka, it was noted that Sinhalese and Tamil were two distinctly dissimilar languages, and hence the translations had to be managed separately for those teachers.

A more serious deficiency in this strategy was the possibility for the teachers to misrepresent, in their translations, what was said by the facilitators in English. This was particularly disadvantageous when the facilitators used socio-cultural references to inform the teachers’ scientific understandings (i.e. communications in Category 3). It was observed, in such instances, that the teachers who volunteered to translate those historic, contemporary and linguistic references used metaphors and analogies from their own language to emphasise what the facilitators were attempting to communicate. It was noted that some of these metaphors and analogies, such as one Indonesian teacher’s explanation of water-insect mobility enabled by surface tension, were not completely accurate in terms of the facilitators’ purposes for those communications.

Moreover, it has been revealed earlier in this study that it is possible to have confusion even when communications are managed only in English. For example, it was explained earlier in this section that the term soft-brakes caused confusion among a group of Australian science teachers. Although these teachers’ first language was English and they shared a (Western) cultural background similar to that of the facilitators, they were
unfamiliar with that term. Although the teachers were familiar with the phenomenon of air getting trapped in a hydraulic brake-system, they may have used another term to describe it. It was highly likely, therefore, that the Sri Lankan and Indonesian teachers, who translated workshop communications into the different mother tongues, were equally unfamiliar with the references made by the facilitators in English.

It was also possible for these metaphors and analogies to promote alternative conceptions. This was observed when the teachers attempted to translate the explanations given by the facilitators about the scientific concepts that were intended by the different hands-on and minds-on activities (*i.e.* communications in Category 4). It was observed, in such situations, that the teachers who translated those scientific concepts used technical models and scientific terms from Sinhalese, Tamil or Bahasa to complement their translations. For example, it was noted that the Sinhalese translation for the term *brainstorming* was a technically entrenched word and directly translated from English. Therefore, the meaning that was offered by that term conflicted with the facilitators’ intention for individual self-reflection.

Gilbert *et al.* (1998) have particularly cautioned teachers about using models and analogies to explain abstract scientific concepts. They maintain that such communications can be inaccurate because many teachers lack sufficiently developed knowledge structures with which to enable those communications. It should be added here that these problems have been highlighted by Gilbert and his colleagues with reference to science teachers who communicate *only* in English. The possibility for these communications to be further disadvantaged by an added layer of another language (and the socio-cultural constructs which are harboured by that language) have not been envisaged in the analogies literature generally. Studies which have examined language-laden cognition in cross-cultural science
learning contexts do so with reference to students who are novices to Western science. For example, Kawasaki (2002) has stated that it is likely for Japanese science students to “develop different science concepts from their counterparts in Western countries” (p.19). It is highly probable, therefore, that the Sri Lankan and Indonesian teachers could have (unconsciously) advanced alternative conceptions, when they used translations in their mother tongues to explain scientific concepts to their peers.

Aikenhead (2001a) has pointed out earlier that constructing scientific knowledge based on one’s mother tongue can be a significant obstacle when scientific information is communicated across cultural boundaries. He has stated that learners from non-Western (and in this particular case English as a second language) cultures need to be offered flexible approaches to make sense of the learning experiences that are presented to them. One such strategy which was adopted in the CPAS workshops for Sri Lankan and Indonesian teachers was to offer the teachers multiple opportunities to experience a given scientific concept. This meant that several socio-cultural references, minds-on and hands-on activities with simple materials were used to inform the teachers’ understandings of a given scientific concept. It was observed, however, that some of the teachers in these workshops did not appreciate the simple materials that were used in those hands-on activities. While these teachers did not dismiss the idea of using simple materials to demonstrate scientific concepts, they were reluctant to use such materials to explain advanced scientific concepts. For instance, when a facilitator informed the teachers that fridge magnets can be used in an experiment to demonstrate Eddy Currents the teachers did not believe that such inexpensive (and non-laboratory-based) materials could effectively demonstrate such an advanced scientific concept. Therefore, they questioned the facilitator about using more specialized equipment to demonstrate this experiment. Although this was
not a majority view, it highlighted a cross-cultural perspective that requires mentioning here.

The literature has stated that alternative forms of pedagogy need to be seen as reasonable by teachers before they are able to accommodate such approaches into their pedagogy. Crossley and Guthrie (1987) have stated that teachers do not dismiss these alternatives irrationally. They are inclined, however, to “rationally weigh alternatives according to the realities they perceive” (p.65). It is possible, therefore, that the idea of using simple materials, like fridge magnets, did not appeal to the teachers as a realistic alternative to more sophisticated equipment that is usually used to demonstrate an advanced scientific concept like Eddy Currents in the laboratory. Some reports in the literature state that teachers have a limited view of science teaching (see, for example, Rennie et al., 2001). So it may be that the Sri Lankan and Indonesian teachers, like many of their multi-national counterparts whose pedagogical practices have been extensively documented, also opt for more conventional forms of practical lessons which involve little ingenuity on the part of the teachers.

However, the author thinks it is more likely that the teachers’ lack of appreciation for simple materials highlighted another cross-cultural perspective. The opinion that simple materials do not accurately demonstrate advanced scientific concepts may have stemmed from the teachers’ beliefs as non-Western learners of Western science. Like many such learners the teachers in the present study may have also fostered beliefs about Western science being “an icon of prestige, power, progress, and privilege” (p.31, Aikenhead, 2001a). Hwang, (2005) points out that it is not uncommon for non-Western practitioners of Western science continue to share this view. The fact that non-Western students continue to foster positive attitudes to Western science (see Sjøberg & Schreiner, 2005) confirm that
Western science enjoys a high social status in many non-Western cultures. As Waldrip and Taylor (1999) have described earlier, non-Western students, therefore, compromise aspects of their own cultures in order to learn Western science, in the hope that by doing so they would be guaranteed better prospects of employment in the future. The Sri Lankan teachers in the present study would also have given up aspects from their cultures in order to enable them to construct (Western) scientific knowledge, which would otherwise have been less meaningful to them. Also, part of their formal science education would have evolved around laboratory classes that used sophisticated equipment. This equipment would have been dissimilar to the simple materials featured around their own homes and the cultures which they had to compromise. It is possible, therefore, that asking the teachers to revert to these simple materials in an attempt to teach science more effectively, would essentially question their beliefs of Western science and the training they received in it. It is probable, therefore, that it was this element of revocation that made a minority of the teachers uncomfortable about using simple materials to demonstrate advanced scientific concepts.

It must be stressed again that the reluctance to use simple materials was not a majority view. Most of the Sri Lankan and Indonesian teachers were highly accepting of simple materials that could be used to demonstrate scientific concepts in their classrooms, as discussions of their interviews confirm in Chapter 7. These cross-cultural perspectives, that were observed in the CPAS workshops for science teachers in Sri Lanka and Indonesia, confirmed findings from earlier studies. It is believed that some of the findings also contributed to research in that area. Attention has been drawn to these findings in the final chapter.
Chapter Summary

Chapter 6 presented observational data from six CPAS workshops that were used to answer the second supplementary research question. Four of these workshops were conducted in Australia (viz. Launceston, Hobart, Ayr and Charters Towers), while the last two workshops were conducted for science teachers in Sri Lanka and Indonesia. Six categories of observational variables were used to describe the different communications which were observed in these workshops.

Communications described by Category 1 were used by the facilitators to establish the different levels of scientific awareness the teachers brought to the workshops. Because these communications encouraged active reflection they provided an opportunity to critically examine the scientific accuracy of the understandings behind the teachers’ awareness. The different attempts by the facilitators to address possible inaccuracies (i.e. misconceptions) were described by communications in Category 2. Attempts to inform the teachers’ understandings with the help of socio-cultural references and workshop activities were described by communications in Category 3 and Category 4, respectively. Category 4 communications employed a wide variety of minds-on and hands-on activities, which were complemented by simple materials. The teachers’ scientific awareness which was advanced as a result of the above workshop experiences were ultimately scaffolded in the context of familiar constructs. These workshop communications were described by Category 5 and Category 6. The implications of these observations are discussed in the final chapter (i.e. Chapter 8).

In addition, this chapter described the cross-cultural perspectives that were observed in the two CPAS workshops for science teachers in Sri Lanka and Indonesia. While some of these
perspectives could be explained by previous literature in that area, it is believed that some of these findings offer further insights to cross-cultural studies in science teacher education. These are discussed further in Chapter 8.

The next chapter presents the findings from the interviews with teachers and the workshop facilitators.
# Chapter 7: Interviews

## Chapter Overview

Part 1: Interviews with workshop participants 245

- Interview part 1 245
- Interview part 2 251
- Interview part 3 282
- Summary 289

Part 2: Interviews with workshop facilitators 291

- Summary 309

Chapter Summary 310
Chapter 7: Interviews

Part 1: Interviews with workshop participants

Part 1 of this chapter describes the interviews that were conducted with teachers who participated in the CPAS workshops. A purposeful random sample of 38 teachers was interviewed. The sample consisted of 19 teachers from the CPAS workshops in Australia, ten teachers from Sri Lanka and nine teachers from Indonesia. They comprised 26% of the total number of teachers who participated in the CPAS workshops that were included in the present study. The teachers were interviewed individually (in person or by telephone) and in groups. The interviews were based on a three-part standardized open-ended interview format (see Chapter 5). Important elements from these interviews are discussed in the subsequent sections. The findings that are highlighted in these discussions have been collectively drawn together in the final chapter to answer the third supplementary research question (i.e. Do the teachers who attend these workshops construct personally meaningful understandings about science?).

Interview part 1

In the first part of their interviews, the teachers were asked if they believed the CPAS workshops had informed their understandings about science; i.e. Did the workshop help you to know more about science? All 38 teachers answered positively to this question. Some of their responses are quoted below:
I think the workshop was terrific. I think that it really demonstrated the concepts easily and you could see it very clearly. And it has also given me a lot of ideas that I can take back and use in the classrooms; because they are simple and use simple materials. So I think it was terrific in that respect. (Hobart workshop participant)

We definitely have something to take back to the classroom. The extra knowledge and information we received from the workshop...we can incorporate this into our classroom teaching. So I think an important and valuable inservice was received as a result. (Teacher from Sri Lanka, translation)

I believe so. I’ve started using some of the things already, because we’ve just started pressure. I was particularly impressed with the explanation they gave us on buoyancy force. I’ve seen many, many before and I am certain the activities they have given here are the best I have seen so far. (Ayr workshop participant)

I’ve been teaching science for 13 years and this is probably one of the best PDs (i.e. professional development programs) I’ve ever been on, in terms of getting ideas for the classroom, and clarifying my own thoughts and concepts... (Launceston workshop participant)

It was evident from these responses that the teachers had benefited from the CPAS workshops. As the teacher from Hobart indicated, the workshops had offered “a lot of ideas that (she) can take back and use in the classrooms”. The fact that the teachers were prepared to use the ideas which were offered by the workshops to teach science in their own classrooms indicated that they found those new ideas acceptable in terms of their own classroom practices.

The literature maintains that there is a strong relationship between what teachers do in the classroom and what they believe (Haney et al., 2002). As Van Driel et al. (2001) state, these beliefs are a complex manifestation of teachers’ science knowledge, conceptions and their values. It is possible to state, therefore, that the workshops did communicate at a deep level to these beliefs that were held by the teachers. The deep level at which the workshops
addressed those beliefs is evident, firstly, from the teachers’ acceptance of the new ideas, and secondly by the fact that the teachers themselves were motivated to initiate pedagogical models that were similar to the ones offered by the workshops. This latter view is highlighted strongly in one of the teachers’ responses:

Personally, I think the workshop provided the initiative to develop new ideas. I agree, some activities never get incorporated into the syllabus. They are innovative and new, no doubt, but don’t get an opportunity to be expressed in the classroom. But I must stress that this workshop has given us some kind of inspiration, motivation and initiative…we have really received some type of awakening. (Teacher from Sri Lanka, translation)

Moreover, the fact that the workshops addressed the teachers’ beliefs by “clarifying (their) own thoughts and concepts”, as the teacher from Launceston mentioned earlier, indicated that the workshops did not merely address superficial beliefs the teachers held about pedagogical practices. As another teacher who attended the workshop in Launceston stated, the workshops addressed deeper levels of understanding:

I came away with a really good package of stuff. And that wasn’t just sort of in-the-hand stuff, but in the head as well. (Launceston workshop participant)

When asked what this teacher meant by stuff in the head, she explained:

In Tasmania we are going through some fairly major curriculum changes at the moment. And that has put a lot of pressure on the staff in specially teaching core disciplines and I believe science is a core discipline...The more in-depth science happens in Tasmania in Grades 11 and 12. Although we don’t really do advanced science in Grades 8 to 10, because the groups we have in those Grades are mixed ability, I think you need sort of sometimes to be able to deconstruct by you and make it sort of palatable. But I also encourage them to become independent themselves, and to take up more responsibility for their own, than just be the gofer and get the stuff they need. It is good to guide them along a little bit, but not to perhaps put
It is clear from this explanation that the teacher was challenged by the recommendations that were made to reform science in her local school. Although the science she taught in middle school was not advanced science, she was anxious about the adequacy of her understandings to facilitate inquiry-based learning (i.e. “encourage them (i.e. the students) to become independent themselves, and to take up more responsibility for their own than just be the gofer and get the stuff they need”). She mentioned particularly that she wanted to be able to facilitate meaningful learning (i.e. “deconstruct… and make it sort of palatable”), and to be confident about her own scientific understandings (i.e. “…it is nice to be able to know what you’re going on about”). She appreciated, therefore, that the workshop allowed her to develop the necessary understandings about science (i.e. stuff in the head), that she would need to help her to teach science through inquiry. Similar views were shared by a teacher who participated in the workshop in Ayr. This teacher believed that the workshop helped him to understand scientific concepts, which he previously “didn’t understand”, and as a consequence enabled him to teach those scientific concepts more effectively:

*Yes it has benefited me because, obviously there are a few things that I didn’t understand or ideas on concepts on actually how I am going to get across the concepts to the kids. And the workshop has given me the mental tools, I guess, to be able to convey those concepts to the kids.* (Ayr workshop participant)

This opinion was broadly consistent across the interviews with teachers from Indonesia and Sri Lanka. The Indonesian teachers pointed out that the workshop enhanced their...
understandings. In the following response, one teacher remarked about an explanation that was offered in the workshop about the changes in the physical states of wax in a burning candle. This teacher believed that the explanation helped to inform the scientific accuracy of his understandings about that scientific concept. He also stated that the workshop had expanded the ways in which he conceptualised science:

*It was fun, entertaining and amazing. It has given us more knowledge and experience about science teaching (i.e. Bahasa: “pangalaman”). For example about the candle. When we thought of a candle burning before, we thought that it was the candle that was getting burnt. But now we understand that there is a state change and that it is actually the wax in vapour state that is getting burnt. Activities done in the workshop have made scientific concepts much clearer to us and our misconceptions have been corrected...These workshop activities broadened the way we think.*

(Teacher from Indonesia, translation)

A response by a Sri Lankan teacher echoed similar sentiments. She spoke about a workshop activity that was used to demonstrate the properties of objects charged with static electricity. In this hands-on activity the teachers were asked to charge a balloon with static electricity by rubbing it on their clothes. As this teacher indicated, this activity was enjoyed by the Sri Lankan female teachers, in particular. This was because they all wore *saris* made of nylon-based fabrics which made it easy to charge the balloons. Using the charged-balloons the teachers were asked to move a ping pong ball that floated in a shallow plastic container (see Figure 21). The teachers were not allowed to push the ping pong ball with their balloons. Instead they were asked to use the static attraction of the balloon to guide the ping pong ball.
The Sri Lankan teacher pointed out that the understandings she constructed based on this activity “enriched her scientific knowledge”. It also helped her to broaden the ways she thought about science:

_The activity where we charged balloons with static electricity, and used it to move a ping-pong ball on the surface of the fluid. It was a lovely experiment (laugh), especially because we lady-teachers wore sarees. The ping-pong ball moved beautifully. It was a very clear experiment and almost self-explanatory. We enjoyed doing it and it was a novel experience for us. This as a result enriched our knowledge and I think it was an exemplary learning experience. At the same time it made us think innovatively too, to think of other ways and of other relevant types of concepts that could also be understood in a similar manner._ (Teacher from Sri Lanka, translation)

![Figure 21: Photograph showing a charged balloon used to move a ping pong ball floating on a surface of water](image)

It was clear from the teachers’ responses, in the first part of the interview, that the CPAS workshops had influenced their conceptualizations about science teaching. The teachers
agreed consistently that the workshops had motivated them to teach science through inquiry, and believed that the workshops had increased their confidence to teach in that way. It is important, therefore, to explore next how the teachers believed this was achieved by the workshops.

**Interview part 2**

In the second part of the interviews, the teachers were asked how they believed their understandings were informed by the CPAS workshops. The teachers’ responses in this part of the interview, essentially, formed the basis on which the third supplementary research question was later answered (*i.e.* Do the teachers who attend these workshops construct personally meaningful understandings about science?). It should also be mentioned here that since all the teachers had agreed earlier in the interview that the workshops had helped them to know more about science, all 38 teachers were asked to comment on how they perceived this was achieved by the workshops.

It is maintained in the literature that teachers are ill-prepared to handle recommended pedagogy (see, for example, Fensham, 2007). While many teachers lack adequate formal tertiary training in science, those teachers who *do* have preservice training are equally unlikely to implement inquiry-based pedagogy. These sentiments were echoed in the present teachers’ interviews. They stated that although many of them had received training at tertiary level in science, it did not offer them the opportunities to construct *links* between theory and practice. The teachers added that an important feature of the CPAS workshops was that they (*i.e.* the workshops) enabled them to make those links. Examples of some of these responses are quoted below:
We are normally taught to directly use formula and textbook explanations to teach scientific concepts. That’s the way we are trained to teach science in Indonesia. But here on the other hand, at the workshop they demonstrated to us how to teach the concepts and thereby understand the meaning of the formulae and definitions, etc. They used simple examples to get the concepts across to us. I guess the development of teachers’ competency should come through the development of the way we think to make connections with formulae and definitions, etc., rather than only through factual knowledge. The way we teach in Indonesia is usually by giving factual knowledge rather than by introducing concepts. This leads not only to a lesser quality of awareness but also to students’ lack of creativity. (Teacher from Indonesia, translation)

...probably I think that’s the crux of it. I think at university I probably rote learnt a lot of it. Guessed a lot of it. And being able to do maths, that was fine. But the link to the practical aspect, like we saw here, was difficult to make. (Charters Towers workshop participant)

Obviously I have some understanding, through my prior experience and knowledge about science. Although even I did physics in my degree it is still very different to what we learnt in this (i.e. the workshop)… What we did in physics was a lot more theoretical at university and a lot of lectures. Hardly any practical stuff at all. Well trying to apply the stuff that was theoretical, trying to apply them practically we can struggle sometimes. There just wasn’t that link made. So really I am finding that I have to learn it all here. (Launceston workshop participant)

Researchers state that links between a learner’s experiences and knowledge about science play an important role when constructing personal and meaningful understandings. Stocklmayer and Gilbert (2002) have pointed out that one’s personal awareness of science could be advanced through the use of links that inform by reminding about previous experiences that are related. Given that an awareness about science is a prerequisite for understanding science (Burns et al., 2003), attempts to advance scientific understandings must inform the bases of one’s scientific awareness. These bases form the foundations for the construction of subsequent understandings and knowledge (Watson & Manning, 2008). Hence a careful examination of one’s knowledge base is required when linking that knowledge to experiences in an attempt to construct understandings. The teachers’ stated
that similar attempts were made during the workshops. Their responses indicated that the workshops paid attention to their fundamental conceptualisations of science:

...science, particularly physics, it’s really hierarchical,... So you need to see how those early concepts are required in a practical sense for some sort of visualization when teaching science... You see, just like building blocks. That’s what the workshop really did. (Charters Towers workshop participant)

...the biggest thing in this workshop was going back to the basics. (Ayr workshop participant)

...when you are looking at the really basic things, I know that it sounds sad but, the simple things that I didn’t really understand, even though I had been teaching that sort of thing... So I think that was the difference with it (i.e. the workshop). (Hobart workshop participant)

You really got to get down to the basics of it and ask the simplest questions. And they are the hardest ones to actually explicate. So I think it was important that we spent time with the basics. (Hobart workshop participant)

“To get down to the basics” (see Hobart workshop participant) or as Davis (2002) states “to begin with teachers’ knowledge, beliefs and skills” (p.27) is a requisite for professional development based on constructivist principles. Researchers maintain that these levels of relevant knowledge and experience are not the same for all teachers (see, for example, Yager, 1991). As Loucks-Horsley et al. (1998) point out “teachers come in all shapes and sizes and have different levels of experience” (p.333). The researchers claim that “one of the biggest crimes of professional developers is lumping together all teachers for the same kind of learning”. It is important, therefore, to examine teachers’ existing understandings, if these understandings are later to be advanced through informative experiences. It is also important to examine these understandings for their scientific accuracy. It is evident from the above responses, particularly the two responses by the Hobart workshop participants, that the teachers were uncertain about their basic understandings. These statements served
to support claims by Gilbert et al. (1998) that many teachers lack deeper understandings about science and are prone, as a consequence, to hold alternative conceptions. As the following two examples indicate, the teachers made special reference to the efforts deployed by the workshops to address alternative conceptions. The response by the teacher from Launceston, in particular, indicated that that teacher shared an alternative conception with students about the burning candle experiment:

Another thing that I felt good about was that there was more focus to debunk some, don’t know if debunk is the right word, but to get us to have a look at what concepts we understand wrongly, and by showing us different experiments to explain this. I thought that was a good approach. (Hobart workshop participant)

There was a lot of stuff about misunderstandings the students might have about science, like the candle underneath the jar. I always thought that experiment showed how much oxygen there was in the air. Didn’t know it was showing something else, like the air cooling and stuff like that. Was blown off (laugh), like the candle, a bit by that. (Launceston workshop participant)

The Sri Lankan teachers, in particular, responded at length about the workshop’s efforts to address alternative conceptions. They made special reference to the alternative conception that was advanced by a textbook diagram, which apparently showed that fluid pressure increased with depth in a fluid (see Figure 16). As one teacher remarked:

They showed us the various errors in textbooks. Not only in Sri Lanka but they showed us that it was the same in other countries as well. So the discussion on misconceptions definitely caused a change I could say. For example what they said about fluid pressure, and all, definitely made us change. There was definitely a change, I could say, we got things that we did not expect. (Teacher from Sri Lanka, translation)

It was mentioned in Chapter 6 that the Sri Lankan teachers found it difficult to accept that the textbook diagram advanced an inaccurate understanding of the concept of fluid
pressure. The above response made it clear that this revelation posed a tremendous challenge to that teacher. As the above teacher emphasised the workshop had in fact caused a conceptual change (i.e. “So the discussion on misconceptions definitely caused a change I could say…There was definitely a change, I could say…”). The deliberations by two other teachers, about the same alternative conception, were highlighted in their responses:

*Even for teachers who know that certain concepts are incorrect it is a good opportunity to investigate and try to find out further why one is right and the other is not. For instance, why is the pressure more at the middle point? Thus we will ourselves have to understand it completely, if not we won’t be able to explain it to someone else. If we simply say to someone that the pressure increases with depth but that the water at the bottom most point shoots less far than the one above it, we will have to explain why it does so. Therefore, we will also have to think analytically why this happens the way it does.* (Teacher from Sri Lanka, translation)

*... the cylinder with perforated sides to show how fluid pressure increases with depth: the deeper the hole the further the distance. Well about this experiment, we could only identify its errors, only if we completely understand the concept involved in it. That is if we do it ourselves and practically understand the situation. It would be difficult to identify that something is wrong with it just by seeing it on paper. Now this experiment was proved to be wrong. It was discussed as a misconception. Even though foreign presenters may come and even show it to us or even if such is discussed at length it would not be clearly understood until and when we ourselves do the experiment and experience it for ourselves. I went home and did this experiment and I saw that water from the lowest point did not shoot the furthest. So I was able to understand exactly what was said only after I experienced it for myself. Until then I cannot explain this phenomenon to the student. I myself have to comprehend it first.* (Teacher from Sri Lanka, translation)

The fact that the teacher had to “understand it in full” and “comprehend it first” strongly supports Crossley and Guthrie (1987) claim that “teachers rationally weigh alternatives according to the realities they perceive” (p.65). Although it was made clear to the teachers in the workshop that the textbook diagram was inaccurate, they had to see for themselves that “water from the lowest point did not shoot the furthest”. This meant that the teachers
had to deconstruct the understandings on which they had relied previously from the
textbook and become confident to construct their own understandings. This was a challenge
for the teachers. As another teacher explained, most teachers are not always confident to
address alternative conceptions in this way:

To have the power to acknowledge that a concept that is presented
inaccurately, is wrong, is empowerment (i.e. Sinhalese: "shakthiya"). Some
teachers continue to teach what is wrong, because they don’t feel that they
have the power to correct it, even though they know and believe it to be
wrong… This workshop was a good opportunity to make us think
differently… It was a valuable opportunity. (Teacher from Sri Lanka,
translation)

This perception of “empowerment” was also mentioned by another teacher. The teacher
pointed out that because of the workshop he felt he “had the power” to construct more
meaningful forms to understanding (i.e. “teachers were made to feel that is okay to teach
differently or correctly when they believe that what is given in the textbook is not
correct…”). He said that he also felt empowered because of the simplicity of the activities
that were offered to conceptualise those understandings:

... teachers were made to feel that is okay to teach differently or correctly
when they believe that what is given in the textbook is not correct or
accurate, like in the case of pressure and depth situation. Teachers have the
power, they feel empowered. Another thing is that teachers should also be
able to perform the activities easily. Some activities that are given in
textbooks cannot be done so simply. I believe that it (i.e. the workshop)
presented such simple activities because they believed that teachers could
also be persuaded to adopt the same strategies. (Teacher from Sri Lanka,
translation)

The literature maintains that learners should be able to make sense of science in diverse
ways (see, for example, Anderson, 2002). This makes it possible for learners to identify and
construct understandings that make the most sense to them. Because these understandings have personal relevance, it is believed that they are more sustainable (see, for example, Goodrum et al., 2001). The sustainability of learners’ understandings, when they are constructed in ways that are personally meaningful, was indicated by a teacher who attended the workshop in Charters Towers. She explained:

I did appreciate having been showed the mathematical equations, because for some reason I had to see the mathematical equations before it was clarified for me. Somehow it needed to have the bridge, from “yes I can see it all happening”. But I just needed it explained in that mathematical way so that I could make connections mathematically in my mind, to truly feel that I had a full understanding of what was going on. (Charters Towers workshop participant)

A teacher from Launceston also felt that it was valuable to have different perspectives when scientific understandings are constructed. She stated that:

... I definitely think they are valuable. I think we just really don’t get enough opportunities to have workshops from people who give us different ways of looking at things... We need more of those really rich ways of looking at science. The more we can have of that, the more different perspectives that they can bring to it, the better. (Launceston workshop participant)

It was evident from these responses that the workshops offered diverse opportunities to construct understandings that were personally meaningful to the teachers. Dillon et al. (2000) have stated that because of the belonging teachers associate with these understandings they are able to take ownership of their own learning, and subsequent teaching. This was highlighted in previous statements by the teachers from Sri Lanka (i.e. “Thus we will ourselves have to understand it full, if not we won’t be able to explain it to someone else.”; “… I was able to understand exactly what was said only after I experienced
it for myself. Until then I cannot explain this phenomenon to the student.”). It is possible, therefore, that ownership of these understandings, that were constructed with the help of the workshops, enabled the teachers to develop confidence which translated into sentiments of *empowerment* that were mentioned earlier.

It was also mentioned earlier that the simplicity of the workshop activities and the accessibility of the materials that were used helped to advance the teachers’ feelings of empowerment. An important observation during the interviews was that all the teachers made some form of reference to the simple materials that were used in the workshops. Some of those responses are quoted below:

*I liked the hands-on nature of it. Really simple stuff really. The accessible materials certainly make good for schools and some of them are pretty impressive with what they (i.e. simple materials) can explain about scientific concepts.* (Launceston workshop participant)

*What attracted me most about the workshop was just the simplicity of the equipment that they used to display the concepts. There was nothing complex there really at all. As I just looked across all of them, that’s really what struck most… It was just all very simple.* (Charters Towers workshop participant)

*I definitely learnt a lot. Specially with the materials that those guys used. It shows that you don’t have to have the expensive labs. You can do the experiments none the less. I particularly liked the sea diver (i.e. Cartesian Diver) and cloud one (i.e. Making a cloud). Never thought of using a PET bottle like that.* (Ayr workshop participant)

*I really liked the hands-on approach. The fact that we did a lot of really good effective little experiments, and many of the things we used we know a lot. So they were sort of bit of fun. They do provide a good lead into some, some good science.* (Hobart workshop participant)

*I thought the hands-on activities were very interesting. They described certain principles, like the Archimedes Principle and so on. And we got to play with them as well. So it was really interactive which I found excellent.* (Teacher from Indonesia, translation)
These responses indicated that the simple materials in the workshop activities communicated effectively to the teachers. As the teacher from Launceston remarked these materials helped to explain scientific concepts clearly (i.e. “pretty impressive with what they can explain about scientific concepts”). It is possible that because the materials that were used in these activities were simple and easily obtainable (i.e. “…many of the things we used we know a lot”: Hobart workshop participant), they helped the teachers to conceptualise their understandings more easily in familiar terms. As a teacher from Launceston pointed out:

*I think everyone is quite fascinated with simple stuff like that. Simple stuff like that is quite amazing really. There is always that element of surprise in it. Something that you never think to see like that. That’s what really captivates about these things. I guess that’s what makes the stuff really interesting...* (Launceston workshop participant)

The Sri Lankan teachers indicated similar levels of amazement about the depth and clarity of the insights that were offered by the workshop materials. They were more descriptive about the scientific conceptualizations than the Australian teachers. For example, one teacher, who spoke with reference to the *Buoyancy see-saw* hands-on activity (which was used in the workshops to demonstrate the increase of fluid pressure with depth), stated that:

*I liked the two cups of water balanced on a strip of wood, which showed that pressure increases with depth. I couldn’t imagine how such a simple experiment could convey such a deep message. It conveyed the message so very easily. It was a novel experience for me… I was completely amazed how such a simple device could convey a message of such complexity.* (Teacher from Sri Lanka, translation)
Another teacher described his experience with the Film-can rocket hands-on activity. It was clear from his response that the explosion he observed in this activity had helped him to clearly conceptualise the properties of an expanding volume of gas:

*An activity that impressed me was how they explained the difference between fluid and gas expansion. We always teach that the expansion of gases is much greater than that of fluids. We only teach it verbally, but we never demonstrate it... Here it is very clearly understood that the expansion of gases is very great. Only a small amount of reactants yielded a very large quantity of gas. So it also gave a very good quantitative description as well. This is only one I can highlight, but there were many such activities that were quite amazing.* (Teacher from Sri Lanka, translation)

The Sri Lankan teachers agreed, therefore, that science teaching which employed simple materials to demonstrate scientific concepts would seem more meaningful to students:

*Usually, most re-producible experiments have a standard result which is learnt by rote. So most of the time students simply know the end result of an experiment without understanding the fundamentals behind it. But the results of the experiments done that day (i.e. on the day of the workshop) were directly evident. All the experiments had definite observable results so it was possible to clearly state their end results.* (Teacher from Sri Lanka, translation)

*If we consider the cloud chamber experiment, it is not only valid for middle school but is also taught at advanced level. They asked us to slowly compress and suddenly let go. This simple exercise demonstrates a very complex phenomenon of cooling and expansion. Though we use various scientific terminologies to explain this concept in the classroom, I don’t think it is conveyed as effectively as through that experiment. Also in lower grades we simply teach that accumulated water vapour produces clouds, but with this activity they would have an experience of the more complex scientific processes that are involved in it.* (Teacher from Sri Lanka, translation)
Teachers in Australia also believed that simple materials would appeal to their students. In fact, some of their responses, which are quoted below, indicate that students would relate better to simple materials than to conventional laboratory equipment:

*I think the kids are very familiar with these simple stuff. They can relate to it much better and they don't get put off and they just don't go off the topic. When they see hardcore equipment they think that's boring, that's hard, that doesn't make any sense and they just get off the track.* (Ayr workshop participant)

*I just liked that hands-on equipment. Hands-on things that you actually see what happens. I don't learn very well from people giving me information or facts, that doesn't actually stick in my head. When you can actually see it, it's much better. And I think that's same with the kids. They can see it happening. And the stuff is pretty familiar to them. It seems to make much more sense to explain things to them in that way.* (Ayr workshop participant)

*Well, when I say they (i.e. simple materials) were ‘effective’ I mean that they were pretty child-safe. The kids could use them, and we could demonstrate them… They didn’t need complicated apparatus or anything… the kids could use them without much difficulty and they don’t need sort of complicated equipment. It was just pretty easy stuff to hand out to kids and recycle and all that sort of thing. So it wasn’t expensive either.* (Launceston workshop participant)

*Well if the setup is quite intricate kids don’t really understand the relevance and they can’t connect it with real life situations. But if you are using equipment that is readily available and what they’ve used before, for example toys, they’ve used it before… And they just watch it operate. But then you are explaining why and how it operates. Then they would get a much greater understanding from it, rather than a really intricate apparatus setup.* (Hobart workshop participant)

During some of the interviews it was revealed that some of the teachers had had the opportunity to actually use the ideas about simple materials from the workshops in their classrooms. Although it was not intended for these interviews to explore the workshop participants’ subsequent classroom practices, the timing of the interviews offered serendipitously a glimpse of that perspective. The feedback these teachers shared was
broadly positive. Their responses indicated that their students had enjoyed the hands-on activities with simple materials. They also pointed out that the students were able to construct understandings about scientific concepts that were otherwise taught through conventional lab-based and lecture-type models of instruction. This observation by the teachers highlights recommendations that have been made by Cohen and Hill (2000). The researchers agree that professional development experiences are undoubtedly important to help teachers construct meaningful scientific understandings. They contend, however, that the essence of these professional development experiences lies in the teachers’ ability to subsequently transform those understandings to improve student learning. Complementing views that were shared by three of the teachers in the present study is given below:

*Oh they (i.e. the students) loved it. I set up stations around the room and we did all sorts of pressure activities at each station and they had an absolute ball... These students, they are level 1 students and they are actually not used to that sort of teaching; used to more chalk, talk so it has taken them a bit of time to adjust to my style. But doing the stations and doing the simple things that’s got marshmallows, balloons, etc. they had a great time. I had to get them to stop and pack up. They really didn’t want to. They simply wanted to keep going. They were really engaged. Even the students who sometimes aren’t interested, they were having fun using the stuff as well.*  
(Ayr workshop participant)

*I spent a long time the other day playing with simple stuff. And tried to get the kids to a point where they actually saw things and they actually do these things. It was a beautiful challenge. A lot of them see these things everyday but they don’t make the link to the learning. They don’t really make critical observations between that and physical principles. To get that connection together you got to make them see crystal clear as you can, to make it self evident. To watch and really see what’s going on. Playing with these simple stuff, I think they got a good chance to link between science and the real world.*  
(Launceston workshop participant)

*I used the simple materials that they (i.e. the workshop facilitators) used in construction tasks. My student love construction tasks. And they are quite familiar with these materials. And they’ll know that they are always around and they can work with those. There were times when we wanted something a bit more complicated, but to have a whole class set up things that are complicated, often you are looking at things not working properly, or there not being enough to go around, and that sort of thing. Whereas they always*
There was, however, a contradictory opinion by one teacher from Launceston. Although this teacher agreed that classroom activities based on simple materials would appeal to younger students, she did not believe that they would be appreciated by students at secondary level.

*I certainly think simple materials is a good idea, particularly for primary school classes, it is excellent to use simple materials. I think it’s also handy to have some of those sorts of activities up your sleeve in secondary school classes. But I am very aware that a lot of the students, particularly in the school that I am a teacher, they are looking to actually have more different things. They don’t just want to see stuff that you see around all the time. That would be a bit frustrating. You think that you are doing something that they can relate to, because you are using simple materials, and then they say “ah we’ve seen this..., we can do this...”* (Launceston workshop participant)

Given that the present study is concerned with middle school science, particularly science teaching during students’ transition from primary to higher secondary level, this teacher’s response requires some pause for thought. She mentions that her students would be frustrated “to see stuff that you see around all the time”. This observation which explicitly states that familiar experiences can discourage certain students from engaging with science contradicts recommendations in the literature (see, for example, Bybee, 1997; Lyons, 2006). It also refutes the teachers’ statements earlier which substantiated that simple materials serve important pedagogical purposes. It was necessary, therefore, to inquire from teachers, who were interviewed subsequently, whether they shared such a fragmented
belief: *i.e.* simple materials are effective to teach science only at primary level. Some of those responses are quoted below:

*My kids are quite happy as long as they can mix things together and see what happens. We are little innocent country kids here.* (Ayr workshop participant)

*We use both, lab-based stuff and simple stuff. Not only simple materials. But I guess even if we did use only simple materials, I’d think they’d like it.* (Launceston workshop participant)

*I guess you’ve got to give some science to make them enthusiastic. You cannot just give them some stuff around the home to play with. I mean you cannot just give them each a balloon and say “here play with this”. But if it is done properly in a suite of things, I think it makes a big difference.* (Hobart workshop participant)

*Students in general enjoy practicals generally. They like it even if it simple. But they need to be structured. Activities for high school students need to have an aim. For example like the experiment to find wavelengths that was done here. It had a good aim. So even though this activity was simple it is good for high school...We think the students would be happy if we used simple materials. They would definitely be more interested in simple materials than with the standard laboratory equipment we use to teach secondary level science in Indonesia. They would learn while they are playing (laugh) and play while they are learning.* (Teacher from Indonesia, translation)

*So long as you pose some enough interesting questions to explore, they (i.e. students) are not going to be the least bit concerned. In fact, they’d feel empowered by it, because it’s all equipment they know they could get hold of at home and explore things at home further, if they wanted to.* (Charters Towers workshop participant)

These teachers’ responses reconfirmed that simple materials, when used to teach science, benefit students irrespective of their level of learning. As the teachers from Indonesia and Hobart mentioned simple materials cannot be introduced randomly to the classroom. Instead these materials should be structured with prior attention to the science lesson at hand. It was also indicated, by the teacher from Charters Towers quoted above, that because simple materials can be resourced from students’ own home environments, they
could “empower” students to learn science. Researchers agree that framing learners’ scientific understandings in everyday experiences enables both meaningful and continued engagement with science (see, for example, Tytler, 2007). Because students are familiar with materials from their own environments they would feel less intimidated to experiment (and play) with those materials. Moreover, because students would continue to interact with these materials in their homes, the above teacher believed that using simple materials to teach science would foster an engagement with science outside the confines of the classroom. This latter opinion was consistent with the views held by other teachers, who stated that:

_I found the materials that they used were excellent. Because we are able to transfer that into the classroom and the students are able to take that home: that knowledge that they have gained from what we do in the classroom to home as well. And they can impart that knowledge on or show their parents what they’ve learnt in class. And the materials they use are readily available. We don’t have to purchase equipment, it’s just little odds and ends I find around the home or classroom. So I found them very useful._

(Hobart workshop participant)

_And also with simple equipment, they can take the equipment out. They can take it home and show their friends and show their family. They actually understand it. A simple thing like a balloon, let go of the balloon and see the direction it will fly. They wouldn’t have been able to explain why that actually happened, if you just explained it to them or gave them problems they had to solve. But why it actually happens they may never know. They can actually take it home and actually explain it to their parents and show off that they actually know the stuff._

(Charters Towers workshop participant)

One Sri Lankan teacher found it interesting that school science could be shared by students outside the classroom (i.e. “What caught my attention was when they said: you can try this out at the next party”). The teacher agreed that teaching science in ways that students would continue to engage with it in informal social contexts was highly desirable. He conceded that science was not taught in Sri Lanka in this way as yet because such an
outlook to science was foreign to the local culture (i.e. “It may be that such a view exists in their (i.e. Australian) culture. They may be doing stuff like that at their parties.”). This singular observation by the Sri Lankan teacher highlighted the abstractness of school science in non-Western cultures, that was mentioned earlier in the literature (see Costa, 1995). It also emphasises the degree of alienation to which non-Western learners subject their own cultures when they learn Western science (see Pamba, 1999; Waldrip & Taylor, 1999).

"What caught my attention was when they (i.e. the facilitators) said: “you can try this out at the next party”. We never think about science like that do we? We never think that what we learn as science could relate to daily life, let alone using it to entertain a group of people who have congregated to have fun. So the presenters had the idea that students would take what they have learnt back home and share it with their families. I don’t think such a “science” is yet taught in our classrooms. I felt that the presenters somewhat made an initiative to promote this aspect of science at the workshop. We never teach science to students expecting them to demonstrate activities to their parents. Not that it is not completely absent, but it is very rare. It may be that such a view exists in their culture. They may be doing stuff like that at their parties. Another reason for this is that they used equipment that is easily obtainable. We on the other hand teach science in the classroom using sophisticated laboratory equipment, so children cannot easily replicate such activities in their homes. Anyway I don’t think we have thought of science in that way... We don’t do science like that and neither have we been keen to do it like that because of the complexity of the equipment we use. If one is to demonstrate some scientific concept at home, one should feel that one is capable of doing it with the resources one may find from one’s own home. Because you cannot feel this way you don’t attempt to do science at home. Also there were also activities that could be enjoyed irrespective of age. I don’t think science in Sri Lanka has that status as yet. (Teacher from Sri Lanka, translation)"

It was pointed out by the above teacher that the workshop may have engendered the Sri Lankan participants to engage with science outside the confines of the classroom (i.e. “I felt that the presenters somewhat made an initiative to promote this aspect of science at the workshop.”). It is possible that this observation was accurate. During an interview with
another Sri Lankan teacher it was revealed that the workshop had motivated her to experiment with simple materials in her own home. She referred to the hands-on activity that was used in the workshop to demonstrate the hydrophobic property of detergents on lipids. In this activity a small volume of dishwashing liquid was introduced into a shallow container of dairy milk. A few drops of food-dye were used to highlight the action of the detergent on the milk (see Figure 22).

![Figure 22: Photograph showing the action of detergent on milk](image)

The teacher explained that she was motivated by the above workshop activity that used simple materials which were readily available around the home. Given that powdered milk is more commonly used in Sri Lanka, she decided to experiment with it, in place of fresh
dairy milk. The teacher added that she even contemplated using coconut milk\(^\text{16}\) to conduct this experiment:

> I was thinking about the detergent and milk experiment, and was wondering that since we don’t use pasteurized milk much here at home, would it be possible to use powdered milk instead. Even the possibility of using coconut milk also crossed my mind. These are familiar and low-cost things around the house and easily obtainable. (Teacher from Sri Lanka, translation)

This teacher stated that while she appreciated the workshop’s efforts to include simple materials to demonstrate scientific concepts, she did not appreciate the term supermarket science to describe this approach. She pointed out that she and her colleagues at the workshop identified the word supermarket with upper socio-economic lifestyles in Sri Lanka. Instead she stated that “there are plenty of things around the home that we don’t need and cannot get from supermarkets… that describe science wonderfully”. For example, she described how she used cellophane paper to demonstrate to her students how light appeared scattered when it was viewed through a polarized film:

> ...We heard the presenter call this type of science “supermarket science”, and thought that was not correct. There are plenty of things around the home that we don’t need and cannot get from supermarkets here. I think it must be a cultural thing. People here must be much richer than teachers here so they can afford to buy things from supermarkets. Here only upper class people go to buy their things from supermarkets... I think there are a lot of things, for example the paper that was used to observe the scattering of light; I tried it out with normal cellophane paper and it worked. The students were very thrilled about it. It is very simple and the children loved it...I think the scattering of light as we did in class was so good because I felt that the students understood the concept...they could even do it at home.

\(^{16}\) Coconut milk is the thick creamy liquid extracted from the meat of the coconut and used extensively in Sri Lankan cooking.
There are several explanations for this teacher’s observation. The author believes, however, that socio-economic reasons are the most likely basis for the alternative materials (viz. coconut milk, cellophane paper) that were suggested by the teacher. Because the teacher identified the word *supermarket* with upper middle-class lifestyles in Sri Lanka, it is possible that she did not believe that simple materials obtained from supermarkets were necessarily the most accessible. Instead, she felt more comfortable to identify alternative materials from her home environment, which she knew she could procure less expensively. 

*Intelligibility, plausibility, fruitfulness and feasibility*, all of which Yager (1991) identifies are necessary for teachers’ conceptual change, supports the above claim. Although the teacher may have found the workshops’ use of simple materials a plausible approach to teach science, she did not believe that the source which was suggested for these materials (*i.e.* supermarkets) was a feasible one.

While the term *supermarket science* was not contended among Australian teachers, several of these teachers stated that they had also developed classroom activities using simple materials based on the principles that were advanced in the workshops. With reference to the Film-can rocket, a teacher from Ayr stated that she had experimented with materials around the kitchen to find the *best* chemical reagents for the rocket. While the film-can rocket in the workshop used sodium bicarbonate and vinegar, this teacher and her students found, instead, that the rocket was propelled higher when lemonade and antacid tablets were used:

...we found what works best for the rockets: antacid tablets and lemonade or antacid tablets and vinegar which works best. But it is all kitchen stuff, something that you can find in the kitchen. (Ayr workshop participant)
In another interview a teacher described her own version of the Guesstimation minds-on activity from the workshop she attended in Launceston. Instead of dropping paper clips into a small vessel of water, this teacher asked her students to guess how many drops of water would be required to cover the surface of a five cent coin. The students were asked to transfer drops of water on the tip of a pencil on to the surface of a coin. With the help of this activity the teacher was able to show her students that the surface of most liquids occupied a minimum space by forming a convex meniscus:

*Can you remember the small bottle that was filled with blue-dyed water and we had to just put paper clips in it to see how many would actually fit into it before they over flowed? The kids really liked that one. So I developed another experiment on sort of the same concept. We put drops of water on a five cent coin. The kids liked it because it completely throws them. They couldn’t imagine how many drops they had to make with their pencils to cover the coin. They had no idea that they can actually put that many in that little space.* (Launceston workshop participant)

Simple materials also appealed to the teachers because they were low-cost alternatives to expensive laboratory equipment. Many teachers mentioned that their school equipment budgets were limited and could not provide adequate teaching resources. They also pointed out that conventional laboratory equipment was expensive. Alternatively, many simple materials could be found around homes or purchased inexpensively. As one teacher from Launceston stated, classroom activities which were based on simple materials did not add pressure on her limited school equipment budgets.

*Simple stuff is really great. We try and use them as much as we can because we only have a limited budget and we try not to, we try to bring stuff in from home like, you know sort of yoghurt containers and all these sort of tubes and cardboard, bits and pieces from here there and everywhere. There are obviously things that are going to get used once and have to be chucked out, but there is much of the other stuff that we can recycle and sort of put aside for certain tasks. Then we do it that way. And you know makes us a little bit*
The Indonesian teachers appreciated immensely the simple materials that were used in the workshops. They agreed that simple materials were cost-effective, and reduced the difficulties associated with procuring conventional laboratory equipment. They lamented, however, that science teaching in Indonesia still relied on conventional laboratory equipment (i.e. “pre-developed props and aids”):

The simple stuff is easy to get and they are cheap. There are some simple materials that we can obtain easily and use to teach science, like plastic bottles, balloons, etc. that we used in the workshop. But the materials that we used here are not normally used in Indonesia to teach science... Back home we simply use pre-developed props and aids to teach. There is a preference to this latter style of teaching where we rely on textbooks and other pre-set activities... When it comes to some sophisticated teaching apparatus etc. that are costly and come from factories this becomes a problem. Also complete consignments of laboratory equipment are not available in every school. (Teacher from Indonesia, translation)

The Indonesian teachers pointed out that it was their lack of initiative that prevented them from using simple materials to teach science. They admitted that, as teachers, they needed to be resourceful and creative to teach science outside the parameters of textbooks and curriculum guides. The teachers believed that the CPAS workshop offered them the motivation “to teach science creatively”:

Yes we think it is possible. But up till now we have not been aware of such teaching techniques and, therefore, are not familiar with the use if simple materials to teach science in our classrooms. Also our lack of creativity limits us when we have to decide and incorporate such strategies... (laugh) we like to teach without having to think too much. It is easier that way, with just textbooks and sticking to the syllabus. But these workshop activities
have made us more open minded to creativity. (Teacher from Indonesia, translation)

These views about cost effectiveness and practicability of simple materials were consistent with the Sri Lankan teachers’ responses. A teacher explained this further with reference to two workshop activities that were used to demonstrate the structures of chemical molecules. In one of these activities inflated balloons were tied at their ends, while in the other activity marshmallows, jujubes¹⁷ and bottle-corks were held together with toothpicks to construct models of chemical molecules. The teacher added that these activities helped to conceptualise clearly the concept of lone-pair electrons, which was not possible with conventional laboratory models:

There was another exercise: the one where they demonstrated the structure of molecules with balloons and with a cork and jujubes. Now this practical exercise on molecular structures is not done in schools due to the unavailability of models of molecules in the laboratory. Also if one of its components is lost the whole model has to be discarded. These models are very expensive and usually not found in most school labs. But from the workshop we understood that with such simple things that it is possible to clearly and very well explain this concept to students... Actually, the concept of the lone-pair electrons was made very clear to me. We often say that a lone-pair “pushes” the other electrons away, but a clear three dimensional understanding of it was made through that exercise. It really made things very clear. (Teacher from Sri Lanka, translation)

Because the workshop demonstrated the benefits of simple materials, the Sri Lankan teachers added they felt motivated to teach science without their former reliance on conventional laboratory equipment. As one teacher stated:

¹⁷ Soft confectionary made of starch, gum and corn syrup.
Most of the time we don’t use simple equipment to teach science. Many schools and teachers in Sri Lanka continue to employ traditional lab-based practices to teach science... I think that the workshop provided a motivational force for us to take something new to the classroom. Also everything that was used was easily and readily available. They were simple materials. They also did not cost a lot. This was something I really appreciated about the workshop. (Teacher from Sri Lanka, translation)

In addition to the workshops’ use of simple materials, that have been discussed above, the teachers’ responses also highlighted elements of peer-collaboration that featured during the workshops. One teacher from Launceston remarked:

*There were other people around, and you felt “well I am part of a group, I’m not just by myself”. People pitching in and saying ‘do it this way, change that’ and so on. You weren’t just on your own. I like that style of group learning.* (Launceston workshop participant)

Researchers state that the opportunity to learn collaboratively from peers is an important feature of constructivist learning. For example, Davis (2002) has stated that offering teachers the opportunity to contribute to a learning community creates a non-threatening learning environment. However, Loucks-Horsley et al. (1998) maintain that collegiality for the sake of collegiality could be disadvantageous. They state that “the right conditions need to be in place to make teacher collegiality contribute to teacher learning” (p.332), since “teamwork and collegiality may not work in cultures of distrust” (p.333). That the CPAS workshops were not such an attempt is confirmed by the above teacher’s response, which states explicitly that she felt part of a safe and functional learning community (*i.e.* “…you felt well I am part of a group, I’m not just by myself”).

273
Researchers also maintain that collaborative learning enables teachers to recognise and establish good practice (Harrison et al., 2008). This was illustrated in several teachers’ responses which confirmed that they were able to work with colleagues from their schools both during the workshops and afterwards to develop activities for the classroom based on what they had experienced in the workshops. Two of these responses are quoted below:

And I found that when we were doing stuff together, because we went to the workshop as a group basically, as a faculty from our school, doing the activities together and we were bouncing ideas off. Now when we come to a classroom environment where we are unsure of something we can at least go and ask one of our colleagues “hey do you know how this happens” or “what the explanation of this happening”. I find that very beneficial, not as a resource, just only as someone to help you when you are doing activities. (Hobart workshop participant)

... the fact that there were a few of us there from this school, so we were able to sort of talk about it afterwards and sort of share what, who done what, and what worked and that sort of stuff with our kids and where we were going to apply it. So over the last couple of months we’ve probably used the buoyancy experiments, that sink or swim stuff, from the workshop quite a bit. (Launceston workshop participant)

The Indonesian teachers who visited Australia for their residential professional development program indicated that they shared ideas and clarified information discussed in the workshop while staying at their hotel in Canberra. The following response by one of these teachers supports findings by Davis (2002), who states that collaborative peer-learning allows teachers to feel that it is all right to learn from each other:

Back at our hotel we spoke with one another to try to clarify points that were not clear to us. If someone didn’t understand or had doubts we tried to clarify them. If someone didn’t understand we explained what we knew again... so we discussed about the workshop each night. (Teacher from Indonesia, translation)
Analysis of the teachers’ responses indicated one further feature of the workshops, which the teachers believed helped to inform their understandings. The teachers pointed out that this was the style of verbal communication that was employed by the workshop facilitators. Four distinct aspects of the facilitators’ style of communication were mentioned. Firstly, the teachers mentioned the *dialogue-type style of delivery*. They commended the dynamic interaction between the workshop facilitators which allowed for this type of delivery. As some of the teachers remarked:

*I liked the dialogue aspect of it all. I felt that was valuable because we felt a part of those discussions. Even if you weren’t contributing you were listening and picking up different people’s ideas. What you didn’t pick up from one you’d pick up from another.* (Charters Towers workshop participant)

*I think you got a good mix there: three people. They all come from slightly different backgrounds… So you’ve got three different people and they are quite happy to get up there and interject and pull the other person back. I like that sense of cooperativeness…* (Ayr workshop participant)

*The whole thing about bringing out a discussion, is probably something that wakes us all up… It had a lot to do with the change in presenters. That means who speaks, who goes first and the interaction they had; how one person comes in while the other is speaking… Yes, things that are subtly put and very spur of the moment… It is nice to see different people with levels of expertise from different areas interact like that.* (Hobart workshop participant)

The teachers’ responses indicated that the level of dynamism and interaction between the presenters was possible because the workshops were conducted by more than one facilitator. This allowed the presenters to interact with one another during the workshop. The teachers also pointed out that the facilitators’ advanced understandings of science helped to maintain the dynamism of that dialogue. As the following response states, the
facilitators were able to critique each other and freely discuss scientific concepts with the teachers because of their “very wide knowledge base”:

*What I find interesting too, is to see peer critiquing. It is humorous, but also very professional. Obviously they’ve got a very wide knowledge base and they are able to communicate the theory behind what’s going on very easily on a level that we’ll grasp at straight away...* (Launceston workshop participant)

Next the teachers referred to the *simplicity of the verbal communications*. They pointed out that the facilitators were consistent in their use of simple language which made the verbal communications easy to comprehend:

*The level of dialogue seems a good mix of academic, but at the same time what a general lay person can speak. They could go on a very theoretical level but they choose not to.* (Charters Towers workshop participant)

*I liked the way the instructors put across information... They used very simple language...* (Hobart workshop participant)

The third distinguishing aspect of the facilitators’ style of communication, as identified by the teachers, was the *use of narratives*. The teachers stated that stories, anecdotes and socio-cultural references formed an integral component of the workshops’ verbal communications. The teachers believed that these narrative devices rendered more familiarity and the ability to relate more easily to the explanations that were offered about scientific concepts:

*I think also when they (i.e. the facilitators) talk they make familiar referencing. Like they talk about driving a car, sport, or something like that. So it makes it more comfortable for us to understand the science.* (Launceston workshop participant)
I particularly remember what they told us about the movie Titanic as a way of describing buoyancy. I thought that was a really good idea... I liked the sort of things they told us to connect the science to a particular sort of stimulus. (Launceston workshop participant)

Yes, I think the sort of stories, some suitable aspect of the real world that they told us helped to make links to science. (Charters Towers workshop participant)

These sentiments were, however, not shared by all the teachers. A teacher from Ayr commented conversely that the narrative devices in the workshop did not serve an important purpose (i.e. “all the information with stories and history and stuff there was really nothing for me”). The teacher believed that she could obtain the same information from sources outside the workshop:

No, I don’t think so. The parts that they were telling us all the information with stories and history and stuff there was really nothing for me, because I can look up information as and when I need it... I haven’t remembered much of that... And anyway a lot of that information, I can look up when I need it. So a lot of that information stuff is not very much useful for me... (Ayr workshop participant)

This observation contradicts previous recommendations in the literature, that have called for persuasion and counter-persuasion based on figurative analogy for effective science communication (Sutton, 1996). The teacher’s counter-comments (i.e. “… anyway a lot of that information, I can look up when I need it”) revealed that she did not dismiss the importance of that information. Her response indicated that she did not appreciate the context in which it was delivered. This was, however, a singular viewpoint which was not shared by any of the other teachers.
Avraamidou and Osborne (2009) state in a recent paper, that narratives are an important means of communicating science and that it can play an equally significant role in science education. The researchers refer to Gould’s (1992) warnings against the possible oversimplification of science, as a result of narratives. Gould regards, however, that it should be possible to convey the complexities of science in everyday language without compromising the scientific accuracies. Avraamidou and Osborne conclude, with reference to Montgomery (1996), that narratives can be accurately used to communicate science in science education contexts by forging a stable plane between scientific and non-scientific speech.

Lastly the teachers indicated the animated style of communication that was used by the facilitators. To some teachers, like the teacher from Hobart below, this animated style of communication conveyed the facilitators’ enthusiasm which she found “infectious”:

*I think also that these guys are very passionate about what they do and that becomes infectious.* (Hobart workshop participant)

To other teachers this style of delivery presented elements of entertainment:

*Oh the way they went about it was very entertaining. I enjoyed the way they told those stories. So much of life involved.* (Charters Towers workshop participant)

The teachers from Indonesia and Sri Lanka believed that the animated style of communication, that was used by the facilitators, served as a medium for interpretation between English and their respective mother-tongues.
We know enough English to understand what was said. But the body language, gestures, the way they moved their hands and their facial expressions (i.e. Bhahasa “isharath”), with these things the message got through better. (Teacher from Indonesia, translation)

Actually, the way in which those teacher educators from Australia went about the training is very different from the way teacher trainers in Sri Lanka would do such a workshop. Unlike local teacher educators they communicated effectively. For instance, they did not rely only on words. But they tried to communicate with us with their expressions, intonation, etc. Every time they wanted to convey the idea behind what they were doing... The way they conducted the workshop was very different. They were completely immersed in it. (Teacher from Sri Lanka, translation)

A recently published study of public physics lectures by Kapon, Ganiel and Eylon (2009) indicates similar findings to those listed above. Based on a Translated Scientific Explanation (TSE), the researchers developed an explanatory framework which comprised of four key elements: Analogical approach elements; Story elements; Knowledge organization elements; and Content elements (see Figure 23).
An important observation that was made by the high school physics students who took part in the above study was that the lectures had advanced their scientific awareness; i.e. “…they got the big picture quickly, where as in conventional physics lessons it takes a long time to grasp the big picture (if at all)” (pp.17-18). Therefore, Kapon et al. conclude that the above explanatory elements (which are essentially science communication practices) can have an important role to play in science education:

This may suggest that presenting students with some aspects of contemporary physics in a popular manner may increase their excitement about physics, not just as a future professional, but also as a literate person learning about cultural artifacts that one should know about and be able to appreciate. (p.18)
Moreover, the key elements that have been proposed by Kapon et al. resemble closely the *Advice of Lecturers* based on the writings of scientists like Michael Faraday and Lawrence Bragg (see The Royal Institution, 1986). Faraday has written, for example, that “A lecturer should endeavour by all means to obtain a facility of utterance and the power of clothing his thoughts and ideas in language smooth and harmonious and *at the same time simple and easy*” (emphasis added).

The teachers’ remarks, in the present study, about the facilitators’ style of communication also indicated elements that closely resembled Burns et al.’s (2003) awareness, enjoyment, interest, opinion-forming and understanding (*i.e.* the AEIOU vowel analogy) definition for science communication in science presentations. These researchers state that “understanding rarely, if ever, occurs without motivation to learn, and enjoyment (an affective response) and interest (a cognitive response) are very powerful motivators” (p.197).

Hence, the facilitators’ efforts to communicate science in ways that motivated the teachers were essentially based on science communication practices. The responses by the teacher from Hobart (*i.e.* “…these guys are very passionate about what they do and that becomes *infectious*”), and the Sri Lankan teacher (*i.e.* “…they tried to communicate with us with their expressions, intonation, etc. *Every time* they wanted to convey the idea behind what they were doing… they were completely immersed in it”), for example, were indicative that practices of science communication were used to underpin the discourses in the workshops. It is possible to conclude, therefore, that the scientific understandings and new level of scientific awareness the teachers constructed as a result of the workshops were assisted by these science communication practices.
Interview part 3

In the final part of their interviews the teachers were asked if they had any suggestions to improve the workshops. A wide variety of responses were obtained. Many teachers indicated that they were satisfied about the workshops’ content and structure and that they did not have further recommendations to offer. Two such responses are quoted below:

I don’t really think so. I think it was really well catered for. I think everybody had access to materials. We weren’t short of anything. The food was good. It was at a different place, so you know, we could just forget about our normal routine, and where we normally operate. But I can’t really think of anything that I thought was, you know, a negative. (Launceston workshop participant)

I really don’t have any shortcomings to remark, but would like to add that I was amazed at the amount of preparation that the presenters had put into it. They had beautifully organized the whole workshop. They had brought enough materials for all the participants, and most of all I liked the way that they communicated. It was very informal and friendly, especially the way they complemented one another in their conversations. It was very friendly and enjoyable... But there was a sense of hurriedness about the whole workshop. But since it was all so very well organized and well presented we did not feel time pass by. We were all kept so very engaged and absorbed in what was going on and did not feel left out. It would have been bad if it was the opposite, fewer activities with more time, I would definitely have felt bored. (Teacher from Sri Lanka, translation)

These responses revealed, once again, the teachers’ satisfaction with the workshop materials, particularly the availability of those materials. These responses also highlighted logistical aspects of the workshops; i.e. catering, organisation, etc. Several of the Sri Lankan teachers expressed concern about the time limitations in their workshop. Unlike the teacher quoted above, who did not object to the hurriedness of the workshop (i.e. “But there was a sense of hurriedness about the whole workshop... It would have been bad if it was the
opposite, fewer activities with more time…”), other teachers believed that more time should have been spent on individual workshop activities:

*I acknowledge that there was a slight problem due to time, there wasn’t enough time to present the many activities...* (Teacher from Sri Lanka, translation)

*...there is a limit of what could be done. I believe that within those limits what all possible was done within the given time frame. I think that was good. But I wonder if it was possible to spend a bit more time on those activities.* (Teacher from Sri Lanka, translation)

The Sri Lankan teachers suggested, therefore, that they would like to see an extension of the workshop. They did not believe that the workshops should be repeated (*i.e.* “newer things and other practical exercises”). They indicated that it would suit them better if this was conducted earlier in the year (*i.e.* first or second term\(^{18}\)). Their responses also indicated *teacher mediated professional development for peers.* As the responses quoted below pointed out, a workshop earlier in the year would make it more feasible to disseminate the information to other teachers through staff development programs that are usually scheduled during the second school term:

*...However, if workshops like this could be conducted, I don’t think we need to repeatedly follow the same workshops. I mean not that they are not good. This workshop was very good. But we would like to see newer things and other practical exercises as well. That would be good... We meet with science teachers in our zone twice per term (i.e. once in four months). We can then disseminate the extra knowledge and experience we receive from this workshop. So I think such activities should not be conducted at the end of the year, as it was done here. But if a workshop for science teachers is conducted at the beginning of the year, I think it would be better.* (Teacher from Sri Lanka, translation)

\(^{18}\) In Sri Lanka the school year consists of three terms: January to April, May to August, and September to December.
Most teacher training programs are conducted in the second school term. So if we could have such workshops in the first term, then we could easily disseminate the information from them to the teachers when we have staff development programs in the second term. (Teacher from Sri Lanka, translation)

The Indonesian teachers agreed that it was important to follow-up the professional development that was offered in their residential workshop in Canberra. One of these teachers also indicated that she was prepared to disseminate the information she received from the proposed follow-up workshops, through teacher association networks in Indonesia:

Perhaps the presenters can come to Indonesia to refresh us about what we have done here. Now after this workshop we will try to implement it into our teaching for our students... but there needs to be continuation and follow up... We have come here from a teachers association in Indonesia. Every week we have a meeting for each subject: mathematics one day per week, biology one day per week. In the meeting we talk about how to improve our teaching skills in the subject. We can use those meetings to talk about these follow-up workshops to help develop the teachers back home in Indonesia. (Teacher from Indonesia, translation)

Teachers who attended the CPAS workshops in Australia did not suggest that the workshops should be followed-up. Instead they proposed that the workshops should be repeated each year. In fact all 19 of the Australian teachers indicated that the workshops should be conducted annually. They believed that such an approach would offer similar opportunities to other teachers in Australia. As one teacher from Launceston believed, by scheduling the workshops at a regular annual interval other teachers could benefit from the same experience:
I think they should be on offer each year. Because each year there are different groups of staff available, it would be valuable for them to experience that... It could be packaged slightly differently however. (Launceston workshop participant)

This view that the workshops “could be packaged slightly differently” indicated that the teacher believed some form of change could be made to the workshops’ structure and content. Analysis of the teachers’ responses highlighted several such suggestions. These have been listed below.

(a) Separate workshops for upper middle school and lower middle school teachers:

The teachers indicated that while the activities in the workshops could be used to teach scientific concepts across middle school grades, some of those concepts related more to upper middle school science. They pointed out that teachers who taught science in lower middle school might have found constructing those understandings a bit challenging and also irrelevant. It was proposed, therefore, by some of the teachers, that the CPAS workshops should differentiate between content for upper and lower middle school science.

Although the activities were very simple some of the concepts they covered are difficult to explain to students. For example the activity which involved magnets and aluminium plates to demonstrate Eddy currents was based on a very complex phenomenon. To teach it within our middle school syllabus would be very difficult. It is a very simple activity but the theory involved would be very difficult to communicate to a student. It would be merely an experience that is all. I think Eddy currents are covered in the upper middle school or even upper secondary science syllabus. And I don’t think the workshop activities had been differentiated in such a way... (Teacher from Sri Lanka, translation)

May be a little more description in the advertisement we get about what it (i.e. the workshop) is and how it’s going to help. To possibly encourage more people and make sure it’s directed at the right level of teachers, so they know whether it is suitable or not, because I felt some of the concepts were for more advanced science teachers. (Charters Towers workshop participant)
(b) Workshop content to cover more areas in science:

Some of the teachers felt that the workshops could include more concepts from other areas of science, like biology and chemistry:

*If they can do other branches of science as well of physics, I reckon it will be fantastic. One of my fellow teachers heard about the workshop and said that he would like if they did some stuff about chemistry. Even if they can explain, or if we can go into depth more about other stuff like biology I reckon it’ll be fantastic.* (Ayr workshop participant)

*As a suggestion I would like to add that it would be good if a similar workshop or workshops could be conducted for other subjects as well. Not only for physics. There was some chemistry, mainly physical chemistry I think, but also for subjects like general chemistry and biology, etc. it would be very good.* (Teacher from Sri Lanka, translation)

One Sri Lankan teacher added that he would also like to see more information about misconception literature discussed in the workshops:

*I guess there are other areas where misconceptions exist as well. So it would be very useful if we are informed of these areas too. If not we will not know about them and will continue to teach them from textbooks. Therefore, I think these should be revealed to us at another workshop.* (Teacher from Sri Lanka, translation)

(c) More participant-centred inquiry:

The teachers pointed out that although the workshops did offer them the opportunity to experiment with scientific concepts, they felt that those experiments were guided more by the facilitators’ input. Some teachers wanted more freedom to experiment with the simple materials. The teachers stated that they would have liked to investigate their own questions. Their responses indicated that they wanted more participant-centred inquiry.
Like I said before the workshops activities were great; lots of experiments and lots of investigations. They (i.e. the facilitators) did have some questions that they wanted us to investigate. But I feel that it would be often better trying to get us teachers to come up with the questions. Because otherwise you are still dictating in some way aren’t you? If we came up with the questions, then we have a little bit more understandings over what we are doing. (Hobart workshop participant)

These sentiments of more ownership of their learning were echoed in the interviews with two Sri Lankan teachers. They explained that they would have liked to investigate the scientific concepts in the workshop with activities which were developed by the teachers:

I think there is another aspect which we expect from the (follow-up) workshop. At this workshop we observed the presenters explaining one concept though a specific demonstration. But it would have been better if we were given the opportunity to try to explain that one concept through different approaches. This is one of the short-comings of our system: the teachers will study this one approach and beautifully replicate it in the classroom. This should not be the way. We should try to see one concept from different view points. This is necessary. Being innovative means to look at one thing from different facets. If the workshop provides the opportunity for this it would be very valuable... I know there were other teachers waiting for the opportunity to express their opinions as well, so it will be good if there is a chance to share ideas as a part of a workshop. (Teacher from Sri Lanka, translation)

There might have been other activities that we have learnt through our own teaching experience, which may have been more effective or even more innovative to teach those concepts that were demonstrated by the workshop activities. Sometimes there are activities that are more engaging that we know and could be used... There is another possibility with this suggestion. That is if there is a short-coming or mistake with the method we use to present something, then there is the opportunity to explore it further and correct it... (Teacher from Sri Lanka, translation)

(d) Strategies to ensure meaning for teachers who are non-native speakers of English:

The CPAS workshops for Indonesian and Sri Lankan teachers had to communicate to non-native speakers of English. While the teachers in Sri Lanka spoke Sinhalese and Tamil, the
teachers in Indonesia spoke Bahasa. The teachers in these workshops did not believe, however, that it would be effective to have a translator to convey the workshops’ communications, which were in English, into their respective mother-tongues:

No, we don’t think that we needed a translator. We know enough English to understand what was said. But the more complicated concepts, we had a bit of trouble understanding... also when there was lack of body language and where they spoke fast, it was difficult to understand (Teacher from Indonesia, translation)

In fact, the marginal attempts to involve a senior teacher educator as a translator in the workshop in Sri Lanka were described as ineffective by one of those teachers:

I of course had no difficulty with the language and understood everything very well. But I must admit English is not my first language, although I teach science in the English medium at school... However, I don’t think a translator would do a good job. Take for example the senior academic who was asked to translate some of the information into Sinhalese. But there was a big difference when you compare her style of communication with the presenters. Although they spoke only in English, the way they conducted the workshop was very different. They completely immersed us in it. So I don’t think a translator would do a good job. (Teacher from Sri Lanka, translation)

Instead of using a translator to manage the workshops’ communications between English and the teachers’ mother-tongue, the Indonesian teachers suggested that it would be a better stratagem to distribute relevant written material (i.e. handouts) between consecutive workshop topics:

So better than a translator, it would be good if we got a summary or a handout of each activity even in English before they spoke to us about it. So that we can first read it and understand it first, or at the end immediately give us a written summary, before they move to the next activity... They gave us handouts, yes I know, but that was at the end. It was difficult to think
Summary: Part 1

The first part of this chapter described the interviews that were conducted with teachers who participated in the CPAS workshops. A total of 38 teachers, from Australia (i.e. Launceston, Hobart, Ayr and Charters Towers), Sri Lanka and Indonesia were interviewed, based on a three-part standardized open-ended interview format.

In the first part of the interviews the teachers were asked if they believed the CPAS workshops had informed their understandings about science. All the teachers responded positively. Their responses indicated that the workshops had addressed their pedagogical beliefs and motivated them to teach science differently.

In the second part of the interviews the teachers were asked to describe how they perceived the workshops had brought about the above change. They pointed out that the workshops had helped them to make personally meaningful links between their scientific knowledge and everyday experiences. While doing so, the teachers highlighted that the workshops had addressed the scientific inaccuracies of their fundamental understandings. The teachers specifically mentioned the activities offered by the workshops to conceptualise those understandings, particularly the simplicity of the materials that were used. Their responses indicated that, because they were more familiar with those materials, they were able to construct deeper and more meaningful understandings about science. Some teachers had developed activities, based on the workshops’ principles, to teach science in their own classrooms, and reported positively about those experiences. Sentiments of *empowerment*...
and *ownership*, of both teachers’ and their students’ learning processes, were highlighted in some of those responses. In addition, the teachers mentioned that elements of collegiality were fostered by the workshops. They also commented about the facilitators’ style of verbal communication which played an important role in their experiences of the workshops.

In the third part of the interviews the teachers were asked to suggest recommendations to improve the workshops. All the teachers agreed that the workshops should be followed-up. However, their opinions differed about the nature of this process. While the teachers in Australia believed that the workshops should be repeated annually, the Indonesian and Sri Lankan teachers recommended that they should be followed-up as extensions to the first workshop. There was a strong emphasis among these two latter groups of teachers for teacher mediated professional development for peers in their home countries. The teachers also highlighted some considerations for future workshops. These included: different workshops for upper and lower middle school science teachers, more coverage of topics from chemistry and biology, and strategies to ensure meaning of the workshops’ communications for teachers whose first language is not English.
Part 2: Interviews with workshop facilitators

The second part of this chapter describes the interviews with the CPAS workshop facilitators. Two workshop facilitators (viz. Facilitator 1 and Facilitator 2) who are instrumental in designing the workshops (i.e. key informants) were interviewed separately. The general interview guide approach (see Chapter 5) was used to cover a series of topics, which explored the content of the workshops as well as the facilitators’ understandings of Constructivism. It was intended, from the interviews, to establish whether these latter understandings served to influence the workshops’ content, particularly the learning experiences that were offered to the teachers. This information was used later to answer the first supplementary research question (i.e. Are constructivist principles used to design the CPAS workshops?).

The facilitators’ understandings of Constructivism were consistent with the views that are maintained in the literature about constructivist learning (see, for example, Shymansky et al., 1997). Their responses indicated that Constructivism, essentially, promoted the advancement of existing knowledge structures, through experiences that were personally meaningful to the learner. As one facilitator stated:

...Constructivism is building very carefully on existing knowledge so far as it can be established, and allowing exploration on the part of the students...to explore the topic in a very free way. To feel very comfortable about asking questions so that they feel very safe. So that they can explore their own knowledge in an environment that is not very critical and which allows them to go laterally as well linearly into a topic, and to understand themselves more. (Facilitator 1)

An important feature in this response was the emphasis placed on the learners’ existing knowledge. As the facilitator elaborated, it is not possible to assume that all learners, who
in this instance were teachers, shared the same scientific knowledge and experience. Different teachers had different levels of understanding about different scientific concepts. Moreover, the facilitator pointed out that it was very likely for some of these understandings to be scientifically inaccurate:

...So I think it is very important if you are attempting to teach in any way through a constructivist framework that you do understand that you have to build on existing knowledge. Now, in teaching teachers that may seem fairly simplistic, because you may assume that they have the existing knowledge that they need to move forward into a different view of how they teach, but in fact it has proved not to be the case...our experience shows us that within one room of teachers you are going to have quite a variety of understandings in a particular area. And so one of the things we do is to try to establish what their existing knowledge is so far as we can, without too much probing and effort that disturbs the teachers. But we do need to recognise, I think, very clearly that there are misconceptions within the teachers’ body of knowledge, that we cannot assume everybody shares the same scientific understanding. (Facilitator 1)

The facilitators strongly held the view that textbooks were responsible for many of the misconceptions that were held by teachers. They maintained that many textbooks and curriculum guides included demonstrations and activities that represented scientific concepts inaccurately. Because many teachers do not have adequate understandings to challenge the science therein, they concede inarguably to the authority of these educational materials. Hence they remain oblivious to the erroneous understandings which they promote through their own classroom practices. As Facilitator 2 commented, teachers are often amazed at the revelation that textbooks can in fact be wrong, and used the example of the lemon battery to illustrate the point:

Textbooks are absolutely full of activities, small experiments and things. The teachers do the activity and it doesn’t work, the way it is supposed to work. And they immediately come to the conclusion that what is wrong is them. We say no, and show the examples. We point out to them, that quite often, many
times textbooks are wrong. They print things which are just not right... Many
teachers believe implicitly in these books: they can’t be wrong. We say
“occasionally they are” and we show them examples... Look at the lemon
battery... you put a piece of copper in you put a piece of aluminium in, the you
connect wires to them and you connect it to a 5 volt globe and it’s supposed to
light. The picture in the book shows it lighting. But it doesn’t light. One thing
we’ve learnt from that is we come to the conclusion that people who write
activity books don’t actually check out what they are writing about...Teachers
say “I assumed it was me that was wrong”. I’ve spent hours sometimes trying
to get things to work like in the book. (Facilitator 2)

The facilitators viewed the teachers’ misconceptions as an important area that needed to be
addressed by professional development. They believed that, to enable conceptual change,
and the teachers’ subsequent pedagogy, it was important to inform teachers about the
inaccuracies in their understandings. In fact, the facilitators indicated that the content of the
CPAS workshops was based partially on addressing such alternative conceptions:

The easy place to start is the misconception literature, because that is an area
that teachers must address in any topic. So if you can devise activities that can
expose the misconception and enable people to talk about it and address it
then you can hope they will promote conceptual change... (Facilitator 1)

It was clear from this response that the facilitators used the workshop activities to inform
teachers about the scientific accuracy of their understandings. It was, therefore, important
to examine how the facilitators devised such activities, especially whether these activities
were consistent with the constructivist principles they mentioned earlier. The Facilitator
was asked, therefore, to describe the processes by which the workshop activities that
exposed misconceptions were developed:

We’ll take the simple case of a misconception and knowing what the
misconception is, and then what we would probably do is to try to show them
that such and such is not the case. So we would look very carefully at the
misconception literature so we understood what the problem was and then at
the physics or other subject texts to make quite sure that we understood the
source of the problem, what it was about the presentation in traditional
physics or chemistry that was not illuminating this concept properly, and try
to understand from where the misconception was arising, so that we have a
handle on it, and can communicate the source of the misconception. Next, we
have a vast amount of activity books, so we would scan those first, and if we
think there is nothing suitable there to take or adapt to illustrate the problem,
we would then have to design from scratch. That would be probably a
minority case where we absolutely start from scratch. Most of the time we do
get inspiration from other sources. Most of the time we don’t take the activity
directly. We would say “that one is in that area, can we now work with that
design to modify it, change it in some way, so that we can use it to clearly
illustrate whatever it is we are trying to show”… (Facilitator 1)

The facilitator stated that activities were often inspired by current misconception literature
and adapted to suit the aims of the workshops. An example of this process was described
by Facilitator 2. This response, which is quoted below, highlighted parallels with models of
professional development, such as the one documented by McBride *et al.* (2004), that are
intended to enable teachers to teach science through inquiry. The CPAS workshop
activity in this instance was meant to address a textbook-based alternative conception that
all objects which contained air were buoyant. As this facilitator explains, the textbook
activity did not, however, produce the outcome that it intended, and served instead to
reinforce the misconception that it meant to address:

*This particular demonstration was to get round the problem that when you ask
a child “why does something float?” they say “because there is air in it”. It in
fact is not the only reason. In fact sometimes that can be wrong. What you get
is one of those old ball-cocks you used to get in toilets. They float on the water
with an arm and as the water level inside increases, it turns the switch off. In
the olden days those were made of copper... hollow copper balls... This
activity from a particular book said, if you drill a hole where the rod fits the
ball, and you put a thread in so that you can fit in a high pressure valve from
a bicycle, you can then pump air into it, and of course because of the bicycle*

---

i.e. Select a science concept/contents to teach the teachers; select a traditional science laboratory activity;
discuss the laboratory activity with teachers; engage teachers in the laboratory activity; put the teachers in
learning teams; and cause the learning teams to interact with each other. (pp. 436–7).
valve the air will go in but it won’t come out… it’s a very tricky experiment to do. I did it one day. You actually put lead shot in the ball… up to the point when you put the ball in the water only the top part of the valve floats above the water. In other words, it only just floats. You then take it out and you screw the valve in and you say “now, if I put more air in, it should float higher, it should float better”. And the kid says “yes, right”. So you pump air in… Now of course what everybody knows is air has a particular weight…so you are increasing the weight of the ball. So what the demonstration is getting at is, when you put the ball back in the water, it should sink… I made a ball and put air into it… and do you know what happened? The ball didn’t sink, it actually floated higher, supporting the misconception. It came up… It took me about an hour to work out what was going on. I put about 200 puffs of air in there, so there was quite a large volume of air in there. So it should be a lot heavier. Indeed it was. But the pressure inside that copper ball had increased quite a bit, just like pumping up a bicycle tyre… In fact the pressure caused it to get bigger. As a result when it went into the water, it displaced more water and increased the buoyancy force, so it came up. Yes, it did weigh more, but the buoyancy force increased due to the fact that it expanded, due to the increased pressure… I saw in a flash that the person who had written the experiment had actually never done the experiment. If he had he would have observed exactly what I had observed. And I tell this to the teachers…I’ve done that many times, and they say “that’s amazing”. And they say “now actually I felt much better. The next time the experiment doesn’t work the way a book says…I won’t automatically think it is me.” (Facilitator 2)

It is apparent from this response that an important feature of the CPAS workshops was to expose teachers to the inaccuracies in their knowledge constructs, which they previously accepted without contest. Facilitator 2 explained further that teachers were rendered passive recipients of scientific knowledge because they lacked deeper and more meaningful understandings about science. As a consequence, teachers self-perpetuated meaningless learning of science to their students. The Facilitator pointed out that this vicious cycle can only be broken by empowering teachers to have confidence to explore and inform their understandings of science:

One thing that has been very important... we actually, not only get to talk about the science, and what’s involved, and how it connects with the everyday, but we are able through these workshops to give the teachers confidence... One of the problems teachers say they have is “we can’t answer all the
“questions”. We say “nobody has all the answers to all the questions”... the important thing is finding out how to find the answer. So one of the things we try to do in these workshops is to give them confidence... They come away quite empowered by the workshop... mainly by what it does to communicate science, the science of the real world. What they really feel good about is that they don’t need to know everything about every question. They feel confident, that if they don’t know the answer to say “let’s go and find out”. (Facilitator 2)

To enable teachers to explore and inform their understandings challenges both teachers and teacher professional developers (see, for example, Loucks-Horsley et al., 1998). While it can be a daunting task for the teachers, it places an equal onus on the professional developers to contextualise these learning experiences. This is necessary to ensure that short-term professional development results in meaningful learning and not “a smorgasbord type feast” (p.10) like Fensham (2007) has described. As Stocklmayer (2001) has stated, it is a challenge to provide contextual experiences which assist learners (in this instance the teachers) to link between a learning experience and a personally meaningful learning outcome. One means of addressing this challenge was highlighted in the above response. The Facilitator emphasised the need for science that was communicated in the workshops to relate to the real world (i.e. “mainly by what it does is to communicate science, the science of the real world”).

The use of learning experiences that are personally meaningful to teachers is an important feature of professional development based on constructivist principles (see Posnanski, 2002; van den Berg, 2001). It has been stated in the literature that teachers need to view science in the context of their daily experiences in order for them to construct understandings that are relevant to them (see, for example, Holt-Reynolds, 1999). Such deeply significant understandings about science are needed if teachers are to facilitate
inquiry-based pedagogy with confidence. Relevance plays, therefore, a crucial role in the learning experiences that are offered to teachers during professional development. The following response by Facilitator 1 was consistent with this view:

...that is an important element of Constructivism: relevance, where this thing applies in the real world, so what we try to do is to draw on those various knowledges, to locate the activity first of all in the area of real world relevance; then to look at the science behind it; then to point out where students and often teachers, are likely to not understand or to misunderstand; and then to work out with the teachers ways to re-illuminate their understandings. Real world application is an important element, that I think is a really critical element of the things we do. (Facilitator 1)

The facilitator stated, in addition, that the workshop activities involved three other features; i.e. simple materials, group work and modelling inquiry-based pedagogy:

Other activities are there to illustrate other things that we believe is very important in teaching. One of those is to use simple equipment. Another of those is to model good group interactions in learning. (Facilitator 1)

With regard to peer-collaboration the facilitator added:

The act of reflection is encouraged not only through careful exposition of the activities but also through the interaction of the teachers in their groups. And we try to keep the groups small so that level of exchange of ideas and knowledge is maintained... and I think if you set up an environment where there is a lot of open discussion, where people are not afraid to say what they think, then you would improve the likelihood that people will indeed move towards a deeper understanding of a topic. (Facilitator 1)

Facilitator 1 stated that although modelling classroom teaching based on inquiry was not overt in the workshops’ content, the workshop did emulate recommended pedagogical practices. Therefore, the facilitator reiterated that the workshops were not intended as a
smorgasbord-type feast, but a model of professional development that offered deeper insights to the teachers:

We usually mention what we think is important about the activity. We may not labour the point. We do certainly say at some point in the prior advertisement or some point of the workshop itself that the activities are designed to model good teaching practice. We do try to make it clear to the teachers what we are about, that the activity has something beyond the simple use of the thing. I think that is important too because if teachers can see a rationale for doing something beyond simple activities I think that the transferability of the idea is enhanced. I would like to think that these workshops are not a set of activities and when they are done that’s the end of the matter. I would hope that’s not the way it works.

In addition to these three features of the workshops’ activities (i.e. relevance, use of simple materials and peer-collaboration) the facilitators pointed out that science communication practices also played an important role in the CPAS workshops. They informed that communicating science in ways that engaged the teachers was integral to the workshops. In order to do so the facilitators had to draw on their extensive experience in informal science communication (i.e. “So we have drawn very much on the science centre tradition here”). The outcome that manifested in the workshops’ style of delivery was, therefore, a result of science communication, rather than science education:

...other elements such as history of science, use of humour, various elements we believe are important in science communication translate into the workshops themselves. Now that’s not as ad hoc as it may appear because we do have a very long and strong history of hands-on and science shows here in Australia on which to build those kinds of understandings. So we have drawn very much on the science centre tradition here, which is a science communication tradition rather than a teaching tradition, to understand what makes science engaging and accessible and to some degree entertaining... (Facilitator 1)
This view was collaborated by Facilitator 2. This facilitator agreed that good science communication practices, which engaged the teachers, were an important feature in the workshops’ style of delivery:

*If I’m communicating science then I tend to talk slower...and I certainly put my body into it. That’s very very important... Just visualise someone who stands there like a stuffed tailor’s dummy and just goes on talking, instead of somebody who walks around, and looks at them, and waves their arms around, and smiles and grimaces, looks happy looks sad...that interests people, that keeps their attention. If you just stand there and say...like a robot, that’s not interesting at all. In fact you’ll have people doing their shopping lists under the desk... (Facilitator 2)*

Facilitator 2 also pointed out that it was important to involve the actual human agencies behind the scientific concepts that were communicated. For instance, the facilitator spoke about the New Zealand physicist Ernest Rutherford, who during the early 1900s pioneered modern atomic science:

*We use these techniques deliberately. We developed those techniques over the years. I used to use that technique in my formal university teaching. If I could ever tell them a story about the scientist whose concept or science we were talking about, I’d put that in. I think it is one of the great shortcomings of all textbooks, I don’t know any textbooks that actually give a small write-up...about the scientist, in this way, whose was principally involved in a particular scientific concept... If you are talking about Rutherford’s scattering, the experiment that he carried out at Manchester back in early part of the last century, then to actually write a little thing about him personally, that he came from New Zealand, that he was a loud spoken man, he was very forthright, sometimes he spoke very tactually...any other stories you can throw in, that’s good. That makes the man come alive. Rutherford’s scattering, what does it tell you about Rutherford? Nothing. That’s just the name of an experiment; nothing to do with the man himself. (Facilitator 2)*
The revelation by both facilitators that elements of science communication were an integral part of the workshops advanced an entirely new perspective to the workshops’ design. Their responses highlighted that good science communication practices were intentionally woven into the workshops’ design to underpin the learning experiences that were offered was an important observation in this response (i.e. “We use these techniques deliberately. We developed those techniques over the years”). This revelation indicated that even when constructivist principles were employed to inform the teachers’ scientific understandings, the CPAS workshops used elements of science communication to underpin those learning experiences. It has been stated, in fact, that science communication serves to affect (awareness, enjoyment, interest, opinion forming and) understandings about science (see Burns et al., 2003). It has also been stated that efforts to communicate science are closely allied to constructivist principles, where personally meaningful links are fostered to advance learners scientific awareness (see Stocklmayer & Gilbert, 2002). While the full implications of this revelation are discussed in the final chapter, it is prudent to say presently that science communication practices seem to have influenced the workshops’ constructivist design.

An advantage of conducting the interviews with the workshop facilitators after the interviews with teachers, who participated in the workshops, was the opportunity to ask the facilitators about the suggestions the teachers made to improve the workshops. The facilitators’ responses to the teachers’ suggestions are presented in the following section.
(a) Separate workshops for upper middle school and lower middle school teachers:

The teachers suggested that it would be more beneficial to differentiate between workshop content for upper and lower middle school science. The facilitators’ responses indicated that they understood the teachers concerns that were highlighted by that suggestion. Facilitator 2 stated that concepts like Eddy currents, for instance, were best reserved for upper middle school science teachers:

_I take the point. There should be differentiation between the two... in fact my differentiation would be to leave eddy currents type demonstrations entirely to the upper middle school... what it involves is Lenz’s Law and that wouldn’t come between Years 6 and 10 in Australia... so I think if we do demonstrations like eddy currents we could limit them to upper school._ (Facilitator 2)

However, the facilitators did not believe that differentiating scientific content in this way would meet the expectations of the workshops. While different teachers would have different levels of understanding, Facilitator 1 explained that it was important for the teachers to be able to adapt their science lessons to suit their students’ needs:

_The things which I think is important about the workshops is that we explain to the teachers that these things are not set in stone; they are adaptable to different audiences and different levels depending on what they want to talk about. That is one of the things we want to stress in the workshops. So having different levels, it seems to me, would be pitching very firmly within the curriculum, which is another thing we try not to do. What we do find is that we have very different levels of understanding with the teachers. That is an issue, and that is a difficulty. But in terms of just suiting it to specific areas of the syllabus, that I think is bit of a luxury we will find hard to implement._ (Facilitator 1)
While the teachers appreciated the workshops’ content, which was focused mainly on physical science concepts, they indicated that they would like to see more concepts from other scientific disciplines. The facilitators were asked, therefore, whether it was possible to include concepts from other areas, for example biology, in future workshops. The facilitators indicated that the teachers’ suggestion was a reasonable one, but the fundamental reason for the workshops’ predominant focus on physics and some chemistry was because the facilitators’ expertise was in those areas. However, as Facilitator 1 pointed out, their experience has shown that many teachers, even those who teach biology, have a keen interest to know more about physics:

*The short answer is, it is what we know best. And we have done an extensive exploration of the physics and chemistry principles that are difficult and the misconceptions in those areas. But of course they (i.e. the teachers) are right. There ought to be the same kind of offering, and even perhaps in the earth sciences area...ideally yes we would cover all those areas. We have tried on occasion, but what we tend to find is that the biology teachers are more interested really in finding out about the physics and the chemistry and tend to think they are more comfortable about the biology. So it has been a mix really of tapping into our own expertise here and understanding that those are the areas the teachers find the most difficult...* (Facilitator 1)

Facilitator 2 agreed that physics is a challenging subject to teach. The facilitator stated, therefore, that it was important to offer teachers support to confront that challenge:

*From my view, there are very few qualified physics teachers in the schools. We’ve often found physical education teachers teaching physics... If you take a bunch of teachers you will find that a large percentage of them, no matter which country you are talking about, are science teachers who have got a good background in biology, environmental science...and perhaps chemistry. But very few of them have got a background in physics... Being that it is probably one of the more tricky subject areas to teach, I think that physics workshops are very important.* (Facilitator 2)
In addition, Facilitator 2 pointed out that the basis for the teachers’ suggestion to include concepts from other science subject areas may be because the teachers were not completely aware of the workshops’ actual content. The facilitator stated that those responsible for informing the teachers in their local areas about the workshops often did not pay enough attention to the fact that the workshops were advertised as having a greater emphasis on the physical sciences:

*I think that is a very reasonable suggestion. The problem is with that the two presenters are mainly physics and chemistry. And we usually start off, in the literature we send out before hand, saying that we are not going to do any biology, mainly because we are not qualified in biology. However, frequently what happens is, that initial literature that goes out is not forwarded to the teachers. So they expect we are going to do physics, astronomy, biology, chemistry... They never see this piece of paper from us that says we are never going to do biology. We can’t, we are not qualified to do it... That’s the reason they are saying that. They are saying it because they never get to see the information we send out. Somebody along the way...blocks that bit, or re-writes it and leaves that bit out. So they (i.e. the teachers) come in the expectation that we are going to do the lot. And the people who are conning them are their own people.* (Facilitator 2)

This claim by Facilitator 2 was confirmed by a teacher in Charters Towers who stated that it would be more beneficial to know more about the workshops in advance (*i.e.* “Maybe a little more description in the advertisement we get about what it (i.e. the workshop) is and how it’s going to help”). It is possible, therefore, that the local bodies that are responsible for organising the workshops failed to inform the teachers accurately about the content covered by the CPAS workshops.
The teachers indicated that they would like to have more involvement in choosing the activities that were used to demonstrate different scientific concepts in the workshops; as one Sri Lankan teacher suggested “it would be better if we can try to explain a concept through different approaches”. They wanted to know, therefore, if it was possible to bring their own experiments and materials that demonstrated particular science concepts to future workshops. The facilitators agreed that an element of experimentation of this type would offer the teachers a valuable experience. As Facilitator 2 pointed out, the workshops aimed, in fact, to enable the teachers to continue to experiment with different materials in this way:

*Ideally we should spend double the time so that they could try some of the activities in slightly different ways, not simply the prescribed way: let’s not try it this way, what would happen if we did it that way? That is an extraordinarily valuable experience... The majority of, in fact just about all our demonstrations are deliberately devised so as to use very simple apparatus. Therefore there should be no problem in teachers afterwards going away and experimenting with apparatus. In fact the whole point of it is that they do do it after the workshop... It suggests that teachers think that everything has to be done in the confines of the workshop. That is not true. The workshop should, ideally, never stop. They should continue to experiment with apparatus later on... Being as we deliberately make the apparatus simple and very very cheap there should be no problem in them spending as long as they like. We are just giving them a start, a gentle push. They should continue to go. They should not believe that when they walk out of our workshop they stop.* (Facilitator 2)

It was evident from the teachers’ responses that were quoted in Part 1 of this chapter that the workshops had in fact motivated them to experiment with new materials and develop activities based on the principles that were advanced by the workshops. One such example was the modified Film-can rocket experiment by the teacher in Ayr who used lemonade and antacid tablets in place of vinegar and sodium bicarbonate. Another was the Sri Lankan...
teacher’s demonstration of the activity of detergent on milk with locally available alternatives, like powered milk and coconut milk. In addition, statements like “they’d feel empowered by it, because it’s all equipment they know they could get hold of at home and explore things further…” by a teacher from Charters Towers served to confirm the expectations for the workshops that were expressed by Facilitator 2.

It was, however, necessary to know whether the CPAS workshops could offer teachers the opportunity to choose different activities to demonstrate scientific concepts during the workshops. Facilitator 1 explained that although this suggestion was a reasonable one, it was not feasible within the logistical constraints of the one-day workshops. The facilitator stated that the longer two-day CPAS workshops do in fact encourage teachers to bring activities they would use in their classrooms to demonstrate specific scientific concepts. The facilitator pointed out, however, that this exercise was not meant for teachers to demonstrate different ways of teaching a particular concept, as is done as part of certain science teacher conferences. It is meant, instead, to encourage dialogue among the teachers about the deeper understandings their teaching methods hope to advance about a particular science concept:

When we have the two-day workshops that’s exactly what we ask the teachers to do. We ask them to come back the next day with something which they do in their classroom that they consider to be an exemplary activity in some area, and they do do that and that works extremely well. To do this in a one-day workshop is difficult on two accounts. The first is that the teachers have to then be primed before they come, which means actually covering some of the material before they get there, which obviously is not practical. The second is that we will become, I believe, bogged down in “who else does the topic a different way”, rather than the object of the exercise, which is to say “the topic is a vehicle to demonstrate something about the actual teaching methods or techniques, or learning methods or techniques”. It’s not so much the content. So talking about different ways of doing a particular topic, I think, would be self-defeating. What we find when the teachers bring it back the next day is that, often they have got very innovative ideas about doing something in a particular way, which we can
then discuss and talk about, not so much in terms of the topic but in terms of what they are saying they do with that topic. There is a thing in Western Australia at the annual conference that is called “You show me yours and I’ll show you mine”, and that’s when the teachers simply do what you’ve suggested; they all bring in a terrific activity and the object of that session...is to learn a new activity to suit a particular topic. That is a different emphasis...We are not talking about topics, we are talking about methods. (Facilitator 1)

It was also inquired from the facilitators at this stage of the interview why the teachers in Sri Lanka believed there was a sense of hurriedness in that workshop. The Sri Lankan teachers felt that more time could have been spent on the workshop activities. As Facilitator 1 explained most CPAS workshops tend to be hurried because of their content and level of participant discourse:

I think the workshops are always a little too full, because we do usually try and cover an awful lot of things. And depending on the level of teacher talk that results in a workshop we can end up with a few activities at the end that are going rather fast. If we have a lot of good interaction that is pretty normal, yes so what the teachers said is true. (Facilitator 1)

While Facilitator 2 stated that it would be ideal to spend more time on the workshop activities, he pointed out the time limitation the teachers experienced was a consequence of funding constraints:

I agree. A lot of our workshops are hurried mainly because as a result of money. We can only spend just so much time. So yes I agree with them wholeheartedly. I would certainly like to spend more time, but it is dictated by the fact you’re going overseas, people pay your living allowances, etc. only for a specific time, and that dictates how long you can spend in front of a group like that. That’s the problem. It’s purely financial constraint. (Facilitator 2)
(d) Strategies to ensure *meaning* for teachers who are non-native speakers of English:

The facilitators were asked about the Sri Lankan and Indonesian teachers’ comments about ensuring meaning of the workshop communications that were in the English medium. These teachers remarked that they did not believe that an interpreter would effectively translate into their mother-tongues what was intended by the facilitators’ communications. Facilitator 1 concurred with this view and stated that it served to reduce the spontaneity of the workshop. The facilitator added that it was difficult to work simultaneously with an interpreter to translate the workshop discourse:

*We have worked with translators in Sri Lanka and in Thailand. I personally find it very stressful with a translator because a lot of the spontaneity is lost: because you have to speak in short bursts, and then you have to listen to the translator and then come back to you and go back to the translator. I find that, apart from the time involved, certainly detracts from the spontaneity of the workshop. I find it difficult. But on occasion, particularly in Thailand, you can’t help it… I don’t have an easy suggestion. In Korea I gave a seminar on one occasion, everybody had a headphone and there was an automatic translation. And obviously that is a highly skilled thing to do, the translator has to be very skilled in both languages and in the jargon of science, and it is not easy and it is very expensive. But ideally that is probably the best way that you get simultaneous translation into a headset and you don’t therefore get that loss of spontaneity.*

A suggestion by the Indonesian teachers to overcome the challenge of English to mother-tongue translation was to have relevant handouts of the workshops’ activities before they were actually presented by the facilitators in the workshop; *i.e. “…it would be good if we got a summary or a handout of each activity even in English before they spoke to us about it. So that we can first read it and understand it first”.* The facilitators’ responses indicated that they understood the purpose of the teachers’ suggestion, but they did not believe this strategy would have the desired outcome. As Facilitator 1 stated:
Giving them the materials before the workshop altogether to read before they come I think is a bad idea, except for certain elements: read up on Constructivism... But to read up the actual experiments before hand I think would be frankly disastrous because I think a lot of the importance of those experiments depends upon them experiencing them in much the same way as the students might do it. Then if there is to be a wow or a surprise or something like that, to kill it all beforehand would be a really detrimental attribute. And also would destroy the group discussion about what do you think is happening here... So I don’t think that would work, except for some sections of the theory. But certainly giving out the experiments beforehand I would feel very unhappy about that. (Facilitator 1)

In addition the facilitator pointed out that this strategy would have practical problems due to the teachers’ different English language skills:

I think it is a difficult suggestion. I think giving them the idea of the material and telling them to “have a little read about this and then we will talk about it” in the workshop is obviously time consuming and would result in an uneven balance when teachers finish reading and their different English skills... (Facilitator 1)

These practical concerns were reiterated in the response given by Facilitator 2. The facilitator was concerned about the fact that the teachers would spend time reading the handouts and not paying attention to the actual workshop discourse. Facilitator 2 also indicated that the Indonesian teachers’ lesser proficiency in English, than the Sri Lankan teachers, may have been a reason for this suggestion, which was made by them:

If we gave the handouts a week before, where there is plenty of time for the teachers to read it, that would be okay... If we gave it to them right before, we’ve done it in Australia, all we look at, we will be talking to the tops of a whole lot of heads. They got their heads down reading what we say. The other teachers will do the same too, Sri Lankans and Indonesians. I think the Indonesians, as I recall, had nowhere as near a good grip of the English language as the Sri Lankans did. And that may be why you got that suggestion form them. Several of the Indonesians hardly spoke any English at all. (Facilitator 2)
Summary: Part 2

The final part of this chapter described the interviews which were conducted with two CPAS workshop facilitators. Their responses demonstrated an awareness of constructivist principles. They indicated that teachers did not share the same understandings about science and that these understandings were often inaccurate. While the facilitators strongly held that textbooks helped to perpetuate such inaccuracies by the way they presented science, they explained, with examples, how the workshops attempted to address those misconceptions. The facilitators also mentioned the use of simple materials and peer-collaboration as important features of the CPAS workshops. Most importantly, they pointed out that science communication principles underpinned the discourses which were used to inform the teachers’ understandings in the workshops. These interviews also explored the facilitators’ views about the teachers’ suggestions to improve the CPAS workshops.
Chapter Summary

Chapter 7 described the interviews that were conducted as part of the research procedures for this study. Two sets of interviews were conducted: first with the teachers who participated in the CPAS workshops and second with the facilitators who designed the workshops.

Part 1 of this chapter presented data from the interviews with the teachers. Responses from 38 teachers, in Australia, Sri Lankan and Indonesia, were used to investigate whether they believed the workshops enabled them to construct personally meaningful understandings about science. The teachers’ responses indicated that while the workshops used constructivist principles to inform their scientific understandings, these were underpinned by principles of science communication. The teachers also suggested improvements to future workshops.

The second part of this chapter described the interviews with two CPAS workshop facilitators. The interviews indicated that constructivist principles were used to design the workshops. An important revelation in these interviews was the facilitators’ conscious effort to include principles of science communication in the delivery of the workshops. The facilitators were also asked during their interviews to comment about the teachers’ suggestions to improve the workshops.

The implications of the above findings, and the workshop observations that have been described in Chapter 6, are discussed in the next chapter.
Conclusions
# Chapter 8: Conclusions

## Chapter Overview

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brief overview of the study</td>
<td>313</td>
</tr>
<tr>
<td>Summary of findings</td>
<td>315</td>
</tr>
<tr>
<td>Conclusions</td>
<td>319</td>
</tr>
<tr>
<td>A constructivist framework for short-term professional development</td>
<td>319</td>
</tr>
<tr>
<td>A science communication presence in science education reform</td>
<td>323</td>
</tr>
<tr>
<td>Challenges for science teachers from non-Western cultures</td>
<td>325</td>
</tr>
<tr>
<td>Recommendations for future research</td>
<td>327</td>
</tr>
<tr>
<td>Epilogue</td>
<td>329</td>
</tr>
<tr>
<td>References</td>
<td>330</td>
</tr>
</tbody>
</table>
Chapter 8: Conclusions

Brief overview of the study

This thesis investigated the possibility of grounding short-term professional development in constructivist principles and thereby, enabling middle school teachers to construct confident understandings about science. The following overarching research question was used as the basis for this study:

Do short-term workshops that are based on constructivist principles enable teachers to construct personally meaningful understandings about science?

Studies during the last two decades have stated that the public is mistrustful about science (see, for example, Stocklmayer, 2001). Contemporary models of science communication have, therefore, emphasised the need to move away from addressing the public’s science knowledge deficits and move towards public engagement of science (see Chapter 2). It is intended that such efforts would pave the way for a public which is scientifically aware, and one which is prepared to engage purposefully with science on an everyday basis.

In a similar way, science education reform in the late 1990s has emphasised that school science should adopt student-centred inquiry-based pedagogy, as a means of fostering continued interest with science (see Chapter 3). Despite these reform efforts, recent research has revealed that students, particularly in middle school, maintain alarming levels of indifference to science (see, for example, OECD, 2006; Sjøberg & Schreiner, 2005). These findings have resulted in pleas to examine the reasons for school science failing to engage students (see Tytler, 2007).
Researchers state that the main reason for students’ disenchantment with school science is the way in which science is taught in most middle school classrooms (see Rennie et al., 2001). Instead of using recommended pedagogy to teach science, most teachers still rely on traditional transmission models of instruction (see Lyons, 2006). An important reason for this predisposition is that teachers are unaware of the actual pedagogical processes that are involved in science education reform (see Lee & Krapfl, 2002). More importantly, it has been found that many teachers lack adequately developed understandings about science which are necessary to underpin inquiry-based pedagogy (see, for example, Barnett & Hodson, 2001).

Several measures have been suggested to help teachers to develop the understandings they require to teach science in ways that are conducive to reform recommendations (see Chapter 4). Among these, professional development which is modelled on constructivist learning experiences is regarded as the most effective means of achieving desired conceptual change in teachers (see Posnanski, 2002). It is believed that personal and meaningful understandings which the teachers construct, as an outcome of such programs, would enable them to confront the challenges of student-centred inquiry (see Loucks-Horsley et al., 1998).

However, not many studies have investigated the possibility of modelling short-term professional development on constructivist principles. While a few have suggested the possibility of further exploring short-term professional development (see for example, van den Berg, 2001), they do not offer confirmatory evidence. It was, therefore, the main aim of this study to investigate the possibility of modelling short-term professional development on constructivist principles and to examine whether participating teachers do develop personally meaningful understandings about science.
There were two auxiliary purposes of this study. The first of these was to investigate the parallel trends in science communication and science education, in the context of science teacher professional development. The second was to examine the challenges encountered by science teachers from non-Western cultures, as learners of science.

The overarching research question in this study was investigated with attention to the one-day professional development workshops that are offered by the Centre for the Public Awareness of Science (CPAS). These workshops were examined from three separate perspectives using qualitative methods, which were based on three supplementary research questions (see Chapter 5). The important findings from those investigations are summarised below.

**Summary of findings**

In the first stage of investigations, observational data based on frequency counts of six predetermined categories of observational variables from six CPAS workshops were used to answer the second supplementary research question (*i.e.* Are constructivist principles used to deliver the CPAS workshops?). These observations revealed that constructivist principles were used to deliver the workshops.

Workshop communications in Category 1 were used by the facilitators to examine the teachers’ existing scientific awareness. This made it possible for the facilitators to identify misconceptions that were present in the teachers’ knowledge framework and to direct subsequent workshop communications to address those misconceptions. The facilitators used a variety of non-threatening forms of communication to inform the teachers about the
scientific accuracy of their understandings. These communications were recorded as observations in Category 2. An important observation of these communications was the examples from textbooks which the facilitators pointed out as sources for misconceptions. These communications caused considerable consternation, particularly amongst the international teachers, because many of the teachers relied on textbooks to teach science in their classrooms. In order to address the teachers’ misconceptions and inform their understandings about those scientific concepts several minds-on and hands-on activities were featured in the workshops. These observations were recorded in Category 4. An important feature of the workshop activities was their use of inexpensive and simple to use materials.

Workshop communications which were recorded in Category 3 were those which used social-cultural references to inform the teachers’ understandings. These socio-cultural references played a different role from the ones which were recorded in Category 5; i.e. while the aim of the references in Category 3 was to help teachers to develop coherent understandings about scientific concepts, the socio-cultural references in Category 5 were intended to enable the teachers to contextualise those understandings in everyday situations. In a similar way, observations that were recorded in Category 6 described further activities which were offered to the teachers to scaffold their new levels of scientific awareness.

In addition, observations from the workshops for science teachers from Sri Lanka and Indonesia were used as bases for the cross-cultural perspectives that were investigated in this study. While some of these observations reconfirmed findings from previous studies, others offered new insights into the area of science education in cross-cultural contexts. Conclusions that are based on these findings are stated later in this chapter.
In the second stage of investigations, data from standardized open-ended interviews with 38 teachers from Australia, Sri Lanka and Indonesia were used to answer the third supplementary research question (i.e. Do the teachers who attend these workshops construct personally meaningful understandings about science?). All the teachers agreed that the workshops had informed their scientific understandings. Their responses indicated, more importantly, that the workshops had achieved this outcome in ways that were personally significant to them.

The teachers stated that the workshops had examined their basic understandings about science and pointed out the misconceptions they held. The teachers were amazed to have been informed that the roots for many of those misconceptions were found in textbooks. The teachers stated that the workshops had given them confidence to move away from their role of subservience to textbooks, and to teach differently when they believed that the information in textbooks was not accurate. The teachers explained that the simple materials which were used in the workshop activities were primarily responsible for these sentiments of empowerment. Because these materials were inexpensive and easily procurable from their homes and local environments, they felt comfortable to experiment with those materials and were confident in the understandings they constructed as a consequence.

The teachers’ responses indicated two further features of the workshops which had helped them to develop confident understandings. The first of these was peer-collaboration. They said that the collaborative learning experiences which featured in the workshops helped them to develop trust and confidence as members of a learning community. The second feature that the teachers mentioned was the facilitators’ style of communication. They explained that the animated and dialogue-type style of delivery and the facilitators’ use of narratives, to describe the social and historic events behind the different scientific concepts,
had helped to engage them in the discourse of the workshop. In fact, one Hobart teacher remarked that the passion with which science was communicated in the workshops was infectious. The Sri Lankan and Indonesian teachers explained that because the facilitators’ style of communication did not rely only on words to express ideas, they were able to overcome the language barriers that existed between English and their mother-tongues.

In the final stage of investigations, key informant interviews with two workshop facilitators were used to answer the first supplementary research question (i.e. Are constructivist principles used to design the CPAS workshops?). The facilitators’ responses indicated that the workshops were intentionally modelled on constructivist principles.

The facilitators pointed out, however, that it was not possible to construct new understandings directly, as many teachers held misconceptions, for which the facilitators blamed poorly developed textbook activities. Therefore, they stated that it was necessary to help the teachers to develop confidence to question such inaccuracies. They believed that this was an important aim of the workshops. The facilitators explained that the workshop activities, which emulated the science-centre tradition of hands-on active investigation, played a key role in this exercise. Because these activities identified with everyday experiences, they helped the teachers to link the learning experiences in the workshop to construct understandings which the teachers would find personally meaningful in the classroom. Hence, it was the relevance of these understandings that offered the teachers that element of confidence, which in their (i.e. teachers’) interviews they described as empowerment.

An important revelation made by the facilitators was that science communication practices were purposefully used to underpin the workshop communications. They stated that while
constructivist principles were at the core of the workshops’ design, science communication practices were used to facilitate those learning experiences.

It was evident from the above findings that the CPAS workshops were based on constructivist principles and that these workshops had enabled the teachers to construct personally meaningful understandings about science. Now the implications of these findings are drawn together to conclude this study.

Conclusions

A constructivist framework for short-term professional development

The findings from this study indicated that is possible to model short-term professional development on constructivist principles. This is an important finding in terms of future short-term science teacher professional development programs. It was revealed, moreover, that the six categories of workshop communications were broadly consistent across the six CPAS workshops that were observed and that they comprised broadly the same proportion of the total communications in each of those workshops. This is illustrated in Table 19 which shows the frequency of communications of a given category as a percentage of the total frequencies that were recorded in each workshop.
Table 19: Frequencies of communications in each category expressed as percentages of the total frequencies in the six CPAS workshops

<table>
<thead>
<tr>
<th>CPAS Workshop</th>
<th>Categories of workshop communications</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Launceston</td>
<td>20.42</td>
</tr>
<tr>
<td>Hobart</td>
<td>18.03</td>
</tr>
<tr>
<td>Ayr</td>
<td>15.27</td>
</tr>
<tr>
<td>Charters Towers</td>
<td>20.55</td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>21.21</td>
</tr>
<tr>
<td>Average</td>
<td>19.64</td>
</tr>
<tr>
<td>~ Average</td>
<td>20</td>
</tr>
</tbody>
</table>

The last row in Table 19 shows the average of the percentages which are listed in the column above it. Hence they indicate how frequently the different categories of communications were experienced, on average, during the six workshops. These average percentages are represented in a pie chart to illustrate the relative proportionality of the six categories of communications in the CPAS workshops (see Figure 24).
The observations of the workshops revealed, furthermore, that it was possible to group the six categories of workshop communications into three stages which exemplified the processes of constructivist learning. These three stages, along with their corresponding categories are described in Table 20.

Table 20: Three Stages of constructivist learning as exemplified by the CPAS workshop model

<table>
<thead>
<tr>
<th>Stages of constructivist learning</th>
<th>Categories of communications in CPAS workshops</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage 1: to examine</td>
<td>Category 1</td>
<td>Examined the teachers’ existing scientific awareness.</td>
</tr>
<tr>
<td>Stage 2: to inform</td>
<td>Category 2, Category 3, Category 4</td>
<td>Informed the teachers’ scientific understandings by deconstructing alternative conceptions, building meaningful links, and offering the opportunity for active experimentation.</td>
</tr>
<tr>
<td>Stage 3: to scaffold</td>
<td>Category 5, Category 6</td>
<td>Scaffolded the teachers newly acquired levels of scientific awareness.</td>
</tr>
</tbody>
</table>

Figure 24: Pie chart showing the average percentage of the frequencies of the six categories of CPAS workshop communications
The pie chart in Figure 24 was used to map the above three stages of constructivist learning (i.e. to examine, to inform and to scaffold) with respect to the areas of the corresponding categories of workshop communications. Such a diagrammatic representation has been attempted in Figure 25.

Figure 25: A map for short-term professional development modelled on constructivist principles.

By charting the workshop communications as shown in Figure 25 it is possible to discern that a major proportion (i.e. 62.38%, on average) of communications were devoted to inform the teachers’ scientific understandings, while a lesser amount of communications (i.e. 19.64%, on average) were used by the facilitators to examine the scientific awareness the teachers brought to the workshops. A lesser number of workshop communications (i.e. 17.98%, on average) were used to scaffold the teachers’ scientific awareness in the context of their daily experiences. It was mentioned that the communications which scaffolded the teachers’ awareness were meant to enable the teachers to construct further understandings.
about science. This meant that the teachers would be able to construct new knowledge structures by further advancing their newly developed scientific understandings. Hence, these communications were meant to leave the teachers’ new level of awareness open for possible future advancement. In order to represent this idea in Figure 25, that margin of the diagram is denoted with a dotted-line. It is intended that this diagrammatic representation would serve as a map for teacher professional developers when designing short-term science teacher professional development programs in future.

A science communication presence in science education reform

It was mentioned that recent reform efforts in science education, like the contemporary trends in science communication, have emphasised elements of engagement, as a precursor to understanding of science. An important feature of the former has been learning experiences that are grounded on student-centred inquiry and constructivist learning. It is maintained in the literature (see Loucks-Horsley et al., 1998) that such practices should be emulated in effective models of teacher professional development.

The findings from this study have shown that the above practices were present in the CPAS workshops. More importantly, it was revealed that science communication practices played an important role in facilitating inquiry-based constructivist learning in the workshops. The teachers’ experiences of the workshops indicated that they were engaged by the style of communication that was used by the facilitators. They mentioned specifically the interactive dialogues and stories which were used by the facilitators, and also their animated styles of communication. These practices are distinct from recommendations in science education and find, more accurately, their origin in science communication. They
resembled closely the recommendations made by Michael Faraday and Lawrence Bragg for communicating science to the general public (see Chapter 2). Moreover, it was confirmed by the facilitators that conscious efforts were made to incorporate science communication practices into the workshops’ delivery. Based on the investigations of the present study, six such science communication practices in the context of teacher professional development are listed below. They have been listed correspondingly with the three stages of constructivist learning that were exemplified in the CPAS workshop model (see Table 21).

Table 21: Science communication practices as exemplified in the CPAS workshop model

<table>
<thead>
<tr>
<th>Stages of constructivist learning</th>
<th>Science communication practices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage 1: to examine</td>
<td>(a) Non-threatening probing devices to become familiar with the teachers’ scientific awareness. For example, anonymous quizzes, references of alternative conceptions in the third person, advance the awareness that the same misconceptions are part of a wider body of scientific knowledge.</td>
</tr>
<tr>
<td>Stage 2: to inform</td>
<td>(b) Tactile and identifiable demonstrations that utilise simple and inexpensive equipment. For example: Experiences that are commonplace and equipment from teachers’ home environments. (c) Historic narratives that describe actual human involvement in scientific achievements. For example: History stories, autobiographies of scientists. (d) Rhetorical devices to punctuate oral delivery. For example: Visual imagery, metaphors, and empathy. (e) Theatrical devices augment oral delivery. For example: Intonation and body language.</td>
</tr>
<tr>
<td>Stage 3: to scaffold</td>
<td>(f) References and linkages to commonplace occurrences. For example: Events and objects from teachers’ daily life.</td>
</tr>
</tbody>
</table>
It is evident, therefore, that science communication practices can in fact serve to inform science education reform. Some aspects of this have been alluded to in recent studies (see, for example, Avraamidou & Osborne, 2009; Kapon et al., 2009). Practices of science communication that intentionally aim to engage the learner are consistent with the aims of education reform which foster continued interest with science. As this study has shown, the pedagogical processes which are meant to foster learners’ purposeful engagement with science were complemented by science communication practices. It may be concluded, therefore, that future science education reform interventions can be sustained with a science communication presence.

Challenges for science teachers from non-Western cultures

Data from the workshops for Sri Lankan and Indonesian science teachers confirmed findings in previous studies in the area of science education in cross-cultural contexts. The teachers’ reluctance to answer questions, for instance, has been explained as an unwillingness of non-Western learners to partake in competitive attempts of eliciting information which appeal to Western learners (see Johnson, 2007). The literature states, therefore, that non-Western learners need support before they feel prepared to cross such cultural borders (see, for example, Aikenhead, 1996).

However, the non-Western learners in the present study were unique in that they were not novices to Western science. Given the Sri Lankan and Indonesian teachers taught understandings based on Western science in their classrooms, it is hardly likely that they were challenged by Western scientific knowledge. Their view of science was, therefore, not the same as non-Western students who learn (Western) science for the first time. The
cultural borders these teachers encountered in the workshops were different from the ones which studies have found to affect non-Western students. Because of this distinction, it is believed that the cross-cultural perspectives in the present study have offered further insights into the area of science education in cross-cultural contexts.

The Sri Lankan teachers’ unwillingness to accept that textbooks could advance alternative conceptions, for example, did not indicate that they were challenged by the information in the textbooks. Instead, it showed that these teachers were not comfortable with the workshop’s efforts to inform them about the inaccuracies that existed in their familiar understandings about Western scientific knowledge. The fact that these teachers had high regard for their Western scientific knowledge (and its training) was highlighted when some of the teachers refused to accept that simple materials could be used as alternatives for conventional laboratory equipment.

Although this was a view by a minority of the teachers, it is believed, nevertheless, that it highlighted two characteristics of non-Western learners who are comfortable in their understandings of Western science. First that the teachers were not prepared to readily adopt alternatives to established practices in Western science, which offers them better socio-economic prospects (compared to others less educated in science). Second, the distinction the teachers, as students, had to create between their home cultures and the science classroom, obstructed simple materials in the former from entering the sophisticated world of the latter. This was especially highlighted by the Sri Lankan teacher who expressed amazement at the facilitator’s suggestion that science activities could be used to entertain guests at a party; i.e. “We never think that what we learn as science could relate to daily life, let alone using it to entertain a group of people… It may be that such a view exists in their culture.”
Hence, the findings from this study have highlighted elements of duality between the teachers’ home cultures and the comfort with which they had grown accustomed to Western science. It is believed, therefore, that these findings offer new insights to cross-cultural studies in the field of science teacher education.

**Recommendations for future research**

The following recommendations are made for future studies in science communication and science education, and the uncharted territory that lies between:

(a) This study investigated the possibility of one model of short-term professional development to be grounded on constructivist principles. In order to widen the scope of the findings made here, it would be ideal to investigate other models of short-term professional development.

(b) The present study was an exploratory account of one short-term professional development program. It did not compare that program to longer-term programs which promote similar aims. Comparative studies of two or more models of short and longer-term professional development are, therefore, desirable to address the dearth which presently surrounds the literature in this area.

(c) This study limited its investigations to the personal understandings teachers constructed during the workshops. It did not, purposefully, explore the teachers’ classroom practice post-workshop participation. In order to obtain a better appreciation of the understandings constructed by the teachers, it is recommended that a follow-up study should examine the
teachers’ subsequent classroom practices by way of reflective journals and written self-reports.

(d) The findings from this study indicated that science communication played a key role in science teacher professional development. This is, however, only one aspect of science education. Formal classroom instruction is another important area. It remains to be investigated how science communication practices can contribute to student engagement with science in the classroom.

(e) This study has highlighted the need for more research to establish the parallel trends in science communication and science education. While such studies would provide historic and developmental perspectives, they would serve to reiterate the complementary nature of those two disciplines. This would offer better insights for science communicators and science educators when informing each other’s efforts.

(f) This study has offered important insights into the area of cross-cultural science education, by identifying challenges that confront science teachers from non-Western backgrounds. It is necessary to investigate further the unique cross-cultural perspectives that govern these teachers’ classroom practices. This understanding would benefit cross-cultural science educators and researchers. More importantly, it would benefit non-Western nations which have embraced Western science. It will offer science and technology policymakers in those countries understandings with which to foster interest in Western science, without compromising the values and knowledge systems of their own cultures.
Epilogue

This thesis concludes that it is possible to model short-term professional development on constructivist principles. This study has shown, with reference to the CPAS workshops, that understandings about science can be advanced in ways that are personally meaningful to teachers, and that teachers emerge confident to confront the challenges of student-centred inquiry. More importantly, this study has shown that the inspiration the teachers received and the deep-understandings they developed were facilitated by science communication practices. This discovery resonates with the writings of Michael Faraday, which state that “the most prominent requisite to a lecturer…is a good delivery…the generality of mankind cannot accompany us one short hour unless the path is strewed with flowers”.

The flowers alluded to in the above quote, take the form of science communication practices in the present study. The science communication practices that were employed in the workshops enabled the teachers to develop understandings about science in ways that they found meaningful. Recollecting the metaphor used in the prologue to this thesis, it is, therefore, apparent that science communication is a versatile pitcher with which to serve up the Pierian Waters.

The role of science communication in facilitating deeper understandings that behoves ownership and confident engagement with science has been explored in this study in the context of science teacher professional development. Other audiences, such as school students and science teachers from non-Western cultures, still remain to be investigated in the arena of formal science education. More studies are needed to examine whether science communication can enable these groups to take similar deep droughts of the Pierian Springs.
References

A


F


G


**K**


L


N


O


U


V


W


Y


Z

Appendices
Appendix 1 : Pillar Roots of Knowledge
The Pillar-Roots of Knowledge

While attending a discussion recently I was intrigued by C.P. Snow’s two mutually exclusive cultures of scientists and literary intellectuals. John Brockman proposes yet another culture: the science communicators, whose responsibility is to bridge the gap between science and society. The following is an attempt to illustrate how I, as a science communicator, see these cultures today.

Personally I do not see many separate cultures, but a multiplicity of ideas, which I shall refer to as modes, after the French loanword for “particular forms, manners, or varieties in which some quality, phenomenon, or condition occur or are manifested”. Also distinguishing between literary and scientific knowledge, I believe to be a redundant exercise. Vidya derived from the Sanskrit root “vid” meaning knowledge, commonly refers to “science” in the East. The Celts who spoke a branch of the same Indo-European language family, called those who gathered knowledge (i.e. vid) from drus (i.e. oak trees), “Druids”. Today’s perception of science and literature is actually a misconception induced through western colonial ideology and is best referred collectively as knowledge.

I would like to compare knowledge to a profusely branched tree. Note however that knowledge is neither immutably absolute nor a relative construction of external objects. Neither is it an extraneous entity: it is part of society to the extent that society constitutes it. Nor is it static: it evolves and grows mutually with society. Like the many individuals that constitute society, our analogical tree bears an abundance of leaves. Each one unique yet linked by common vascula in the trunk, which in this case symbolises collective knowledge.

---

20 Essay submitted by Author and adjudged into the finalists of the New Scientist Essay Competition, 2005.
Interestingly the angle each of these leaves forms with the trunk, I believe, illustrates the many social viewpoints constituents of society maintain towards knowledge. Furthermore, a single leaf may have several different orientations towards the tree-trunk during its lifespan. Likewise individual perceptions of knowledge are not static. This interplay of perspective manifests as modes that are perceived as cultures that continue to change with society and knowledge.

I cannot however, rule out the possibility that modes may not collectively manifest a prominent culture. For example, our tree would exhibit dichotomous phototropism if it were exposed to two equal sources of illumination from opposite directions, as when perceived by Snow\(^1\). Such a collective endeavour is not static, but constantly changing. More than four decades have passed since Snow last saw this tree.

The increase in leaf population has resulted in a wider trunk, more proliferate branches and deeper roots. Likewise society and knowledge have changed mutually. Today’s knowledge-society is no longer dichotomous, but an assortment of multifarious branches. Branches of knowledge previously identified as being scientific have crossed over to realms that are recognised as being literary and vice versa. Cross-disciplinary hybrids of knowledge are emerging as well as those of an inter-disciplinary nature together with branches of knowledge that are intra-disciplinary. At such a stage of rapidity the emergence of prominent cultures are becoming more ephemeral. No longer are there two cultures or three but many diverse modes seeking an improved experience between knowledge and society.

There is however, a limit in canopy expansion that the trunk could tolerate. But trees have been known to produce pillar-roots. It is to these pillar-roots that I assign a newly emerging mode, one necessitated due to the rapid changes in knowledge and society: science communication.

Science communication should not be categorised as a different entity. Like pillar-roots support a canopy, its role is to facilitate interaction between society and knowledge. Despite the resemblance of pillar-roots to the trunk, science communication should not be confused with knowledge. It possess a singular relationship with knowledge and society, like the unequal perspective of the trunk and unique association with the canopy enjoyed by
pillar-roots. The challenge lies however, in its strategic application, like propping pillar-roots in areas with the greatest potential to withstand change.

Change, like the present evolutionary phenomenon besetting us, is inevitable and must be directed towards an improved experience of knowledge, if science communication is to prove effective. No longer is our source of illumination from the West as prominent as it once was. Our tree is gradually spreading its branches in other directions.

Illustration showing a banyan tree with pillar roots (© www.gutengerb.org)
Appendix 2 : Observation Report of Creative Science Teaching Using Simple Materials Workshop, St. Patrick’s Primary School, Cessnock (NSW)

Introduction

Logistics

Logistical Issues

Workshop Content: Science

Hands-On Activities

Workshop Content: Pedagogy

Misconceptions & Teaching Issues

Workshop Communications

Elements of Workshop Communications:

(a) Historic Information

(b) Challenges of Finding Relevance

(c) Terminology

(d) Effective Presentation

(e) Participant Contribution

(f) The Human Element

Workshop Evaluation

Conclusion
Introduction:

The Creative Science Teaching Using Simple Materials workshop for teachers at St. Patrick’s Primary School Cessnock (NSW), was observed as an example of the one-day workshops conducted by the Centre for the Public Awareness of Science (CPAS) of The Australian National University (ACT). The observations that are documented here will be used as a prototype study for my thesis, which focuses on the perspective of communicating content knowledge and pedagogical skills to secondary science teachers through in-service education.

Logistics:

Date - Monday, 21 June 2004
Duration - 9.00 am – 3.30 pm
Venue - St. Patrick’s Primary School Hall Cessnock (NSW)
Participants - Twenty (20)

The workshop was presented/facilitated by Prof. Mike Gore (MG) and Dr. Susan Stocklmayer (SS) from the Centre for the Public Awareness of Science.

The presenters arrived at the venue one hour in advance of the scheduled time to organise and prepare the room and props. The workshop commenced on schedule after a brief introduction by the school’s Principal. Almost all participants arrived on time. Late-comers, including the last arrival at 9.40 am were received at the door and briefed by the Principal.

The participants ranged from different levels of teaching experience. While some were novices others were senior science teachers.

The workshop was conducted in the School Hall and the layout of the room has been illustrated in the figure below.
Figure: Layout of School Hall for CPAS workshop

1 – Projector screen

2 – Whiteboard

3 – Audio-visual equipment

4 – Participants’ tables

5 – Catering area with sink

6 – Extra props and material

7 – Main entrance to seminar room

X – Observer’s posts
Five to seven teachers were seated around each table and the order of seating reflected their levels of confidence and an invisible “hierarchy” of teaching experience. Senior teachers were noted to occupy tables at the front of the room, with seats facing the main entrance. However, no gender effect was observed in seat selection, although it was noticed that “younger” teachers opted for seats at the back of the room, despite the fact that some seats remained vacant at the front of the room. The table nearest to the catering area and sink were observed to be the most favourite and teachers at that table were observed to be more casual in their attitude.

Logistical Issues:

Most of the workshop logistics were beneficial both to the participants and presenters. The catering area at the end of the room provided the participants with refreshments upon their arrival and in doing so helped create an informal and relaxed atmosphere, which allowed them to get to know one another before the commencement of the workshop. The facilities (ie. sink and garbage bin) in the catering area provided the presenters with a ready source of water and means of waste disposal.

The extra props and material needed for the workshop were strategically placed at the end of the room and thus provided the need for the presenters to walk to and fro. This enabled them to mix and interact with the participants in a non-invasive manner, fostering an adult-friendly learning environment.

However, the room where the workshop was conducted seemed inadequate and crowded with respect to the number of participants and limited the movement of the presenters among them. Although three tables were provided, the space between the tables was observed to be inadequate and restricted the presenters’ movement. It even lead for the accident with the barometer falling off the table.

The presenters encountered constraints in time during the second half of the workshop. SS was compelled to take the participants rapidly through her lesson plan and was remarked of the same in the participant evaluation forms. The fact that the lesson plan was given to the participants in print to follow through, helped the participants and presenter to communicate at an accelerated speed.
Workshop Content: Science

They explored topics in physics using simple, inexpensive materials that are easy to introduce to a teaching environment; discuss techniques for teaching complex concepts with the aid of current ideas from educational research; and provide a variety of hands-on activities and techniques that aren’t available in textbooks.

The workshops commenced with MG’s show: Sink or Swim – Archimedes, which consisted of demonstrations and complementary explanations on the properties of fluids, atmospheric pressure and buoyancy. The demonstrations incorporated simple, easy to use, inexpensively items, which could be readily obtained from the learners’ own environment (for example, PET bottles, syringes, etc.). The presenters provided further information on alternate materials and more region specific substances (for example, products used in vineyards), that the teachers could adopt in their teaching.

The other physical science topics covered in the workshops included optics, symmetry, forces and sound. It was highlighted that similar activities and strategies could be used by the teachers.

The participants were also quizzed on their beliefs and conceptions on forces and energy, which were later used by the presenters to address alternate-conceptions. A complete set of handouts illustrating the activities presented during the workshops was given to each participant at the end of the day.

Hands-On Activities

Although the participants were observed to enjoy the detailed discussions during the earlier part of the day, many gradually seemed to require hands-on activities to experiment with, around the middle of the first session, as it was noted that some of the teachers were gradually assuming defensive body postures.

It was interesting to note the participants’ reaction to the imaginary exercises of pushing various sized balls under water, and many even physically animated the activity, which may imply the need for a more hands-on approach at this stage. Since it is cumbersome and also redundant to have props of the above demonstration at each individual table, it may be therefore suggested, that at this stage of the workshop, one of the presenters dramatically
introduce a large beach ball (preferably brightly coloured and initially concealed) from the back of the room to the audience, as a means to ensure participant involvement and offer some form of tangible activity till sufficient content is established for more substantial individual/group experimentation later in the workshop.

Workshop Content: Pedagogy

The presenters spoke about Constructivist Learning Theory, where new knowledge is scaffolded upon the learners’ existing understanding while providing room for future awareness, as a means of teaching science.

Conceptual Change Theory was also discussed in terms of building on existing scientific knowledge, use of intelligible words and plausible ideas. Teachers were asked to practice the use of reflective thinking and concept-maps, wherein they were shown how individuals conceptualise and relate to existing knowledge differently. They were encouraged to use similar metacognitive approaches when dealing with epistemology in the classroom.

Teachers were however, cautioned in developing ideas into successive models and analogies that might give rise to misconceptions. They were asked to examine whether their teaching was intended to generate content or promote understanding. This was demonstrated with the help of the video footage of a study on graduating students’ beliefs on seasonal change, at Harvard University. Participants were advised to re-examine such teaching-models through a process of diligent feedback, to ensure that no “counter-intuitive-ideas”, as one teacher phrased it, had been generated in the process. The presenters also took this opportunity to reinforce the need to critically examine experiments prescribed in textbooks, since many, as demonstrated later, don’t produce the expected results and learning outcomes, (viz, the lemon battery and candle/water trough experiment) as well as ingrain substantial misconceptions.

Drawing of a concept maps also served to reinforce the idea that individuals think differently and that teachers like all individuals would construct their own knowledge differently to one another. It also showed them that innovation in science teaching is only possible if they acknowledge this difference. Furthermore the participants were exposed to the fact that their learners also have unique mind-maps and the challenge in teaching science is to find relevance and place for the new concepts taught in the classroom, in each
individual students’ epistemological framework, in order to make science learning and teaching effective.

SS also spoke about the Nuffield Theory and explained that scientific knowledge is constructed over years of time and thus spontaneous enlightenment is not feasible. The teachers were advised to teach for understanding and not content.

Misconceptions & Teaching Issues

The presenters constantly drew the participants’ attention to alleviating misconceptions in the classroom (viz. pressure is not a force). However, a sensitive stage of the workshop was reached after the viewing of the video footage at Harvard University, when SS began addressing misconceptions generated in the classroom and teaching issues that served to aggravate the situation. It was observed that communication was difficult during this session and many teachers were noted to assume defensive postures. The participants were noted to remark that many of the difficulties they encountered in dislodging alternate conceptions, was a result of deficiencies in primary science teaching. Teachers also complained that they had little opportunity to rectify misconceptions as these were deeply ingrained during primary science teaching and that redressing fundamental science topics resulted in diminished student interest in the science classroom.

As a result the presenters were posed with the challenge of maintaining an adult-friendly environment that would be conducive of science learning and teaching. MG informed the teachers about similarities in primary and secondary science teaching and SS informed the teachers about studies in diminishing interest in science enrolments at secondary level and that the human factor in science education is needed to maintain interest. The presenters also reiterating that the science teacher is an integral part in the students’ learning of science. The presenters also took the opportunity to digress from mainstream issues in science teaching towards related areas of scientific conflict. This strategy of communication was effective both as a means of continuing the teachers’ interest in the day’s proceedings as well as making them aware of similar confronting issues that existed elsewhere. However, it must be remarked that communicating information such as misconceptions, that confront teachers’ beliefs is a very challenging task for science teacher educators.
Workshop Communications

It was noted that the communication strategy employed in the workshops was received positively by the teachers, as they were regarded as peers by the presenter in discussing education reform. The teachers were made to feel and understand that they were part of the process of education policy (viz. Teachers are an important factor in students’ science learning) and not mere passive “implementers” in a process of change they had not control over. As a result the participants were made to feel confident in their role as science teachers.

The presenters attempted to maintain a relaxed and adult-friendly atmosphere during the proceedings of the workshop and used humour from the very onset, to create an informal learning environment.

The presenters’ also maintained an informal level of communication between themselves both as a means of drawing familiarity from participants as well as a strategy for mutual-critiquing. The informal manner in which they communicated their individual opinion about one another’s demonstrations gave the participants a sense that nothing could be flawless and that science teaching should be enjoyable and not devoid of the human element.

Since as many as five to seven teachers occupied one table, individual contribution during group work was questionable, although it provided an opportunity for some teachers to explicitly communicate their ideas and views as requested in some activities (viz. the number of paper clips required to overflow the small plastic bottle of blue coloured water and the number of coins needed to sink the patty cup). It also provided me as an observer the chance to perceive the varying degrees of efficacy among the participants. It was observed that one of the younger female teachers was confident in her views in solving some of the challenges posed by the presenters and effectively communicated her ideas to the rest of her group, while her fellow female companion continued to express assent non-verbally. It was also observed that a senior female teacher who was seated at the back of the room seemed to be slightly efficacious in her manner of presenting her ideas to her fellow male teachers at their table.
Elements of Workshop Communications:

(a) Historic Information

The participants were presented with detailed historic accounts during the introduction of topics, and Archimedes and his discovery of the law of fluid displacement was narrated at the beginning of the workshop. Some participants were observed to be indifferent to the information been communicated and continued to maintain defensive body language. This may have been due to the change of atmosphere, which resulted after the introductory speech, as mentioned above, or due to some of the participants’ apathy, as they did not see the relevance of such historic information.

(b) Challenges of Finding Relevance

During demonstrations on fluid pressure, reference was made to “soft-brakes”, which was used to explain the difference in properties of compression in gases and liquids. The participants were observed to be unfamiliar with the term, as many of the participants wore expressions of confusion, although the phenomenon may have been a commonplace experience to many of the teachers who travelled by car. Thus they were noted to be slightly ambivalent in comprehending the facts and the information did not produced the desired effect anticipated by the communication. As a result the presenter was noted to further expound the phenomenon. Such a situation may arise not due to lack of prior knowledge or relevance, but due to lack of intelligibility of terminology.

(c) Terminology

The presenters were very selective about the terminology and scientific jargon they permitted themselves during the workshop, as was noted in reference to the Conceptual Change Theory. Great effort was taken to adhere to words that were intelligible to the participants. For instance the presenters made light the use of the term sublimation, such that it reinforced in the participants the need for more detail to the concept been introduced than to the proper scientific terminology to describe it by. Furthermore, the presenters were
cautious when using scientific formulae to explain their demonstrations and Mike Gore was noted to remark that he shouldn’t be doing it.

(d) Effective Presentation

The presenters were observed to go to great lengths in making the demonstrations as attractive and appealing to the participants, as possible. The use of colour was evident in all the props and overhead-slides. They were also noted to employ many theatrical devices as well: mouthing words without sound to demonstrate the relationship between pressure and sound waves. The presenters also allowed for “wait-time” during most demonstrations, such as a dramatic and functional pause during the narration of the Archimedean account allowed introduction of related topics. The story of Archimedes was resumed later and allowed to cascade into a medley of demonstrations and descriptions, related to pressure.

The element of theatre was strategically poised throughout the workshop with dramatic demonstrations to maintain audience attention (viz, the wooden ruler and sheet of newspaper, exploding cylinders) and pose gamesome challenges (viz. balancing experiment). It should be noted that the workshops possessed an element of entertainment and it is debatable whether its purpose was to entertain or educate. However, all demonstrations were strongly linked with relevant content knowledge and used captivating pedagogy to personalise the learning experience. Therefore, it is unquestionable that the workshop didn’t provided the participants with a reproducible bag of tricks but an awareness of their own scientific knowledge and a perspective of how the same could be used to effectively communicate, with similar significance, to the learners in their classrooms.

The fact that the demonstrations were both entertaining and that the teachers were provided with adequate content knowledge to re-introduce the same, befitting the classroom and teaching context, served as a catalyst for communication as was seen during MG’s analogy of the rule of thumb (i.e. The surface area equal to that of an average thumbnail measures approximately one square centimetre upon which is exerted one kilogram of atmospheric pressure). To further illustrate the point he asked the participants how much pressure they thought was exerted by the atmosphere on a table and said that similar activities could be re-produced by obtaining dimensions of objects in the teachers’ own classrooms, and
thereby generate awareness of physical concepts among their students, while giving them the opportunity to experience science in a more hands-on manner.

(e) Participant Contribution

As mentioned earlier the participants were very responsive and as a result were eager to contribute information. It was noted during the demonstration of varying degree of density of in different fluids that one of the teachers proposed the development of a graduated system to demonstrate and teach density through the concept of buoyancy. It was interesting to observe the communication pattern that followed: the teachers proposed various devices by which to demonstrate the above, the presenters refined these ideas through discussion with the other participants. This was a remarkable observation and is extemporary of Constructivism in a teacher-training environment, where existing knowledge is identified and built upon, allowing for further development in the learners’ (ie. teachers’) own environment (ie. the classroom). It is also a noteworthy mechanism, which may be employed to communicate feedback during in-service education as well as a model for schoolteacher-university academic collaborative lesson planning.

(f) The Human Element

The presenters reiterated the need of the human-factor in teaching science for relevance. In accordance the communication strategies throughout the workshop focussed on issues faced by teachers when teaching science and finding solutions to these problems by relating to them in a sociological context.

The idea that to err is human was also inculcated in the teachers and they were reminded that not only was it unnecessary but also impossible to be absolutely informed about science and that teaching is a learning experience as well. The participants were showed by example that errors would always occur and the presenters drew attention to various shortcomings during the workshop proceedings from mundane tasks like the lack of page numbers in the sample teaching material that was handed out, to why certain demonstrations did not happen as they should. Teachers were also advised to be sceptical about experiments laid out in textbooks and the presenters humoured them with anecdotes about similar experiments that did not produce desired results.
The above communication style was observed with great interest as it incited confidence in the teachers as professionals, which was acknowledged in the Vote of Thanks. The presenters were also very subtle in showing the participants “wrong science” and telling them how not to do it while yet maintaining a receptive, learning atmosphere.

Workshop Evaluation

The participants were requested to complete an evaluation form wherein there were expected to express their views and comments on the positive and negative aspects of the workshops as well as to make recommendations for future in-service training. These forms were collected by the presenters and complied into a report, which is sent back to the workshop organisers.

The presenters showed great interest in the evaluation forms both as a means of understanding the participants’ opinion of the workshop proceedings and as a tool for critiquing their (i.e. presenters’) style of communication. It must be mentioned that after each workshop the presenters spent a great deal of effort analysing the evaluation forms and critiquing each other.

Conclusion

The *Creative Science Teaching Using Simple Materials* workshop, conducted in Cessnock, which was observed and documented above, portrayed a variety of communication strategies: among participants, between the presenters and especially that which occurred between these two groups. Throughout the presentations the style of communication was informative yet informal and very especially adult friendly. Each participant was acknowledged to possess a unique metacognitive framework and encouraged to perceive the same with their students in order to teach science befitting a Constructivist learning environment.

The strategies of communication also reflected the need to recognise teachers as professionals who should be confident in their role and that curricula need not be adhered to in a “teacher-proof” manner but rather adapted and modified to be relevant to the
learners’ own environment. It was interesting to note the significance the teachers attached to the lesson plan as they found it relevant to their needs in teaching.

The relevance of the workshops from the point of view of the presenters was concentrated on participant feedback in the form of the evaluation responses. The presenters paid considerable attention to the participants’ comments as well as peer evaluation of each other. The latter style of constructive criticism is essential among teacher educators and one that the CPAS workshop presenters excel in.

Acknowledgment

My sincere thanks to Dr. Sue Stocklmayer, Prof. Mike Gore and the teachers at St Patrick’s Primary Cessnock for a wonderful learning experience, in all respects.
Appendix 3 : Copy of the application form submitted to the Human Research Ethics Committee (ANU) and samples of consent forms

THE AUSTRALIAN NATIONAL UNIVERSITY
HUMAN RESEARCH ETHICS COMMITTEE
APPLICATION FORM

Surname of Researcher: Perera
First name/s: Pettikirige Sean Francis
Title (e.g. Ms., Mr., Dr. etc.): Mr.

Position Held (staff, postgraduate, undergraduate, etc.): Postgraduate

Student or Staff ID no. (if applicable): u2537013

Dept/School/Centre: Centre for the Public Awareness of Science (CPAS)

Mailing address: CPAS, Bld # 38A, The Australian National University, Acton, ACT 0200

Telephone: (02) 6125 1073
Fax: (02) 6125 8991
Email: Sean.Perera@anu.edu.au

For students:
Name of ANU supervisor: Prof. Susan Stocklmayer
Email address of ANU supervisor: sue.stocklmayer@anu.edu.au

PROJECT TITLE: Treading the familiar: Investigating relevance as the basis for science communication25

Date of this application: 29/03/05
Anticipated start date for project: 05/04/04 (Date of commencement of PhD)
Anticipated end date: 05/04/07

25 This title was initially decided to describe this research thesis, but later changed to the one currently used on the cover of this document.
1. The researcher/s

Who are the investigators (including assistants) who will conduct the research and what are their qualification and experience? Please include their Department/School/Centre (or external institution for external researchers). Students should not include supervisors at this point unless they are actually participating in the research project as partner researchers.

Pettikirige Sean Francis Perera
PhD Candidate, Centre for the Public Awareness of Science, The Australian National University
Master of Science, University of Peradeniya, Sri Lanka (2001)
Bachelor of Science (First Class), Bangalore University, India (1999)

2. Understanding the national guidelines, the “National Statement on Ethical Conduct in Research Involving Humans” (1999)

Can the proposer certify that the persons listed in the answer to Question 1 above have been fully briefed on appropriate procedures and in particular that they have read and are familiar with the national guidelines issued by the National Health and Medical Research Council (the National Statement on Ethical Conduct in Research Involving Humans) (cited below as the “National Statement”)? If there are guidelines from any relevant professional body with which the researcher/s are familiar they should also be listed below.

I have read and fully understood the National Statement on Ethical Conduct in Research Involving Humans (1999). I also wish to mention that neither does my study involve individuals listed in sections 4 through 9 nor does it propose to employ techniques mentioned in sections 10 through 17. It is also not envisaged that the study would result in intellectual property at this stage. The participants will only be interviewed about their professional work (ie. science teaching) and no topics of personal nature will be entertained. However, with regard to Privacy of Information mentioned in Section 18, the participants will be informed and their consent obtained, before the interview (refer Section 3: Design pp 3-5 of this application).

3. Purpose and design of the proposed research

Purpose

(a) Briefly describe the basic purposes of the research proposed (in plain language intelligible to a non-specialist).

It is proposed to study the science communication perspective of the Science Teacher Professional Development Workshops conducted by the Centre for the Public Awareness on Science (CPAS), Australian National University.

The study hopes to investigate the effectiveness of the communication strategies employed by Workshop presenters to bring about conceptual change in the participants’ (ie. teachers’) awareness of science.
The aim of the study is to understand the significance of individual relevance when communicating and receiving scientific information as a tool to teach science conforming to the Constructivist Theory (ie. the construction of new knowledge that occurs when people are exposed to new information).

Design

(b) Outline the design of the project (in plain language intelligible to a non-specialist). (If interviewing people or administering a survey/questionnaire, please attach either a list of the broad questions you propose to ask, or a copy of the questionnaire.)

The data for the study will be obtained from the three following sources:
1. Observations made during the CPAS Science Teacher Workshops
2. Interviews with teachers who participated in the Workshops
3. Interviews with presenters from CPAS who conducted the Workshops

1.0 Observations made during the CPAS Science Teacher Workshops

1.0.1 Detailed observations of both the presenters (refer 1.1.2) and the participants (refer 1.1.3) will be made during the Workshops based on recommended practices in literature adapted to suit science teacher education (Acheson & Gall, 199226 Gall, Borg & Gall, 199627; & Ball, 199728).

1.0.2 A pre-conference will be held with the presenters prior to the observation of the Workshops to discuss the science communication strategies they wish to employ and determine which areas and aspects of the Workshop they believe will be the most effective in communicating science (refer 1.1.2). Later in a post-conference, their opinions and views about the preceding Workshop will be obtained in consultation and reference to the Workshop Evaluation Forms (Annex IX) that will have been completed by the participants (refer 1.1.1).

1.1 Ethical considerations at this stage:

1.1.1 Permission to observe and study the CPAS Science Teacher Workshops, as described above as well as consent to access participant feedback provided in the Workshop Evaluation Forms has been obtained from the Director, CPAS (Refer Comment On Project From Head Of ANU Department Group/Centre pp 12).

1.1.2 Workshop presenters will be asked to express their consent to be observed and their communications recorded, by endorsing a letter of consent (Annexes I & II). They will also be asked for permission to be photographed during workshop presentations.

1.1.3 Workshop organisers will be informed through the Director, CPAS, of my intention to study the Workshops (Refer *Comment On Project From Head Of ANU Department Group/Centre* pp 12). However, it will be stressed that my observations and subsequent recordings will not bear on any of the participants’ identities and that the study will be exclusively devoted to the science communication strategies employed at the Workshops. The Workshop organisers will also be informed that it is intended to contact the participants subsequently and that their (ie, participants’) consent and contact details (Annex III) I will be obtained during the Workshops.

2.0 Interviews with teachers who participated in the Workshops

2.0.1 Teachers who express their interest to participate in the study (refer 1.1.3) will be sent an introductory letter (Annex IV) and a survey questionnaire (Draft, Annex V) comprising of two sections, approximately six months after their participation at the Workshop (refer 2.1.1).

Section 1 of the Questionnaire - A semi-structured questionnaire to obtain background demographic information that will be used to understand and illuminate the information that will be provided in Section 2 of the Questionnaire.

Section 2 of the Questionnaire - An open-ended questionnaire to gather conceptions of science and opinions about how science should be communicated within a Constructivist teaching/learning environment, that will be used to substantiate the information obtained in Section 1 of the Questionnaire.

2.0.2 A non-probability sample of up to 25 survey respondents will be subsequently contacted by telephone for a semi-structured, personal interview (refer 2.1.2). The initial questions will be based on the respondents’ conceptions of science and knowledge construction expressed in their survey responses (refer 2.0.1). Subsequent questions will probe the interviewees’ beliefs concerning science learning and teaching; and will differ for each interviewee depending upon their responses. A list of sample questions that will be asked is provided below:

(a) How would you describe science?
(b) Is science about knowing facts, laws or theories?
(c) How do you describe your science teaching?
(d) What are your strengths as a science teacher?
(e) What are the challenges you face in the position?
(f) What are your greatest frustrations in teaching science?
(g) How did you envisage the Workshop would help you to teach science?
(h) Did you find the Workshop features helpful?
(i) What were the most memorable and beneficial aspects of the Workshop?
(j) Did the Workshop change your attitudes/beliefs about teaching science?
(k) Why do you think the Workshop changed your conception about science teaching?
(l) How did the CPAS Workshops contribute to your science teaching?
(m) What features of the Workshop would you like to change?

2.0.3 Each telephone interview will last for approximately one hour. It will be recorded, transcribed verbatim and coded for contextualization (referring to real life examples), linking ideas to past experiences and POE (Prediction, Observation & Explanation) strategies.
2.1 Ethical considerations at this stage:

2.1.1 Participants will be informed of the intention to be contacted subsequently (refer 1.1.3) and their permission will be sort to do so (Annex III), wherein they will be requested to provide their contact details. They will also be informed that by returning the surveys, they consent to the information therein to be used as data for this study.

2.1.2 Participants for telephone interviews will be selected from among the teachers who respond to the survey and endorsed their consent (Annex VI) to be contacted by telephone. Their availability of time and compatibility to be interviewed for approximately an hour will also be asked for. They will be informed that the telephone interviews will be recorded and later transcribed verbatim and that all communication will be treated on a strictly confidential basis. Interview transcripts and audiocassettes proceeding from the interviews will be secured in a locked office. They will also be informed that they will be given the opportunity to retract any of the statements they will have made, prior to publication of the thesis and if they wish to have their names and job descriptions included as well (Annex VIII). If not all communication will be dealt with anonymously. A letter (Annex VII) confirming the date and time of the interview as well as the initial questions the interview will be based on (refer 2.0.2) will in turn be sent to the selected respondents. Interviewees will be notified if there is to be any change in the schedule, although such an eventuality is presently not envisaged (refer Annex X).

3.0 Interviews with presenters from CPAS who conducted the Workshops

3.0.1 Workshop presenters29 from the Centre for the Public Awareness of Science (CPAS) will be personally interviewed with a set of open-ended questions. They will be asked to describe the communication strategies they employ in the Workshops and explain why they believe these strategies to be effective in science learning/teaching (refer 3.1.1). Sample questions that will be asked to initiate the interviews are listed below:

(a) What are the challenges science teachers face in their position?
(b) How do the workshops contribute to the attitudes about teaching science?
(c) What aspects of the Workshop influence in participants’ attitudes in teaching science?

1. How would the CPAS Workshops compare with other science teacher workshops (the presenters have experience with)?

Additional questions will be posed to the presenters as appropriate in order to draw from their personal experiences in science communication, to substantiate their claims about the effectiveness of the Workshops.

3.0.2 The interviews will be recorded, transcribed verbatim and coded (refer 3.1.1). As in the case of interviews with teachers who participated in the Workshops, the coded interview transcripts will be analysed for emergent themes. Possible warrants (ie. themes in the data that give rise to conclusions) will be highlighted and the data will be analysed on Grounded Theory (ie. seek to generate a theory based on the data in which the theory is grounded).

29 Prof. Susan Stocklmayer AM (Director, CPAS), Prof. Micheal Gore AM (Professor Adjunct, ANU & Founder Director Questacon) & Prof. Christopher Bryant (Professor Emeritus & Former Dean of the Faculty of Science, ANU) have all agreed to be part of this study.
3.1 Ethical considerations at this stage:

3.1.1 Workshop presenters will be asked to express their consent to be (Annexes I & II). Their availability of time and place to be interviewed will also be asked for. They will be informed that the interviews will be recorded and later transcribed verbatim and that all communication will be treated on a strictly confidential basis. Interview transcripts and audiocassettes proceeding from the interviews will be secured in a locked office. They will also be informed that they will be given the opportunity to retract any of the statements they will have made, prior to publication of the thesis and if they wish to have their names and job descriptions included as well. If not all communication will be dealt with anonymously.

Sources of data involving humans
To ensure compliance with privacy legislation the committee needs to know your sources of information, i.e. where you are obtaining data involving humans. If you are using individual participants, tick at (a). If you are accessing personal records held by government departments or agencies, or by other bodies, e.g. private sector organisations, please tick and complete the relevant sections (b), (c) and/or (d) below.

(a) Individual subjects

(b) Commonwealth Department/s or agency (specify)* (✓)

(c) State/Territory Department/s or agency (specify)*

(d) Other sources (specify)

*Please include an estimate of how many records you expect to access:_________________________

5. Personal identifiable data for medical/health research
Are you obtaining personal identifiable data specifically for medical/health research that is held by a government or private sector agency? (The committee needs this information to determine whether it needs to comply with relevant National Health and Medical Research Council guidelines relating to privacy legislation.) NO

6. Recruitment
Describe how participants will be recruited for this project. Indicate how many participants are likely to be involved, how initial contact will be made, and how participants will be invited to take part in this project. A copy of any relevant correspondence should be attached to this application. Does the recruitment process raise any privacy issues, e.g. does the researcher plan to access personal information to identify potential participants without their knowledge or consent? Describe the steps to be taken to ensure that participation or refusal to participate will not impair any existing relationship between participants and researcher or institution involved.
The study hopes to survey consenting CPAS Science Teacher Workshop participants and subsequently interview up to 25 of them by telephone. A detailed account of how the participants will be recruited and ethical considerations made at each stage have been provided in detail in Section 3: Design (pp 3-5) of this application. Templates of all intended correspondence have also been annexed (refer Annexes I through IV & VII through VIII).

The participants for both questionnaire surveys and interviews will only be approached with their prior consent. It is not intended to obtain the participants’ personal information, which will identify them without their prior knowledge. It is only proposed to study the effectiveness of the communication strategies employed in the Workshops and this information too will only be accessed with the participants’ endorsed consent to do so.

The Workshops focus on the professional development of science teachers, working in various schools across Australia and whatever correspondence the teachers wish to entertain with CPAS post-Workshop is also of a strictly professional nature. If a Workshop participant does not wish to consent to participate in the study there is no envisaged impairment of his/her relationship with the researcher (myself). Furthermore the request for participants’ consent to be surveyed and interviewed (refer 1.1.3 of section 3: Annexes III & VI) will be treated with strict confidentiality. Hence it will be ensured that any relationship he/she wishes to foster with CPAS will not be impaired.

7. *Arrangements for access to identifiable data held by another party*

   In cases where participants are identified from information held by another party (e.g. government department, non-governmental organisation, private company, community association, doctor, hospital) describe the arrangement whereby you will gain access to this information. Attach any relevant correspondence.

The study does not intend to access CPAS Science Teacher Workshop participants’ information held by another party. The Workshop Evaluation Forms (Annex IX) that will have been completed anonymously by the participants and are the property of CPAS-ANU will only be accessed with written consent from the Director, CPAS (Refer Comment On Project From Head Of ANU Department Group/Centre pp 12).

8. *Vulnerable participants*

   Will participants include students, children, the mentally ill or others in a dependent relationship? If so, provide details.

The study will only include adult, professionals working in the capacity of science teachers and science teacher educators and does not envisage the participation of any of the above listed categories of individuals.

9. *Payment*

   Will payment be made to any participants? If so, give details of arrangements.
Only self-consenting, voluntary participants will be included in the study and payment of any from is not intended.

10. Consent
Describe the consent issues involved in this proposal (see the National Statement, in particular Section 1.7-12, and other sections relevant to your research). Describe the procedures to be followed in obtaining the informed consent of participants and/or of others responsible. Attach any relevant documents such as a consent form, information sheet, letter of invitation etc. If you do not propose to obtain written consent (e.g. if working with non-literate people) give a detailed explanation of the reasons for seeking oral consent, describe the procedure you intend to adopt, and specify the information to be provided to participants. If you have answered YES to Question 8 above please address any issues of consent and the possibility of coercion.

The CPAS Science Teacher Workshop participants who will be involved in the study will only be approached with their prior consent. A detailed account of how their consent will be sort prior to recruitment and ethical considerations made at each stage have been provided in detail in Section 3: Design (pp 3-5) of this application. Since the study will include a literate adult community of science teachers and science teacher educators, consent will be obtained in writing and not otherwise. Templates of all relevant correspondence that is intended have also been annexed (refer Annexes I through IV & VI through VIII).

11. Protection of privacy (confidentiality)
Describe the confidentiality issues involving in this proposal. Give details of the measures that will be adopted to protect confidential information about participants, both in handling and storing raw research data and in any publications. Blanket guarantees of confidentiality are not helpful. If the term “confidential” is used in information provided to participants, a full description of what precisely confidentiality means in the context of this research should be given. You should be aware that, under Australian law, any data you collect can potentially be subpoenaed. Depending on the nature of your research, it may be helpful to qualify promises of confidentiality with terms such as “as far as possible” or “as far as the law allows”. [See the National Statement, in particular Sections 1.19, 18 and Appendix II]

Questionnaires from survey respondents and audiocassettes and transcripts from interviews will be secured in a locked office. The participants will be informed that they will have the opportunity to retract any of their statements made during the interviews, prior to publication of the thesis. They will also be asked if they and wish to have their names and job descriptions included in the thesis and as if not all communication will be dealt anonymously to ensure confidentiality (refer 2.1.2 & 3.1.1 of Section 3 of this application) of the participants’ identity and the information they provided.

12. Cultural or social considerations
Comment on any cultural or social considerations that may affect the design of the research. [See the National Statement, in particular Sections 1.2 and 1.19].
The study will investigate the effectiveness of the communication strategies employed by the CPAS Workshops for Science Teachers and in doing so aims to understand how the aforementioned strategies would serve to bring about conceptual change in the participants’ own personal awareness of science by attempting to understand the significance of individual relevance when communicating and receiving scientific information.

The study will only be related to the participants’ professional knowledge of teaching/learning science and will not affect them culturally or socially. Nevertheless, the study will respect the participants’ own beliefs and perceptions of science.

13. How the research might impact on participants
Describe and discuss any possible impact of the proposed research on the participants or their communities that you can foresee. This might include psychological, health, social, economic or political changes or ramifications.
Discuss how you will try to minimise any impact. [See the National Statement, in particular Sections 1.3 to 1.6 and Section 1.14]

As mentioned earlier, the study will investigate the participants’ professional knowledge of teaching/learning science in order to better understand how the communication strategies employed by the CPAS Workshops for Science Teachers use individual relevance to bring about conceptual change for better science awareness.

The study will neither pose any risk nor harm to the participants nor will it disrespect their dignity and wellbeing. Furthermore, investigations in this study are based on sound practices successfully employed and documented in literature (Acheson & Gall, 1992; Gall, Borg & Gall, 1996; & Ball, 1997). The study will in no circumstance place the participants in discomfiture.

14. Other ethical and any legal considerations
Comment on any other ethical considerations that are involved in this proposal, including any potential for legal difficulties to arise for participants.

There will be no potential for legal difficulties for any of the participants involved in this study.

15. Benefits versus risks
Describe the possible benefit/s to be gained from the proposed research. Explain why these benefits outweigh or justify any possible discomforts and risks to participants. In framing your explanation make explicit reference to the ethical considerations mentioned in your answers to previous questions on this form. [See the National Statement, in particular Sections 1.3-6 and 1.13-14]

As explained in Sections 12 & 13 (pp 8) of this application, the study will neither place the participants in discomfiture in terms of their dignity and wellbeing nor will it affect them culturally or socially. It should be mentioned that the benefits hoped to be derived from this study will be of great value in understanding the significance of individual relevance when communicating and receiving scientific information within the context of a Constructivist environment.

16. **Handling possible problems arising from the research**

*Describe the arrangements you have made to handle concerns and complaints by participants, or emergencies involving participants or researchers.*

Participants will only be interviewed on their professional knowledge of teaching/learning science and not about topics of personal nature. Consent will be sort from the participants prior to engaging them in the study. Logistics as to where and when it is most suitable to be interviewed will be confirmed in advance and participants will be informed if there is to be any change (refer Section 2.1.2 pp 5). Thus it is not anticipated that any difficulties or emergencies should arise during the interviews, either to the participants or to the researcher. However, if the interviewees should become in any way distressed or anxious, which is very unlikely, the interview will be immediately terminated.

17. **RESEARCH PROTOCOL CHECKLIST**

There are some key ethical principles that need to be addressed in your protocol (as an ethics application is known). In particular the committee needs to see how you have addressed the issue of informed consent and the issue of confidentiality, i.e. how the identities of participants will be protected in the raw research data and in published material. The usual way to obtain informed consent is in writing, by use of a consent form that is signed by the participant and retained by you. Because you retain the consent form the same information needs to be included in an information sheet that participants retain. Both the consent form and the information sheet should include your name, contact details, title and brief description of the project, details on how the identities of participants will be protected (both when storing the raw research data and in its published form), a statement that participation is voluntary and participants can withdraw at any time, and contact details for the Human Research Ethics Committee in case of any ethical concerns. If you do not propose to seek written consent, you need to explain why oral consent will be sufficient and how you propose to obtain it.

**Please tick the relevant boxes below to indicate what has been included in your protocol:**

Outline of proposal and purpose  
-No ☐  
-Yes ✓

Measures to be taken to protect confidentiality  
-No ☐  
-Yes ✓
Explanation of how written informed consent will be obtained  
Yes ✓
No □

If written consent is not being sought, justification of a verbal consent procedure is included N/A

Full details on investigators (name, institution, etc.)  
Yes ✓
No □

All researchers on this project are familiar with the national guidelines (*National Statement*)  
Yes ✓
No □

Details re how participants will be recruited  
Yes ✓
No □

Is personal data from a Commonwealth department/agency or private sector organisation being used?  
Yes □
No ✓

Details on how cultural and social sensitivities will be addressed  
Yes ✓
No □

Consideration of likely risk to participants (e.g. psychological stress; cultural, social, political or economic ramifications)  
Yes ✓
No □

Do your research participants include:
Aboriginal or Torres Strait Islander peoples  
Yes □
No ✓

Children and young people (i.e. minors under the age of 18)  
Yes □
No ✓

People with an intellectual or mental impairment  
Yes □
No ✓

People highly dependent on medical case  
Yes □
No ✓

People in dependent or unequal relationships  
Yes □
No ✓

Do you intend to pay participants?  
Yes □
No ✓

Description of method and amount is included N/A

Description of clinical facilities (for medical research)  
N/A

Period of research  
Yes ✓
No □
SUPPORTING DOCUMENTATION: *The committee requires copies of all relevant documents*

Consent form to be signed by participants
- Yes ✓
- No □

Information sheet for participants to retain
- Yes ✓
- No □

Dot point list of the points that will be made when seeking verbal consent
- N/A

List of interview questions
- Yes ✓
- No □

Copy of questionnaire/s
- Yes ✓
- No □

Invitation or introductory letter/s
- Yes ✓
- No □

Publicity material (posters etc.)
- Yes □
- No ✓

Other (*specify*)
- Yes □
- No □

18. SIGNATURES AND UNDERTAKINGS

PROPOSER OF THE RESEARCH

I certify that the above is as accurate a description of my research proposal as possible and that the research will be conducted in accordance with the *National Statement on Ethical Conduct in Research Involving Humans* (version current at time of application). I also agree to adhere to the conditions of approval stipulated by the ANU Human Research Ethics Committee (HREC) and will cooperate with HREC monitoring requirements. I agree to notify the Committee in writing immediately of any significant departures from this protocol and will not continue the research if ethical approval is withdrawn and will comply with any special conditions required by the HREC.

Name and title (please print): .................................................................

(Proposer of research)

Signed: ........................................ Date: ..............
ANU SUPERVISOR

Where the proposal is from a student, the ANU Supervisor is asked to certify the accuracy of the above account.

I certify that I shall provide appropriate supervision to the student to ensure that the project is undertaken in accordance with the undertakings above:

Name and title (please print): ……………………………………………
(ANU Supervisor)

ANU Department/School/Centre: Centre for the Public Awareness of Science (CPAS)

Signed:………………………………….. Date:……………..

COMMENT ON PROJECT FROM HEAD OF ANU DEPARTMENT/GROUP/CENTRE:

The Head of ANU Department/School/Centre is asked to certify that this proposal has his/her support:

I certify that:

• I am familiar with this project and endorse its undertakings;
• the resources required to undertake this project are available; and
• the investigators have the skill and expertise to undertake this project appropriately.

Any additional comments (optional):

I grant the researcher permission to observe and study the Workshops conducted by the Centre for the Public Awareness of Science (CPAS) for Science Teachers and permit him access to the participant feedback provided in the Evaluation Forms from these Workshops.

CPAS will indicate to the respective organisers, the researcher’s intention to study the Workshops.

Name and title (please print):
(Head of ANU Department/Group/Centre)

ANU Department/School/Centre: Centre for the Public Awareness of Science (CPAS)
Applications should be submitted as follows:
(a) 13 hard copies (one master copy with original signatures + 12 photocopies) and all supporting documentation

PLUS

(b) an identical email version emailed to Human.Ethics.Officer@anu.edu.au.

Hard copies of the completed protocol form, together with all supporting documents, should be sent to:
The Secretary
Human Research Ethics Committee
Research Services Office
Chancellry 10B

The Australian National University  ACT 0200

Tel:  6125-2900
Fax:  6125-4807
Email: Human.Ethics.Officer@anu.edu.au
Annex I

Researcher: Sean Perera

Project Title: Treading the familiar: Investigating relevance as the basis for science communication

Information Sheet - CPAS Workshop Presenters

4. This research will form part of my PhD thesis hopes to investigate the science communication perspective of the Science Teacher Professional Development Workshops conducted by the Centre for the Public Awareness on Science of the Australian National University and may eventually be published.

5. I intend to observe and record (including photographic data), based on recommended practices in literature adapted to suit science teacher education, the science communication practices employed by you during the Workshops.

6. I hope to consult with you prior to the Workshop to discuss the science communication strategies you intend to employ and identify which areas and aspects of the Workshop you believe will be the most effective in communicating science.

7. I will also consult your opinions and views about the proceedings of Workshop after its completion, with reference to the Workshop Evaluation Forms that will have been completed by the participants.

8. At a later date arranged to suit your convenience, I wish interview you about why you believe the communication strategies employed by you in the Workshops, to be effective in science learning/teaching. The interview is expected to last for approximately one hour. It will be recorded on audiocassettes and transcribed verbatim. They will be conducted at your discretion and you should feel free to end it at any time you choose to.

9. I have obtained permission from Prof. Susan Stocklmayer (Director, CPAS) to observe and study the Workshops and to access the participant feedback provided in the Evaluation Forms from these Workshops.

10. All information that you communicate during the study as detailed above will be treated as confidential and all material relating to it (ie. audiocassettes and transcripts) will be kept in a locked office.

11. You will be sent a copy of the interview transcripts and photographs, prior to publication. You may request that some or all of the material therein contributed by you be omitted form publication.

12. Should you wish you consent to the above, in assisting me in my study, I kindly request you to complete and endorse the Consent Form, overleaf.

13. If you have any questions or concerns about this research please contact:

Sean Perera
Tel: 02 61251073 E-mail: Sean.Perera@anu.edu.au
Susan Stocklmayer (Director, Centre for the Public Awareness on Science, ANU)
Tel: 02 61258157 E-mail: Sue.Stocklmayer@anu.edu.au
Human Ethics Officer, ANU
Tel: 02 61252900 E-mail: Human.Ethics Officer@anu.edu.au
Thank you Sean Perera.
Annex II

Researcher: Sean Perera

Project Title: Treading the familiar: Investigating relevance as the basis for science communication

Consent Form - CPAS Workshop Presenters

I consent (please indicate consent by checking (✓) each respective item you wish to consent to) to participate the following aspects of the study titled “Treading the familiar: Investigating relevance as the basis for science communication” conducted by Sean Perera.

- To be observed and while presenting the CPAS Science Teacher Workshops
  - [ ]

- To be photographed during the Workshops
  - [ ]

- To be consulted prior to and after the workshops with regard to the science communication strategies employed there in and reference to participant feedback
  - [ ]

- To be interviewed subsequently for approximately one hour with regard to why I believe the communication strategies employ by you in the Workshops to be effective in science learning/teaching
  - [ ]

- To the interview proceedings to be recorded on audiocassettes and transcribed verbatim
  - [ ]

- To be sent a copy of the my interview transcripts prior to publication
  - [ ]

- To have my name and job description published / remain anonymous (Strike out that which is inapplicable)
  - [ ]

Name of Workshop Presenter (please print): ………………………………………

Signed:…………………………………… Date:…………………………
Annex III

Researcher: Sean Perera

Project Title: Treading the familiar: Investigating relevance as the basis for science communication

Information Sheet - CPAS Workshop Participants/Teachers

14. This research will form part of my PhD thesis hopes to investigate the science communication perspective of the Science Teacher Professional Development Workshops conducted by the Centre for the Public Awareness on Science of the Australian National University and may eventually be published.

15. I intend to observe and record, based on recommended practices in literature adapted to suit science teacher education, the science communication practices employed by during these Workshops.

16. As part of my study I intend to send out a survey to you some time (approximately within six months after this Workshop), to obtain information about your science teaching experiences.

17. By returning the above surveys you consent to the information therein to be used as data for this study.

18. Should you wish you consent to assisting me in my study as described above, I kindly request you to provide your contact details in the detachable section at the bottom of this page.

19. By proving me with your contact details and endorsing the detachable slip below you consent to be a participant in this study.

20. If you have any questions or concerns about this research please contact:
Sean Perera
Tel: 02 61251073 E-mail: Sean.Perera@anu.edu.au
Susan Stocklamyer (Director, Centre for the Public Awareness on Science, ANU)
Tel: 02 61258157 E-mail: Sue.Stocklmayer@anu.edu.au
Human Ethics Officer, ANU
Tel: 02 61252900 E-mail: Human.Ethics.Offer@anu.edu.au

Thank you
Sean Perera.

Do you wish to be contacted as a participant for the above described study? □ YES □ NO

Name of Workshop Participant (Dr., Mr., Mrs., Ms.) ..........................................................

Postal Address: ..................................................................................................(Street Address)
...........................................................................................................(State) ...........................................................................(Postal Code)
Introductory Letter – Workshop Participants/Teachers

Thank you for agreeing to be part of my research study, in which I hope to investigate the science communication perspective of the Science Teacher Workshop that you attended in (Date), conducted by the Centre for the Public Awareness on Science of the Australian National University.

Please find attached a short survey in which I would like to know about your teaching experience and what you think about science and science teaching in general. The survey will take a short time to complete and once done please post it back to me in the envelope (postage-paid) that is also enclosed. By returning the surveys you consent to the information therein to be used as data for this study.

I would like to interview some of the teachers, after I receive their surveys. The interviews only deal with the professional aspects of science teaching and will not involve the interviewees to discuss any personal matters. The interview will be conducted by telephone and is expected to last for approximately one hour and may be discontinued at anytime if the interviewee finds the need to do so. All information that is communicated during the interview will be recorded and transcribed verbatim. All information will be treated as confidential and will be kept in a locked office.

Interviewees will be sent a copy of the interview transcripts prior to publication and they may request that some or all of the material therein be omitted from publication. If they wish, they may have their names and job descriptions included in the publications. If not all communication will be dealt with anonymously to ensure confidentiality of the interviewees’ identity.

Should you wish you consent to be interviewed as described above, please complete and endorse the Consent Form overleaf and send it along with your completed survey. If you do not wish to be interviewed, I would appreciate it if you could complete and return the survey nevertheless.

Thanking you for your time and corporation,

Sean Perera
PhD Candidate, Centre for the Public Awareness of Science
If you have any questions or concerns about this research please contact:
Sean Perera
Tel: 02 61251073  E-mail: Sean.Perera@anu.edu.au

Susan Stocklmayer (Director, Centre for the Public Awareness on Science, ANU)
Tel: 02 61258157  E-mail: Sue.Stocklmayer@anu.edu.au

Human Ethics Officer, ANU
Tel: 02 61252900  E-mail: Human.Ethics.Officer@anu.edu.au
Annex V

Researcher: Sean Perera

Project Title: Treading the familiar: Investigating relevance as the basis for science communication

Draft of Questions for Workshop Participants/ Teachers

Section 1 - Participants’ background demography
(a) How long have you been working as a teacher?
(b) How long have you been teaching science?
(c) To what grades/age groups do you teach science?
(e) Have you majored in science at university?
   (i) If yes please give details of your undergraduate course:
       Duration: Major:
   (ii) If no please give details about your professional qualifications:
       Course: Duration:
(f) How often do you receive professional in-service training in science teaching?
   (Please tick appropriate category)
   More than twice a year □ At least twice a year □
   Annually □ Every few years □
   Occasionally □
2. Does the school you teach in have collaborations with universities or any other institution to help science teaching? If “yes” please specify

Section 2 – Participants’ conceptions of science and science teaching
(a) How would you describe science?
(b) Is science about knowing facts, laws or theories?
(c) How do you describe your science teaching?
(d) What are your strengths as a science teacher?
(e) What are the challenges you face in the position?
(f) What are your greatest frustrations in teaching science?
(g) How did you envisage the Workshop would help you to teach science?
(h) Did you find the Workshop features helpful?
(i) What were the most memorable and beneficial aspects of the Workshop?
(j) Did the Workshop change your attitudes/beliefs about teaching science?
(k) Why do you think the Workshop changed your conception about science teaching?
(l) How did the CPAS Workshops contribute to your science teaching?
(m) What features of the Workshop would you like to change?

Do you wish to be contacted for a further telephone interview? □ YES □ NO

If ‘yes’ please complete and endorse the Consent Form attached overleaf.
Annex VI

Researcher: Sean Perera

Project Title: Treading the familiar: Investigating relevance as the basis for science communication

Interview Consent Form - Workshop Participants/Teachers

I consent (please indicate consent by checking (✓) each respective item you wish to consent to) to participate the following aspects of the study titled “Treading the familiar: Investigating relevance as the basis for science communication” conducted by Sean Perera.

To be interviewed for approximately one hour about my science teaching during one of the time options provided by me

☐

To the interview proceedings to be recorded on audiocassettes and transcribed verbatim

☐

To be sent a copy of the my interview transcripts prior to publication

☐

To have my name and job description published / remain anonymous (Strike out that which is inapplicable)

☐

Name of Workshop Presenter (please print): ………………………………………

Please provide a telephone number where it is convenient for you to be interviewed:

(………………)Area Code  (……………………………………………)Telephone Number

Please indicate a day and time when it is convenient for you to be interviewed:

Option 1. Day: Mon/ Tue/ Wed/ Thu/ Fri/ Sat/ Sun (please circle suitable day)  Time:……………(am/pm)
Annex VII

Researcher: Sean Perera

Project Title: Treading the familiar: Investigating relevance as the basis for science communication

Interview Confirmation - Workshop Participants/ Teachers

Dear ……………………….,

Thank you very much for returning the survey sent earlier and agreeing to be interviewed for the study, in which I hope to investigate the science communication perspective of the Science Teacher Workshop that you attended in (Date), conducted by the Centre for the Public Awareness on Science of the Australian National University.

Given below is the time and date arranged for your interview. Please inform me (Sean Perera Tel: 02 61251073, E-mail: Sean.Perera@anu.edu.au) if there is any error in your telephone number and/or if you would like to make any changes to the date and time of the interview. I would appreciate it very much if this could be attended to at your earliest convenience.

Name of interviewee: …………………………………..

Contact telephone number: (………)Area Code (……………………………)Telephone Number

Allotted time for interview: (Day), (Date), (Time)

The initial questions will be based on your replies to the questions in the survey completed by you. A list of these questions have been given below to refresh you memory.

3. How would you describe science?
4. Is science about knowing facts, laws or theories?
5. How do you describe your science teaching?
6. What are your strengths as a science teacher?
7. What are the challenges you face in the position?
8. What are your greatest frustrations in teaching science?
9. How did you envisage the Workshop would help you to teach science?
10. Did you find the Workshop features helpful?
11. What were the most memorable and beneficial aspects of the Workshop?
12. Did the Workshop change your attitudes/beliefs about teaching science?
13. Why do you think the Workshop changed your conception about science teaching?
14. How did the CPAS Workshops contribute to your science teaching?
15. What features of the Workshop would you like to change?

Subsequent questions will be based on your responses to these questions.

Thanking you once again for consenting to be interviewed and looking forward to speaking to you as mentioned above,
Yours sincerely,
Sean Perera.
PhD Candidate, Centre for the Public Awareness of Science Australian National University.

Annex VIII

Researcher: Sean Perera

Project Title: Treading the familiar: Investigating relevance as the basis for science communication

Interview Transcript Confirmation - Workshop Participants/ Teachers

Dear ……………………….,

Thank you very much for taking part in the interview in my study, in which I hope to investigate the science communication perspective of the Science Teacher Workshop that you attended in (Date), conducted by the Centre for the Public Awareness on Science of the Australian National University.

As you have been informed earlier, interviewees may request that some or all of the material therein be omitted from publication. Hence please find attached a copy of your interview transcripts of (Time and Date) sent to you prior to publication. Please inform me (Sean Perera Tel: 02 61251073, E-mail: Sean.Perera@anu.edu.au), if there is any information you wish to retract from the transcript.

Please also confirm if you wish to have your name and job description included in the publications. If not all communication will be dealt with anonymously to ensure confidentiality of your identity. If you do not reply, it will be assumed that you will adhere your decision in the Consent Form to have your name and job description published / remain anonymous.

Thanking you once again for all your corporation in making this study a success,

Yours sincerely,

Sean Perera.
PhD Candidate, Centre for the Public Awareness of Science
Australian National University

If you have any questions or concerns about this research please contact:

Sean Perera
Tel: 02 61251073 E-mail: Sean.Perera@anu.edu.au
### Appendix 4: Quiz (other) used in some of the CPAS workshops

<table>
<thead>
<tr>
<th></th>
<th>What do you think?</th>
<th>True</th>
<th>False</th>
<th>Unsure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>An object at rest has no energy</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Heat is a transfer of energy</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>If an object is at rest, no forces are acting on it</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Light travels faster than sound</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>When an object runs out of force, it stops moving</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Friction always hinders motion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Heat rises</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Energy is used up in a torch bulb</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Metal is naturally cooler than plastic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Heat is a substance contained in a body</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>If a pen is dropped on the moon, it will fall to the surface of the moon</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Pressure and force are not the same thing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>A golf ball sinks because it is heavier than water</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Stored energy is energy contained in an object: for example, in a battery</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>A more massive pendulum bob on a 50cm string will swing faster than a less massive one</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix 5 : Summaries of CPAS Workshop Activities

Eureka! Archimedes!

Equipment:
- One small floating container (the "boat")
- A plastic container to hold water
- About 20 steel washers, coins or other small heavy objects whose individual mass is known
- Lump of plasticine
- 100 cc measuring cylinder

This experiment involves prediction – it can be used as a “Predict, Observe, Explain” experiment.

1. Students are asked to predict how many coins will be needed to sink a floating container. They should attempt to justify their guess before testing.

2. Fill the plastic container with water to about the three quarters full. Float the boat on the surface of the water and carefully place coins inside until it sinks. How close were the guesses? Why was that number of coins needed?

Clues to the answer are provided as follows, which could be a demonstration carried out before the activity itself.

Take the piece of plasticine provided and roll it into a ball. Predict what will happen when the ball is placed in the water. Now test your prediction! Place the ball in the water and observe what happens.

Now mould the ball with your fingers into a bowl shape. Carefully place it back on the water and observe what happens.

By now students may wish to find out how much water the boat would displace when floating. They can measure its volume and compare this weight of water with the weight of the coins they added. (Remind them that 1cc of water has a mass of 1g.)

The Explanation:
An object will only float in a fluid providing that it displaces an amount of fluid equal to its own weight. In other words, if the object has a mass of 50g then it must displace at least 50g of fluid if it is to float.
If the object, when it is completely immersed, still does not displace an amount of fluid equal to its weight, then it will sink just like the ball of plasticine. In the second case the moulded plasticine displaces more water than it did when it was in the shape of a ball, sufficient to cause it to float.

Two forces act on an object when it is wholly or partly immersed in a fluid. One is the gravitational force of attraction between the Earth and the object and the other is the buoyancy force.

The two forces act in exactly opposite directions. The gravitational force acts vertically downwards towards the centre of the Earth and the buoyancy force vertically upwards directly away from the centre of the Earth. Depending on the relative magnitudes of these two forces, the object will either float up or sink down. There is also the special case where the two forces are exactly equal and this produces what is known as 'neutral buoyancy'. Fish and submarines are able to achieve this state, in which the object neither rises nor sinks.

© M.M. Gore, C.Bryant and S.M. Stocklamyer, The Australian National University, 2003
Origin of the buoyant force

The pressure at any point in a fluid acts in all directions. As we descend into any fluid the pressure increases in all directions.

Consider a ball totally submerged in water. The pressure exerted on the ball by the water will push inwards towards the centre of the ball, in all directions. However, because the pressure increases with depth, the push on the underside of the ball will be larger than the push on the upper surface. Hence there is a net upward push on the ball, and this is the origin of the buoyant force.

Extension activity: How accurate are these measurements?

Students should examine their technique in this experiment. Discuss with them what errors might occur in this activity.

Possible sources of error:

1. How accurately known is the weight of the coins or washers used to sink the boat?
2. The wall of the boat may be flexible. It may therefore distort when filled with water. What effect will this have on the measured volume?
3. If the walls of the boat can bend, what effect might this have as it sinks deeper and the pressure of the surrounding water increases? How does this affect their results?
4. The units of weight measurement are the coins. How accurate is the added weight required to sink the boat? The load can only be added in discrete amounts - the last coin added might have been more than is necessary.

Probably your students will come up with more sources of error than just those above.

Are students satisfied with the accuracy of their measurement? How might they improve it?

How does this experiment fit into the history of measurement?
Equipment: One large PET bottle
Small piece of plasticine
Ball point pen cap or a plastic pipette
Length of solder for weighting the pipette

This is a fascinating device and has long been a popular toy. Although it is a simple device both to make and to operate, it demonstrates a number of concepts about buoyancy.

Attach just sufficient plasticine to the clip of the ball point pen cap so that it just floats when placed in water. The tip of the cap should protrude out of the water by no more than 3-4mm. Note: there may be a hole in the top. If so, block it up.

The PET bottle is then filled with water and the cap carefully inserted so that the air trapped inside the cap does not escape. The PET bottle cap is then firmly screwed in place. If the sides of the PET bottle are now squeezed, the cap will sink, and when the pressure is released it will float up to the surface again.

The Explanation

An object floats when it displaces a sufficient mass of water to produce a buoyant force that balances the object’s weight. Initially it was arranged that the cap just floated. That means that it just displaced sufficient water. The water was displaced by a combination of the plastic cap, (the submerged portion), the plasticine and the air trapped inside the cap.

When the pressure inside the PET bottle increases, the air inside the cap is compressed into a smaller volume and consequently does not displace as much water. As result the buoyancy force is reduced and the cap sinks.

You can also use the plastic pipette so as to behave in the same way. Simply weight the pipette with the solder so that it just floats like the ball point pen cap.

This activity is often thought to be a child’s pastime – a playing. It is anything but a playing, however, for it incorporates many of the principles of buoyancy and the theory of fluids. It relies on the concept gases can be compressed whereas liquids cannot. The very act of squeezing the sealed PET bottle involves Pascal’s Principle. This states that if the pressure is increased at any point in a confined fluid, the pressure will increase by exactly the same amount at every other point in the fluid. Finally the Cartesian Diver illustrates the concept that for an object to float in a fluid, it must displace a mass of fluid equal to its own mass.

© M.M. Gore, C. Bryant and S.M. Stocklmayer, The Australian National University, 2004
It is also worthwhile noting that Pascal's principle is the underlying concept of automobile brakes. When the driver depresses the brake pedal in a car, this increases the pressure of the brake fluid contained in the master cylinder. This cylinder is in turn connected by metal tubes to the brakes on all four wheels. When the pressure increases in the master cylinder it also increases by the same amount at every point in the hydraulic system including at the wheels where it activates the brake pads.

The fluid in the brake system is a liquid and is therefore incompressible, hence the force applied by the driver at the brake pedal is transmitted at once to activate the brake shoes.

When air - a compressible fluid - gets into the brake’s hydraulic system - there is then a mixture of compressible and non-compressible fluids in the system. This results in what is commonly known as soft brakes. When pushing on the brake pedal, much of the effort goes into compressing the air and not to applying a force to activate the brakes.
Equipment:  
Candle in candle holder  
Matches  

The candle is a marvellous way to see all three states of matter at once! Light the candle and allow it to burn for a few moments. You will see solid and liquid wax very easily—two states of matter at the same time. But where is the gaseous vapour?  

Extinguish the candle quickly between finger and thumb, and bring a lighted match over the candle about two centimetres above the dead wick, in the vapour trail. The candle should immediately relight even though the lighted match did not actually touch the candle wick. This is often called the dinner party experiment!  

The Explanation  

As you will discover, if the experiment is carried out quickly enough, the hot paraffin vapour is still present in the air directly above the wick and it is this vapour that reignites. This phenomenon is frequently responsible for bad accidents with petrol. One does not need to bring a lighted match into contact with liquid petrol. It is sufficient to have a naked flame in the presence of the petrol vapour for the whole lot to ignite.
Buoyancy Seesaw

Equipment: 2 plastic 35 mm film cassette holders
            Wooden ruler
            Pencil (hexagonal)
            Water

Set up the see-saw using the pencil and the ruler and place a plastic “can” on each end. Three quarters fill each plastic “can” with water and then make small adjustments to their positions at each end, so that the see-saw is finely balanced with one end up and one just down.

Now dip your finger into the water in the “can” on the high side. Take care to put your finger only in the water. Don’t touch the plastic “can”!!

Watch what happens!

The Explanation
The explanation for what happens lies in the fact that the pressure in any fluid, (in this case water), increases with depth.

When the finger is dipped in the water it causes the water level to rise. This increases the water depth, which in turn increases the pressure at the bottom of the “can.” Hence the force on the end of the see-saw is greater, with the result that it tips.

Something else to try
It is not intuitively obvious that a force is transmitted through the water to the see-saw. In order to demonstrate that the force is really transmitted, sit a tank of water on a set of ordinary kitchen scales. Now push a fist into the water and the scale will clearly indicate that the water and its container get heavier.

© M.M. Gore, C.Bryant and S.M. Stocklmayer, The Australian National University, 2004
Guesstimation!

How many paper clips fit in the bottle?

Equipment:  
Box of small paper clips  
Small bottle with narrow neck e.g. yoghurt drink bottle

The challenge is to guess how many paper clips will fit into the bottle when it is “full” of water.

Students should fill the bottle until it is level with the top. After guessing how many will fit in the bottle, they should add paper clips, dropping them in carefully and vertically so as to disturb the surface as little as possible, until the water overflows. The best way to do this is as a guessing game, as people do not believe the number that actually fits.

Observe the behaviour of the surface as the water rises.

The Explanation

Surface tension is a strong force in the surface of a liquid. It is this force which is responsible for insects being able to walk on the surface of water. This force causes the surface to occupy the minimum area which results in a spherical shape. Falling water drops form spheres. The water above the neck of the bottle also forms a hemispherical shape as it rises out of the bottle.
Film Can Rocket!

Equipment:
Empty white film canister (The best type for this activity is one where the lid fits inside the main body of the canister. Fuji films are packed in this type of canister. Most stores that develop films will freely give away these canisters.)
Bicarbonate of soda
Vinegar

Place about a teaspoon of vinegar in the film canister. Carefully place bicarbonate of soda in the lid of the canister in the central saucer-shaped depression in the lid. An appropriate amount is that which half fills the indentation. Use your thumb to pack the bicarbonate of soda down firmly.

Now be quick!

In a single movement, put the lid firmly on the canister and turn it upside down on the bench. It is a good idea to stand the "rocket" on 2-3 sheets of newspaper in order to minimise the clearing up after the launch.

After placing the cap firmly in place don't waste any time in inverting the canister and placing it on the newspaper. It is also useful to check that there are no lamps or breakables directly above the launch site because the main part of the film canister shoots into the air very rapidly.

The film canister will take off vertically with a loud bang!

The Explanation
The reaction between bicarbonate of soda and vinegar produces carbon dioxide, a gas. This occupies quite a lot of space, so the lid is pushed off the canister and the expanding gas causes a sound effect - a loud "pop", like a cork coming out of a bottle.

This is not unlike the process that takes place in carbon dioxide fire extinguishers that are used to smother electrical fires.

© M.M. Gore, C.Bryant and S.M. Stocklmayer, The Australian National University, 2004
Equipment: One large PET bottle
Box of matches
Water

Take an ordinary PET bottle and put a teaspoonful of water in the bottom. Now drop a burning match into the bottle. The water will put out the match. Once this happens screw the PET bottle cap on tightly as quickly as possible. Now squeeze the sealed PET bottle and then release the pressure suddenly. A cloud will form!

The Explanation

When you release the bottle very quickly, two things happen. There is a sudden increase in the volume of air and there is a decrease in temperature. This causes the water vapour in the air to condense and become visible. Even the small drop in temperature is sufficient to cause the water vapour to condense as a mist. A cloud is formed in the PET bottle. The cloud will clear quickly but the experiment can be repeated several times.

An important part of this experiment is the burning match. This is because the burning process produces small invisible carbon particles in the bottle and it is these small particles that act as points for the water vapour to condense on.

This is the reason why fog is more likely to form in industrial areas where there are a lot of particles in the atmosphere.

Working for Understanding

Many students have misconceptions about clouds. They may not even know that clouds are water droplets. This experiment enables students to answer questions such as “Why are there clouds in some parts of the sky and not others?” because they begin to see that it is a combination of pressure effects and temperature effects, together with atmospheric dust and other particles.
HOT and Cold nails

Equipment:
- Nail
- Red felt tipped pen
- Blue felt tipped pen
- Hot water and cold water
- Ice

Put the nail into some cold water with an ice block to make it really cold. While you are waiting for it to cool, mark out a 2 cm square on the back of your hand using one of the pens. When the nail is cold, take it out of the water, shake off any drops and then gently touch the nail to a corner of the square. Touch the nail at various spots down one edge of the square and you will feel that some spots feel "cold" to the touch. Mark them with a coloured pen. Continue to "map" the square, marking each spot that feels cold. You will need to put the nail back in the iced water from time to time to cool it down.

Now try a hot nail. The water you use will need to be very hot, because the nail cools very quickly. You will need to put it back in the hot water very often. Map the "hot spots" with a different colour.

Now you have a map of all the heat sensors on your skin! Do you have more hot ones or more cold ones?

The Explanation

Your skin has different sensors for different experiences. The hot sensors are warning devices, to send a message to your brain to pull your hand away from the heat. Cold is not quite so dangerous so you don’t need as many.

As soon as the sensory receptor detects “hot” it sends a message along sensory nerves to the central nervous system. The message is processed and the brain sends a message back to the muscles of your hand saying "Hot! Pull away!"

You have several different kinds of sensory receptors in your skin – including the ones which detect touch.

Something Else to Try

Equipment:
- Two bristles from a stiff broom
- Glue
- Two matchsticks
- A blindfold
- A ruler
- A felt-tipped pen

Testing your sense of touch needs two players, one to be blindfolded. The other will do the testing. Glue the bristles to the matchsticks.

Using both matchsticks at once, the tester must gently touch the bristles to various parts of the skin of the blindfolded player. The tester should place the bristles onto the skin very close to each other (less than 1 mm apart) and the blindfolded player must state whether they feel one or two bristles. If only one point is felt, the tester should move the bristles apart a bit more and test again.

Measure and record the distance between the points where two bristles are felt. Try the skin on your finger tips, your hand (front and back), your upper arm, forearm and lips! Which parts do you expect to be the most sensitive?

© M.M. Gore, C.Bryant and S.M. Stocklmayer, The Australian National University, 2003
Equipment: 30cm plastic ruler
Calibrated scale for the ruler
Glue

The person "giving" the test should hold the ruler between thumb and forefinger around the 240 millisecond mark so that it hangs vertically. The person who is being "tested" should hold the thumb and forefinger around the START mark at the bottom end of the reaction timer, just below the 50 millisecond mark. The person being "tested" must not hold the ruler, and in fact their thumb should be at least a centimetre clear on one side and their forefinger should have the same clearance on the other side.

The "tester" releases the reaction timer and the person being tested grabs the falling device between their thumb and forefinger. The place where they grip will give an indication of their reaction time. The person being tested must wait until they see the ruler begin to fall before they attempt to stop it.

The Explanation

The time between the eye seeing something and the brain and limbs responding is called the reaction time. For a motorist the sequence of events could be like this. The motorist sees an animal walk out into the road in front of the vehicle. The eyes then signal the information to the brain. The brain reacts by sending a message along the body's nervous system to command the leg and foot to press down on the brake. Such a sequence can easily take a significant part of a second and during that time the car is still moving.
**Construction of the timer**

A simple reaction timer can be constructed from a piece of card appropriately calibrated. When the card is dropped it will fall under the influence of gravity and it is a simple matter to calculate how far it falls in a given time using the expression:

\[ S = 0.5 \cdot g \cdot t^2 \]

where "S" is distance in metres, "g" is the gravitational acceleration (9.8 m/s²) and "t" is the time in seconds. The results are as follows:

<table>
<thead>
<tr>
<th>Time (seconds)</th>
<th>Time (milliseconds)</th>
<th>Distance (centimetres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.075</td>
<td>75</td>
<td>2.8</td>
</tr>
<tr>
<td>0.100</td>
<td>100</td>
<td>4.9</td>
</tr>
<tr>
<td>0.125</td>
<td>125</td>
<td>7.7</td>
</tr>
<tr>
<td>0.150</td>
<td>150</td>
<td>11.0</td>
</tr>
<tr>
<td>0.175</td>
<td>175</td>
<td>15.0</td>
</tr>
<tr>
<td>0.200</td>
<td>200</td>
<td>19.6</td>
</tr>
<tr>
<td>0.225</td>
<td>225</td>
<td>24.8</td>
</tr>
<tr>
<td>0.230</td>
<td>230</td>
<td>25.9</td>
</tr>
<tr>
<td>0.235</td>
<td>235</td>
<td>27.1</td>
</tr>
<tr>
<td>0.240</td>
<td>240</td>
<td>28.2</td>
</tr>
</tbody>
</table>

Take a standard ruler 30cm long and cut a strip of paper to be the same length and width. Using the above values calibrate the strip of paper with times in milliseconds. When complete the calibrated strip should look like the illustration.
Equipment: One small mirror
Several experimental cards

This set of activities explores symmetry.

Looking at the alphabet

1. To use an experimental card, place it flat on the table.
2. Hold the mirror against first the top edge and then against one of the side edges, and look at the mirror image.

Many letters of the alphabet are symmetrical about a particular line or axis. This means that it is just the same on one side of the axis as it is on the other. The images of some letters in the mirror are reversed. Others are not. Those letters which are not reversed are symmetrical about a line (axis) which coincides with the edge of the mirror.

The mirror itself is the plane of symmetry. The mirror is a valuable tool for investigating symmetry. Letters are two dimensional, but most objects are three dimensional. In these cases we have planes of symmetry rather than lines or axes.

It is an interesting exercise to get students to discover the axes of symmetry for various objects in the classroom. A book has three axes about which it is symmetrical. Ask your students how many axes or planes of symmetry a cube has.

The following object is not symmetrical about any axis.

© M.M. Gore, C.Bryant and S.M. Stocklmayer, The Australian National University, 2004
Symmetry and the Human Body

Human beings, when standing upright, are roughly symmetrical about a vertical axis. However, it is not uncommon for a person to have one foot slightly larger than the other. The two sides of the face are not exactly the same. The human face is not perfectly symmetrical.

The organs of the body are not arranged symmetrically. The heart is on the left of the body as is the liver. Many women tend to cradle their infants on the left hip, possibly because the child is pacified by the mother’s heartbeats. Anthropologists have suggested that the reason might really be because the mother needed the dominant right hand free to throw stones in hunting and in defence.

The behaviour and habits of humans shows that there are many examples of pronounced asymmetry. The most common example is the fact that most people favour using their right hand over their left. They are right-handed.

It is interesting to try a number of experiments with your class. It may be a useful exercise to get each student to record the results that they obtain about themselves.

Get the class to find out which way they

Clap their hands, as if in prayer,

Fold their arms,

Cross their legs,

Clap (as in applause) and

Which eye they use to wink.

If you talk very quietly to a person, they will turn their head so as to present their dominant ear towards you.

A nice exercise, that has the added advantage of introducing the concept of parallax, is to get class members to determine which is their dominant eye.

To do this you focus your eyes (both must be open) on some distant object. Now hold up your index finger so that the tip coincides with the object you have chosen. Then by first closing one eye, and then the other, you will observe that the object and the fingertip are only truly aligned for one eye – your dominant eye.

Working for Understanding

Students often have misconceptions about mirrors. The more they can explore them, the more likely it will be that the misconceptions will be challenged. In particular, the location of the image is often not understood. Misconceptions about light generally are very common – for example, some students think that we see by light coming out of our eyes. Encourage students to move to either side of the mirror and to see where, and under what conditions, they can see the image. Encourage them to discuss their views.

One testing activity is to have your students try to trace around a shape, a star for instance, not by looking directly at the shape, but by looking at it through a mirror. It is quite a frustrating exercise. Your eyes, hands and brain are coordinated to function in the real world. But when you try to operate in the world “behind the mirror”, your brain sends the wrong signals to your hand.


© M.M. Gore, C.Bryant and S.M. Stockmayer, The Australian National University, 2004
Corner Reflector

When light bounces off an ordinary plane flat mirror it behaves in the same way as a rubber ball does when bouncing off a flat surface. A beam of light striking a flat mirror makes one bounce and keeps on going forward.

If three mirrors are arranged so as to form a corner, each mirror at right angles to the other two, then a beam of light striking it is bounced back on itself. The beam makes three reflections, one reflection at each mirror and is then reflected back to the source. This is the unique property of the corner reflector.

See if you can find a corner where there are two brick or concrete walls and a concrete floor. There may be such a corner outside the building or in the back corner of a squash court. Now try throwing a tennis ball, or even better a super ball, as hard as you can down into the corner. You should find that the ball will, after bouncing off the three surfaces, return to you.

Making a corner reflector

Equipment: Three mirrors

It is very simple to make a corner reflector. All you need are three mirrors and some marking tape. Hardware stores sell 300 x 300mm mirror tiles which are ideal for the purpose. Before you begin, cut yourself an accurate right angle from a piece of stiff cardboard. This is used to ensure that each mirror is exactly at right angles to its neighbours.

Experiments with a corner reflector

When you look into a corner reflector you will notice that your image is reversed from that which you see in an ordinary flat plane mirror. In other words you actually see yourself the way others see you. To prove this to yourself tug on one ear. You will find your image will tug on the same ear. When you try the same experiment when looking into a plane mirror you will find that when you tug on your right ear your image will tug on its left ear.

© M.M. Gore, C.Bryant and S.M. Stocklmayer, The Australian National University, 2004
Next close one eye. You will now see that in the mirror, the eye that remains open is exactly in the corner where the three mirrors meet. If you now open the eye you closed and then shut the other – you will discover that the open eye is once again right in the corner.

Now look into the corner reflector with both eyes open. One eye will probably appear to be closer to the corner than the other. This is your dominant eye.

Try shining a torch into the corner reflector. A torch that emits a focused beam is best. Now walk slowly around in front of the device and observe how the light is always reflected directly back to you.

**Lunar corner reflectors**

When the astronauts landed on the Moon they left behind a very accurately made corner reflector. Since that time laser beams have been directed from laboratories on Earth so as to bounce off this Lunar corner reflector. The average distance to the Moon is 385,000km. The beams have been sent out in a series of pulses rather like bullets from a machine gun. It is possible accurately to time how long it takes for a pulse of laser light to go to the Moon and back to Earth. We know the speed of light, so it is a simple matter to calculate the distance between the Earth and the Moon. As a result it has been possible to calculate the distance to the Moon to within 3cm! From these measurements, we now know that the Moon moves about 4cm away from the Earth each year.

**Surveying**

Surveyors are often to be seen working along the road, making sightings using a small telescope in order to observe a graduated pole. It is a familiar sight to see one person peering through the telescope and the other holding a pole upright. These days the telescope has been replaced by a laser and the object that they sight on is a corner reflector. Next time you see two surveyors making sightings, go and ask to see their corner reflector.

**Corner reflectors in shops**

Frequently, when entering a shop you will set off an alarm. This is usually done by your breaking a beam of light which shines across the entrance way. The beam is reflected by a corner reflector back to an electric sensor on the same side as the light source. When the beam is broken the sensor activates the alarm.

**Corner reflectors on bicycles**

Corner reflectors are sold for bicycles. They are fastened to the spokes of the wheel. This application provides a much needed safety factor for cyclists as the light from a car will be reflected directly back to the car no matter from which direction it approaches the cyclist.

**Military uses**

The US Pentagon realised a few years ago that the metal right angled corners on their naval vessels were providing wonderful reflectors for radar beams that were seeking them out. The corners greatly improved the reflecting properties of the ship and made it much easier to “see”. At the time much thought was given to having future vessels built without any right angled corners.

**Corner reflectors on ocean going yachts**

Next time you are in the vicinity of a boating marina have a careful look at the mastheads of some of the ocean going yachts. You will find that there is a device hanging from the top of the mast which resembles a sort of a star. It is in fact eight corner reflectors and it makes the yacht much easier to find by a search aircraft equipped with radar.

© M.M. Gore, C.Bryant and S.M. Stocklmayer, The Australian National University, 2004
Clucking Cup

Equipment: Polystyrene or cardboard cup  
Match stick  
Length of string  
Wet cloth

Make a small hole in the base of the cup and place a 40 cm length of string through the hole, knotting it on the outside onto a matchstick so that it can't be pulled through. With a small piece of damp cloth, tug on the string!

![Cup, Matchstick, Cloth diagram]

The Explanation

Sound is made whenever vibrations are set up. The sound travels through the air, and we hear the noise when the travelling vibrations make reach our eardrums, which then also vibrate. Some sounds are too weak to make our eardrum vibrate, so we have to make the travelling vibration bigger so we can hear it. Bigger vibrations need resonance chambers, which are often just enclosed air spaces. This is what works in a drum, where the wood and the air inside magnify the sound of the vibrating drumskin, or in a violin, where the wood and the air inside magnify the sound of the vibrating string.

Your cup is a box of enclosed air, surrounded by the cup itself which is a solid. This makes a much better sound!
Electrified Table-Tennis Ball

Equipment:
- Plastic take-away container
- Table-tennis ball
- Plastic pipette
- Balloon
- Water

Fill the container almost to the brim with water, but not overfull. You should aim to have the water surface concave in shape, - like a saucer. In other words the water level at the centre is slightly lower than at the edge. Now carefully place a table-tennis ball on the surface of the water. Shield the ball from air currents, because even the slightest draught will upset this experiment. You will see that the ball moves towards the side of the container.

Next, using the plastic pipette add water very carefully until the surface of the water becomes convex. In other words the centre of the water surface is higher than at the rim of the container.

Watch what happens to the table-tennis ball! You will see that it will move away from the rim and move to the middle. It will come to rest at the highest point of the water surface.

When the ball is at the centre and has stopped moving, blow up the balloon and rub it on some cloth. A woollen sweater is ideal. Now slowly bring the balloon near the ball - but don't actually touch it - and watch what happens. You will find that it is possible to "pull" the ball all over the surface of the water.

The Explanation

It is easy to make plastic balloons (and similar objects) electrically charged with 'static' electricity, by rubbing them on suitable surfaces. The neutral balloon acquires a surface electrical charge, due to the frictional effect of rubbing it on the cloth. The charge can't escape from the balloon because the plastic does not allow the charge to move through it - so the charge stays on the surface.

When the balloon is brought near the neutral table-tennis ball it affects the surface of the ball, because it too is plastic. The charge on the balloon (+) attracts opposite charges (-) in the ball and they cluster at the surface. Unlike charges attract and so the balloon and the ball attract each other. As long as you don't touch the balloon to the ball, the ball will continue to follow the balloon around!

Something Else to Try

When the table tennis ball floats on a convex surface, you have in effect constructed a spirit level. If you now tilt the container very slightly the ball will move away from the centre. This is because when you tilt the container the highest point of the surface will no longer be at the centre, and the ball will move accordingly to the new high spot.

© M.M. Gore, C. Bryant and S.M. Stocklmayer, The Australian National University, 2004
Equipment:  
Wire coat hanger
Cotton
String

Take a metal coat hanger and tie two pieces of strong cotton or string as shown in the diagram.
Wrap the free ends of string, one around each of your index fingers.

Next put your fingers in your ears, lean forward slightly and have the coat hanger bang against the back of a chair or a table.

You will hear the most beautiful sound like a peal of church bells.

If you are in a group, someone else can tap the metal and ask the group to say when they can no longer hear the sound. You can indicate when the sound goes away by standing up. The times will be quite different!

The Explanation

The vibrations in the coat hanger, which are responsible for the sound you hear, do not travel to your ears very well in air. A much better method of transmitting the sound is through a solid like the cotton or string and into your ears through the bones in your fingers. Sound travels to your ear more effectively through solids than it does through air.

Try wetting one of the strings with water to see if it makes any difference to the way the sound is transmitted. You will also hear sounds better through liquids than through air, but not as well as you hear them through solids.

Something Else to Try

a. If you have used cotton threads with your first coat hanger "chimes", then make another one but this time use thicker string.

b. Another experiment is to hang several teaspoons by short lengths of string to the coat hanger. Then when you not only bang the coat hanger against something like a table, you also strike all the teaspoons.

© M.M. Gere, C.Bryant and S.M. Stocklmayer, The Australian National University, 2005
Musical Straws

Equipment: Drinking Straws.
(Scissors)

Cut the end of the straw in a ‘V’ shape and flatten it out a bit. Put your tongue against the base of the ‘V’ and blow as if you are blowing a musical instrument. You will hear a great sound!

Asking a friend to cut the straw as you continue to blow produces a higher and higher note!

The Explanation

The music of pipes is well known all around the world. The frequency of the note produced depends on the length of the pipe, with higher notes from shorter pipes.

© M.M. Gere, C.Bryant and S.M. Stockmayer, The Australian National University, 2004
Appendix 6 : Transcripts of Teachers’ Interviews (In Chronological Order)

(18.11.05) Sri Lankan teachers’ focus group 1 (4 teachers) (Translation)

Q1. What did you expect to obtain by attending the Workshop last Thursday?

Actually we wanted to find out how science could be taught with the use of non-expensive equipment and I believe that this objective was successfully achieved at the workshop. I acknowledge that there was a slight problem due to time, there wasn’t enough time to present the many activities, but the bottom line is that we wanted to know how could learn this method of teaching.

Did you expect to obtain anything else apart from teaching science with the aid of inexpensive equipment?

Yes of course, but the name of the workshop was to teach science with the aid of inexpensive equipment. However, just by saying inexpensive equipment used to teach science is not enough, but the workshop helped to identify what these inexpensive items are. The presenters had selected different types of equipment for different activities and so it provided the opportunity for an innovative teacher to think creatively about other similar equipment that could be used as alternatives to teach science. That is, what other items could be used to teach other science topics; what items could be easily obtained from the environment. Teachers usually attempt to teach science using conventional materials, but how could alternative equipment be used instead. There were even alternatives that we usually not recognize as been useful. For example the use of clips to demonstrate surface tension; we usually don’t think of using things like that.

If I remember correctly the workshop was about science communication; developing teachers’ science communicating skills. Although this aspect was not conspicuously evident, I acknowledge that it happened, however, I don’t think enough time was taken for the presentations as a result I felt that the workshop did not fully address the development of science communication skills. The presenters did not seem to pay enough attention and time about the way the various items were presented, they presented many demonstrations, rapidly one after the other. I agree that there were time constraints; however, when a lesson is taught in the classroom, I know this was not a lesson, it was a collection many small demonstrations. For instance if it were the former as we have been discussing in today’s workshop we would use strategies to attract students’ attention and thereby sometimes explain the concept to the students. Therefore, I think there was not enough thought given to how these activities could be incorporated into the classroom. I expected such an aspect in from this workshop as it was aimed to popularize science. I don’t think that presenting demonstrations successively, like a magic show would help popularize science. The presenters did not go into depth and enough detail about a single concept as how it would be useful to us, rather they continued to rapidly present many activities one after the other. That is, I think if more time is taken it would be effective to develop the teachers’ science communication skills, as that is what I was expecting from the workshop: to develop science communication side of teaching and as a result I think they did not go into the
communicating of the science that was involved in these activities. I think the activities in this workshop may have been an accumulation of a two day workshop.

Yes I agree, there were many activities that were successively presented in a very short period of time, and the presenters took trouble to achieve this aim.

As a suggestion I would like to add that it would be good if a similar workshop or workshops could be conducted for other subjects as well. Not only for physics. There was some chemistry: mainly physical chemistry I think, but also for subjects like general chemistry and biology, etc. it would be very good.

Q2. Did the workshop have an effect on the way you have perceived science teaching so far? Did it cause a change in your teaching beliefs and concepts?

I could say that many misconceptions were cleared.

They showed us the various errors in textbooks. Not only in Sri Lanka but they showed us that it was the same in other countries as well. So the discussion on misconceptions definitely caused a change I could say. For example what the said about fluid pressure and all definitely made us change. There was definitely a change, I could say, we got things that we did not expect.

Drawing of concept maps also made us think differently about teaching.

The idea that I should try to clear myself of misconceptions was entrenched in my mind as a result of the workshop. The other thing is that we received very simple activities and ideas. For example the activity on inducing static electricity: the balloon and table tennis balls are simple alternatives that could be used in the classroom. We would like this type of activity in future as well.

Teachers should also be able to perform the activities easily. Some activities that are given in textbooks cannot be done so simply. I believe that they presented such simple activities because they believed that teachers could also be persuaded to adopt the same strategies. Another thing is that teachers were made to feel that is ok to teach differently or correctly when they believe that what is given in the textbook is not correct or accurate, like in the case of pressure and depth situation. Teachers have the power, they feel empowered.

To have the power to acknowledge that a concept that is presented inaccurately, is wrong is empowerment. Some teachers continue to teach what is wrong, because they don’t feel that they have the power to correct it, even though they know and believe it to be wrong. On the other hand some teachers are totally unaware that some concepts are wrong and such workshops are a good opportunity to make them think differently at least and to investigate/research further. It is a valuable opportunity.

Even for teachers who know that certain concepts are incorrect it is a good opportunity to investigate and try to find out further why one is right and the other is not. For instance, why is the pressure more at the middle point? Thus we will ourselves have to understand it full, if not we won’t be able to explain it to someone else. If we simply say to someone that the pressure increases with depth but that the water at the bottom most point shoots less far
than the one above it, we will have to explain why it does so. Therefore, we will also have
to think analytically why this happens the way it does.

You all agree that the workshop was very useful. Therefore, I think you have answered the
next question already (i.e. Q3. Did the workshop provide you with any useful information
for your work as a science teacher/teacher educator?).

Q4. What other aspects would you expect from professional development workshops of this
nature?

I guess there are other areas where misconceptions exist as well, so it would be very useful
if we are informed of these areas too. If not we will not know about them and will continue
to teach them from textbooks. Therefore, I think these should be revealed to us at another
workshop. Also I think another very important thing is to have activities that would attract
students. There are some activities that are not very interesting/engaging when children
attempt to do them. If the activities are engaging then students wouldn’t even be reluctant
to attempt them.

This will also foster an interest/fondness for science. For instance, things like abstract
concepts become clear when it is done with such experiments. Thus science is seen as
connected to daily life and students would be more enthusiastic as a result.

I think there is another aspect which we expected from the workshop. At the workshop and
observed the presenters explaining one concept though a specific demonstration, but it
would have been better if we were given the opportunity to try to explain/teach that one
concept through different approaches. This is one of the short-comings of our system: the
teachers will study this one approach and beautifully replicate it in the classroom. This
should not be the way. We should try to see one concept from different view points. This is
necessary. Being innovative means to look at one thing from different facets/sides. If the
workshop provided the opportunity for this it would have been very valuable. It should not
be a mere transmission of ideas: conveying their knowledge to us. There were teachers
waiting for the opportunity to express their opinions as well, so it would have been good if
there was a chance to share ideas as apart of the workshop.

There might have been other activities that we have learnt through our own teaching
experience, which may have been easier/more effective or even innovative methods to
teach those concepts. Sometimes there are activities that are more engaging that we know
and could be used. We received new information that is true, however, we hadn’t the
opportunity to express our own ideas and activities.

I don’t think the workshop was meant to be a one-way communication. There were lots of
participants with a lot of experience to share: teacher educators from teacher training
colleges, lecturers from universities, were there. They were not passive recipients. They
had also the capacity and experience to contribute. So it would have been good if there was
an opportunity to share ideas and knowledge. It would be very good if this could also be
incorporated into the workshop.

There is another possibility with this suggestion. That is if there is a short-coming or
mistake with the method we use to present something, then there is the opportunity to
explore it further and correct it. (Since the presenters were experts in the field we can
expect such a degree of clarification). They could say: “teaching this concept like this is
wrong” or “as a result of this mistake this may happen”, etc. They can direct us like this as
they would know better.

They could give the opportunity to teach something: by saying: “could you demonstrate
how you would plan to teach something like this?” After that they could have shown us
how they do it.

Then there would have been contribution from us as well towards the workshop. This
would have even been useful for future workshops. For instance the activities that we do
with regard to pressure could also be used in future.

**CPAS conducts workshops of this nature, where the participants are allowed to contribute
their own ideas and activities. This however is a two-day workshop. Anyway I am very
thankful to you for expressing this view as it will help prepare better for future workshops.
Now I will go to the last question which would like each of you to answer individually.**

**Q5. What from your point of view was the most memorable component of the workshop and
why was it so?**

The item that most took my attention was the charged balloon that was used to lift the table
tennis ball. We can present such activities very nicely (attractively/ effectively) to the
students. That was the good thing that I saw at the workshop. The reason I liked it was
because this concept it’s usually taught using conventional methods in the classroom. But
many teachers have not been successful to teach it this way. This on the other hand would
be very successful as it would effectively convey the idea about electrical charge
(knowledge) to the child.

I also found the above activity to be most memorable. Another thing that I liked was the
guesstimation exercise: how many paper-clips could we put into the bottle. It was the same
with number of coins required to sink the patty cup. Such activities make one think first
before doing something. It also helps to think logically and analytically. This helps to
develop the POE skills.

What caught my attention was when they said: “you can try this out at the next party”. We
never think about science like that do we? We never think that what we learn as science
could relate to daily life, let alone using it to entertain a group of people who have
congregated to have fun. So the presenters had the idea that students would take what they
have learnt back home and share it with their families. I don’t think such a “science” is yet
taught in our classrooms. I felt that the presenters somewhat made and initiative to promote
this aspect of science at the workshop. We never teach science to students expecting them
to demonstrate activities to their parents. Not that it is not completely absent but it is very
rare. It may be that such a view exists in their culture. They may be doing stuff like that at
their parties. (Another reason for this is that they use equipment that is easily obtainable.
We on the other hand teach science in the classroom using sophisticated laboratory
equipment, so children cannot easily replicate such activities in their homes). Anyway I
don’t think we have thought of science in that way. (That is what I said, we don’t do
science like that and neither have we been keen do it like that because of the complexity of
the equipment we use. If one is to demonstrate some scientific concept at home, one should
feel that one is capable of doing it with the resources one may find from one’s own home. Because you cannot feel this way you don’t attempt to do science at home). Also there were also activities that could be enjoyed irrespective of age. I don’t think science in Sri Lanka has that status as yet.

Another reason is the way we perceive science. We also see it as a complex set of activities which requires laboratories. We don’t see it at something close to home.

I enjoyed making clouds in a bottle. It is a very simple activity that could be presented very easily.

However, although some activities were very simple they are difficult to explain. For example the activity which involved magnets and aluminum plates to demonstrate Eddie currents was based on a very complex phenomena. To teach it within our syllabus to an average student would be very difficult. It is a very simple activity but the theory involved would be very difficult to communicate to a student. It would be merely an experience that is all. (I think Eddie currents are covered in the A/L syllabus but are not discussed at O/L and I don’t think the workshop activities had been differentiated in such away). This area is addressed with a lot of short comings in the local syllabus. For instance it does not discuss the usage of Eddie current although it teaches the concept involved.

(18.11.05) Sri Lankan teachers’ focus group 2 (3 teachers) (Translation)

Q1. What did you expect to obtain by attending the Workshop last Thursday?

I of course was expecting to see how simple experiments could be performed in a captivating manner to students. And I think that objective was achieved.

We here hoping that as advertised in the notification about the workshop, that there would be simple demonstrations. We have often seen demonstrations where complex and sophisticated apparatus are used to explain scientific concepts to students. So like the notification said we expected to see this new trend of using inexpensive material and teaching science thereby.

So to recap you wanted to see how simple inexpensive alternatives could be used to take science to the classroom.

Yes and also the design of innovative experiments. If I remember correctly, the circular about the workshop also had asked us to bring an empty PET bottle. So from that I gathered that the workshop was expecting to design experiments with the use of simple, low-cost, materials. So I was expecting to gather some ideas about how I could produce experiments that would help enhance scientific subject knowledge. I was expecting to receive special/unique ideas in this area.

Q2. In my next question I would like to ask you if the workshop had an effect/s in your beliefs about teaching science.
Yes there was one instance. I got a clear message that without having to depend on complex ways of presenting information, it would be possible with the help of many simple materials to teach science. This message clearly came through.

*So you got the idea that science could be thought through simple material? What else?*

Yes. We are aware that low-cost equipment and alternative equipment is used to introduce and teach scientific concepts in lower grades. However, at advanced level these types of activities are more or less non-existent. Most of the time they depend on conventional methods and complex apparatus to teach science. If these equipment is not available the teacher will only use only the textbook or the blackboard to teach a particular concept. Even complex phenomena like, cloud formation, eddie currents, and so on, are not taught through experimentation and demonstration if the required conventional apparatus is not available. If the equipment listed is not available, the sad reality is that teachers omit the entire experiment. However, here we saw that simple experiments were not only used to teach scientific concepts at lower grades but also experiments that are need at more advanced levels of science teaching/learning could be done with simple and low-cost equipment.

*Yes there is a tendency to teach science with simple everyday materials at lower-secondary level, however, as students progress to senior grades it is seen that science teaching/learning detached itself from everyday life.*

Yes and then science becomes something confined to the laboratory. We too held the same position before, but after the workshop we also became aware that it need not be so. Another aspect is that teachers are strongly focused on traditional practices. They are very or almost exclusively dependant on the class textbook. So when attempting to do experiments that have been given therein and are found to be unsuccessful, they do not continue from there onwards. They stop a there. However, in the case of these activities, students find them very simple and very familiar to do. The workshop presented activities that could be done up from grades six up to about eleven. They were also very attractive. If we use such an approach to teach science, their (ie. students’) development within the subject will not digress. They will like the subject and receive more. I definitely received that idea from the workshop.

It was a great experience for us. There were things that I saw that I never hoped to except.

If we take the cloud chamber experiment, it is not only valid for primary but also taught at advanced level. They asked us to slowly compress and suddenly let go. This simple exercise demonstrates a very complex phenomenon of cooling and expansion. Though we use various scientific terminology to explain this concept in the classroom I don’t think it is conveyed as affectively as through the experiment. Also in lower grades we simply teach that accumulated water vapor produces clouds, but with this activity they would have an experience of the more complex scientific processes that are involved in it.

*Q4. So I gather the workshop has provided you with a lot of information. In that case I won’t go into the next question, but would go into the one after that: What other aspects would you expect from professional development workshops of this nature? If there were short-comings what were they?*
Personally I think the workshop provided the initiative to develop new ideas. I don’t mean to say that other programs should follow the same pattern, but must stress that this workshop has given us some kind of inspiration, motivation and initiative. This initiative was only for a select few among us, however, if workshops like this could be conducted for other like us in the field of science education, by the NIE or by providing the required facilities to do, I think it will be good. I don’t think we need to repeatedly follow the same workshops, it would be good not that I am saying it is not the case. We too would like to see newer things and other practical exercise, but we have already received some type of awakening, but as I said there are many others in this field and if they too could also be inspired in the same way, by such workshops, I think it would be very good.

Another thing is that from this workshop, we have something to take back to the classroom. We as teacher educators meet with science teachers in our zone on the average about twice per term (4 months) and through them we could deliver this information to the students. The extra knowledge and information we received from the workshop we disseminate to the teachers. So they can incorporate this into their classroom teaching. So I think an important and valuable service is received as a result. Therefore, I think such activities should not be conducted at the end of the year as it was done here, but if a workshop for science teacher educators is conducted at the beginning of the year, I think it would be better. So then we can plan who best we are to disseminate this information to teachers in the terms ahead. As a result these activities will be automatically incorporated into the teaching curriculum.

I agree. Some activities never get incorporated into the syllabus. They are innovative and new, but don’t get an opportunity to be expressed in the classroom.

Most teacher training programs are conducted in the second school term. So if we could have such workshops in the first term, then we could easily disseminate the information from them to the teachers when we have staff development programs in the second term.

Q5. As my last question I would like to ask you from your point of view what was the most memorable component of the workshop and why was it so?

I liked the two cups of water balanced on a strip of wood, which should that pressure increases with depth (ie. buoyancy see-saw). I couldn’t imagine how such a simple experiment could convey such a deep message. It conveyed the message so very easily. It was a novel experience for me. There was nothing personal that triggered an interest in it for me, I was completely amazed how such a simple device could convey the message of such complexity.

Also the action of detergent on milk, clearly explained the action of detergent. It will also be a very important experience for young children as it is very interesting will easily convey the message to them as well.

Yes the action of a detergent, this is even in the grade eleven syllabus, where they discuss the bi-products of mineral oil. Normally in such lesson units we only concerned about conveying the particular subject knowledge to the students. There is no practical exercise designed for it not even at advanced level. So students don’t appreciate the practical side of this knowledge, so I think that this activity was very important.
Also the results of the experiments that were done were directly evident. Usually, most reproducible experiments have a standard result which is learnt by rote. So most of the time students simply know the end result of an experiment without understanding the fundamentals behind it. All the experiments had definite observable results so it was possible to clearly state their end results.

There was another exercise: the one where they demonstrated the structure of molecules with balloons and with a cork and jujubes. Now this practical exercise on molecular structures is not done in schools due to the unavailability of models of molecules in the laboratory. Also if one of its components is lost the whole model has to be discarded. These models are very expensive and usually not found in most school labs. But from the workshop we understood that with such simple things that it is possible to clearly and very well explain this concept to students. That is very important.

Also the concept of the lone-pair electrons was made very clear. We often say that a lone-pair “pushes” the other electrons away, but a clear three dimensional understanding of it was made through that exercise. It really made things very clear.

For me there a few items that took my attention. The first was cloud formation. It is a very complex phenomenon, however, it was demonstrated very clearly to be understood with ease. The other thing was eddie currents. The use of powerful magnets and aluminum strips to show how strong these currents were and they way the formed a unique pattern was marvelous. The other was the buoyancy: the super ball, the plastic ball and wooden ball which floated at/sank to different levels in the water gave a very clear and deep understanding about density and buoyancy. If I am to talk further about this activity, the way the super ball balanced in between the two fluids, exactly at the place where the two fluids met, was a very clear demonstration about density which students would comprehend. Another activity that impressed me was how they explained the difference between fluid and gas expansion (ie. film-can rocket). We always teach that the expansion of gases is much greater than that of fluids, we only teach it verbally, but we never demonstrate it. It was because the drop of ether, which is the liquid, expanded as it did into gas that has a greater degree of expansion that it resulted in an explosion. Thus it is very clearly understood that the expansion of gases is very great. Only one drop of fluid yielded a very large quantity of gas, so it also gave a very good quantitative description as well. There were many such activities, but these are only a few that I can highlight as been very important.

Another activity is the position of the ping-pong (table-tennis) ball on the convex and concave menisci. It centered itself when it was convex and was seen on the edge of the surface when it was concave. Then we charged a balloon with static electricity, remember, well even that, textbooks state various methods by which a balloon could be charged with static electricity, but many people cannot practically do it. Now at the workshop they did it beautifully by rubbing it against shirt (clothes) that was worn and charged the balloon and with it raised the ping-pong ball. Now the lesson syllabus for grade eight speaks of static electricity, but teachers complain that the experiment described in the textbook cannot be performed and they don’t do it. However, when teachers see such a simple exercise, they will definitely do it in the classroom. The textbook speaks of ebonite rods, thin copper sheets and other sophisticated stuff. These are very difficult to come by and when used when there is humidity in the air, they prove useless.
Now when teaching surface tension we say that the meniscus of a liquid takes a concave shape. This is also described only by words and shown with a diagram. However, by using something familiar and visible like a ping-pong ball and showing that it slides to the edge, it makes it much clearer to the student that the surface of the liquid has a concave shape.

*Some students really understand what concave and convex is only after they have gone as far as the advanced level when they are asked to perform titrations, because they need to take readings along specific menisci. Although they may draw convex and concave menisci they really experience it at that stage.*

Even in the classroom when there is need to focus students’ attention and reduce chaos, I think the experiments that used guessing are useful. This is also a very interesting experiment. Having to guess how many paperclips would be need to over-flow the liquid, is very interesting. I would even recommend and think it very good if even simple activities like that are included into our science syllabi. When students are free it would be ideal exercise for them to develop their analytical thinking skills.

(19.11.05) Sri Lankan teacher individual telephone interview (Translation)

Q1. What did you expect to obtain by attending the science teacher professional development Workshop at the NSF two weeks ago?

What I expected was to how I could best use simple materials and make science learning more enjoyable to my students. So I wanted to see if the workshop would be able helpful to me in that aspect.

*So you really expected to see science being taught with the help of simple materials. So could I know if by attending the workshop, were you able to achieve this goal?*

Yes I could say that most often it did.

Q2. I have to ask you something else. I am sure you hold you won beliefs about teaching science, so by attending the workshop did it have an effect on the way you have perceived science teaching so far? Did it cause you to change your beliefs or did they continue to hold on?

I don’t think there was anything to change.

*So if I remember at the workshop, they spoke about science been link with society and that science teaching should foster a long term, life-long relationship with the subject in the students, that it is relevant to daily life etc., so didn’t you hold a different belief to this before?*

Actually no. Not only this time but at many teacher training sessions before this too, we have been told that, science teaching should be done is a manner that students like and that involves (engages) them. So I have always held this opinion. So I can say that this opinion was further confirmed as a result of this workshop. We also felt encouraged that we can teach science this way.
Didn’t you also see it as a challenge?

Actually yes, I see it as a challenge. Actually science teaching is a considerable challenge. When compared to teaching other subjects: having to teach science creatively is a challenge. Not only creatively, but also the teaching should also relate (link) to the students. Also maintaining their interest is also a big challenge. I felt that the workshop assisted us a lot in addressing this challenge.

Q3. In saying so was the workshop useful to you?

Definitely yes, it was very useful. I also spoke about it at College (SJC), and the Rector was keen that we should ask you to conduct one at school if possible.

Q4. I have another question. What other aspects would you expect from professional development workshops of this nature in future?

To do/teach the subject called science in the classroom in a manner that the students would like and also to encourage students to get involved in activities that make them think on their own. To direct students in that direction, that is what I would like to look for.

You would like to see something that would make children interested in science in the own accord.

Yes, I would like it to be where the teacher is a guide and encourage students to get involved in science more. Not telling them what to do or doing a lecture, but a process where the student is involved. As you know there is little interest in science, especially when it is just more or less like a lecture. But if the child can think and do something then it would be more interesting and engaging.

Did you see any shortcomings in the workshop?

Not that I noticed. When you say shortcomings, there is a limit of that which could be done, I believe that within those limits what all possible was done within the given time frame.

What many complained was that time was not enough. Do you agree?

Time being not enough: well there was a limited time in which to do all that had to be done, so they couldn’t have taken as much time as they wanted could they?

Do you think that if the number of items that were presented were limited and instead would it have been better if a few items were presented in more depth?

No I don’t agree, I think that the way it was done was very good.

Also was there a problem with the medium of communication? Did you have any difficulty understanding the way the communicated with the participants?

No actually no, I did not have any difficulty. They communicated very well as a mater of fact, especially the use of props made communication very effective.
Q5. One last question. What was the most memorable component of the workshop to you and can you tell also why it attracted your attention as it did?

Actually, the way in which those teacher educators from Australia when about the training is very different from the way teacher trainers in Sri Lanka would do such a workshop. Unlike local teacher educators they communicated effectively, for instance, they did not rely on words, but their expressions, intonation and everything they tried to give/communicate with us. Every time they wanted to give to us/communicate the idea behind what they were doing. Take on the other hand the Sri Lankan translator who is also an academic, well there was a big difference when you even compare her style of communication with the presenters. The way they (Sue & Mike) conducted the workshop was very different. They were completely immersed in it.

So you say that they were very dedicated in their work?

Yes, there is a detachedness in the way such training programs are done here. They on the other hand had the skill to engage/connect to the audience. Yes, the way they talk, the words they use and the props they select was significantly different. There isn’t a lethargic feeling to things like the way things are done in Sri Lanka. Participants did not feel dull, and their interest was maintained. They also created a very friendly environment. There was no stratification, I am a teacher educator and so you are beneath me type of attitude was not there. Everyone felt equal. I even felt the way they approached things was different from the local professors who were present at the workshop.

(20.11.05) Sri Lankan teacher individual interview in-person

Q1. What did you expect to obtain by attending the professional development Workshop two weeks ago?

Actually we expected a new experience in this particular area of study. As teachers and teacher-educators, we have this problem of finding better ways of putting information to students; better ways of introducing different types of experiences to the students. In that respect these are things that have been selected from various corners of our curriculum which will be of benefit to the students as far as this motivation of the students towards this type of learning is concerned.

So necessarily you expected, as the workshop title said, to go about explaining scientific concept and help teachers and teacher educators. In that question I would also like to ask you whether the workshop had an effect on the way you see science and science teaching?

Yes, in fact it gave us the things that we also expect in putting these things to the students. The nature of science, actually, now what I believe, most is that if we put it like this, people try to define science, to me it is very simple, what I can say is science is science to me is all organized common sense. It has been there right form the beginning of human history. Right form the early days there has been science. We have examples from our local settings also people use scientific thinking and reasoning. For example the concept of the sample, the way our villages take samples, from various materials, for example a sample of paddy, whether it will germinate properly, the way they select: random sampling from the whole stock. Then the way they see whether a fruit is ripe, say a banana. If we take one and taste
it and see that it is ok to use, then he generalizes that the whole bunch is fir for use. Various examples can be given that give the basic concept of science. What we normally do as science proper is that we organize that thinking. So organized common sense has become a formal subject field called science.

Q2. Did the workshop in anyway change that concept you had about “science”?

For me of course, that was what I also wanted to highlight, through various selected experiences, to see/ perceive what science is. It is not something imported nor it is something new: everywhere we find science, we live with science. That was the message that we wanted to get out of it.

Q4. I think the next question has been answered (Q3.). I wanted to know if the workshop provided you with any useful information as a science teacher educator. You have answered that question already. The next question I want to ask you is What aspects of development would you expect form such science teacher professional development workshops (apart from what was done at this workshop), what other areas which should be addressed in such a workshop?

Actually the process part of science, apart form taking specific examples, the process art of science, specially inquiry stages, say the scientific way of tackling a certain problem, examples of such cases, which can be found from our living environment, such process aspects of science is also very important in addition to what we experience as discrete experience situations. There are various aspects to the processes of science: the UNESCO handbook introduces a set of 13 processes like that we have to use scientific processes in our learning process, which should include scientific reasoning and thinking. Now say starting with observations, classification, measuring, number relations, hypothesizing, predicting, controlling variables, controlling samples, designing experiments, recording observations, interpreting; all these things what a scientist normally does, that is ultimately is science.

To go to the question what science is, if we ask a scientist what you normally do in your area as a scientist, these are the things he normally engages in. That way also we can introduce to the student certain selected areas where these scientific processes, processes in science, are to be seen.

So you mean to say that you suggest a more randomized process.

Yes to start of, but it could be structured later. Say for instance, observation, for example you light a candle and ask the students to record as many observations as possible as time goes on. For example, within an hour what are the changes you can see, in that way it will be possible to make them perceive the actual process of observation: what is observation. In that way such things could be further highlighted/emphasized, to give them an over view about what science is actually. Another way is, why do people classify things? That is also a very necessary process.

So you mean to imply that not only the method, but a deeper understanding.

Yes an deeper understanding as to why we do it and these are the process a scientists does. So why does he follow such a process and why doesn’t he do it in another way or basically
why a classification is necessary. When there is complexity with regard to a certain phenomenon we classify. Everywhere there is provision for classification. Nature has a pattern, it is not complicated. It has diversity and unity, both are there. If there are created by someone they have been created in such a way.

What I expect by teaching science is to make them perceive the processes in science rather than specific cases. I agree that cases/experiences are necessary, but through them the overall process of science should be the most important thing. So you could arrange workshops that could bring about actual information that could be given to them as far as these different processes are concerned.

Q5. So you say that a more process-focused approach is necessary. The last question that I want to ask is if there was anything that took your attention at the workshop? Which aspect of it got your attention and why did it do so?

Sorry as far as the whole setup was concerned there are things which we normally don’t think of when planning certain things to get their attention, in order to make science fun, especially for the youngsters, primary, junior secondary, this type of presentation has to be thought about, thus in fact almost all were of a similar level, which one can use at suitable points in their curriculum to initiate thinking, ideas and likewise with this experience the teachers can think of many more such things. That’s what I wanted to highlight, not specially with regard to a particular situation, taking all together. There was a diversity of instances, so the use of appropriate cases when and where necessary, people can think of such appropriate types of experiences in order to initiate a science lesson or a scientific session, for the students at different levels. What I see is something as a whole. I am not in a position to compare and say this is more important. I see everything as important to the same extent and this is the way things should happen in a science classroom and our science teachers are awakened to the fact how these things could be put to the students, simple as that. People think of science as a big thing and the syllabus is something that we should teach the students newly. That should not be the case.

I totally agree with your point of view, science is not something new, it has always been there. The word science may be new. It may have been referred to by different names in different cultures and in different periods of history. Science is a by-product of civilization. So each society and civilization in that time period and geographical location, they saw this awareness or organized commonsense as you call it.

Every person is living with science. Every society, culture, everywhere you find scientific principles in operation everywhere. Consciously or otherwise, we live with science. Our common sense is strongly linked with science. Not only science, but science and technology, both have been there.

In the western context science and technology are seen as very different, but in eastern societies, they are seen as two sides of the same coin. They are very similar, one contributes to the other.

I too never saw it that way earlier. I have taught students that technology is a product of science, but it can be the other way about as well. Actually when I was in England sometime ago, I met a physicist at the London Institute of Education. When I showed them our syllabus, the themes: technology as a product of science etc., She asked me why I
stated it like that, as it has not always been the fact. It can be that technology gave rise to
science. It is a both way process. Most of the time it is that technology gave rise to science.
Take for example, fitting an iron rim to a cart wheel, well in those days, even these bellows
or the minahama, which people use to get a higher temperature, well those things have
contributed to science. From the very early stages, the hunter man used to find certain sharp
objects to tear off meat, that is thinking that necessary development or organized common
sense.

Also technology is a product of culture as well. I mean because the hunter gather wanted
the meat he needed a sharp implement. It was only after that that he would have thought of
the science behind it and developed something better.

Sophistication came only later, originally there have been science and technology. They
have always co-existed.

The biggest problem is the modern western definition of science. We see it as something
very western, very Christian in certain way, so it doesn’t fit in easily with other cultures.
All cultures have this organized commonsense, however, perhaps everyone’s commonsense
is not organized in the same way. I think where the problem lies.

(25.11.05) Sri Lankan teacher individual telephone interview (Translation)

Q1. What did you expect to obtain from the science teacher professional development
Workshop that was conducted at NSF a few weeks ago?

You want to know what I obtained? Yes actually there was a lot of information presented
that day. Most of the demonstrations contained simple, low-cost materials. So I learnt that
it was possible to do science with simple materials. This was what I hoped to achieve. I
also received something new. The experiments that were presented were targeted at easily
engaging students. They were also very interesting. I believe that when students enjoy what
they are doing they are more engaged and thus more involved. Also it is easy to remember
when things are taught in that way. This was what is expected to receive and am glad to say
I did.

Q2. Another question that I have to ask you is you say that you believe that science
learning/teaching should be engaging and enjoyable. What other beliefs do you hold about
teaching science and I would like to know whether the workshop had an effect about the
way you believe science should be taught?

Most of the time we don’t use simple equipment to teach science. Many schools and
teachers in Sri Lanka continue to employ traditional practices to teach science. There is
very little student engagement, it is mostly a lecture-type style of teaching that is used.

Do you think that the workshop would have influenced a change from this traditional
method of teaching?

I think so definitely, there was motivation to change. We felt that if we employ such
strategies of engagement, students would be more enthusiastic towards and fond of learning
science. I use every opportunity I can to teach science this way and I have noticed that students like to be taught using such strategies. I am definitely making a more committed effort to teach science in a more enjoyable and engaging manner.

So if you are to adopt such a practice do you think the workshop covered an area within the syllabus, or would you have to adapt the materials from the workshop so that your new pattern of teaching to be in accordance with the syllabus?

Most of the activities that were done that day are relevant to your syllabus. Even if there might have been some differences the basic concepts would be the same, so it would only require that these concepts be identified and adapt them to cater to the local syllabus.

So I gather that this workshop has caused some sort of a conceptual change, am I correct?

Yes there has been some sort of change in the idea about how I see science and how science should be taught.

Q3. Another question that I have to ask is, you say that as a teacher you received many benefits from the workshop, but if I am to ask you a specific example what would you state?

As teachers we go to the classroom to teach and students come there to learn. However, this interaction would only be successful if the teacher and student connect with one another. If the students like what is being taught and the manner in which it is introduced it will be an enjoyable teaching/learning process. So I can say that if it if possible to teach science in such a manner it would be very successful.

Can you give me an example, something that grabbed your attention?

The activity where we charged balloons with static electricity, and used it to move a ping-pong ball on the surface of the fluid. It was a lovely experiment. The ping-pong ball moved beautifully. It was a very clear experiment and almost self-explanatory. We also enjoyed doing it and it was a novel experience for us. This as a result enriched our knowledge and I think it was a exemplary learning experience. At the same time it made us think innovatively too, to think of other ways and of other relevant types of fact/information that could also be understood in the same manner.

Yes you have mentioned a key element of the workshops. These workshops aim at presenting science as something familiar to us and show teachers ways and means by which they could take it to the classroom in a non-threatening fashion.

Another item was the cylinder with perforated sides to show how fluid pressure increases with depth: the deeper the hole the further the distance. Well about this experiment, we could only identify its errors only if we completely understand the concept involved in it, that is if we do it ourselves and practically understand the situation. It would be difficult to identify that something is wrong with it just by seeing it on paper. Now this experiment was proved to be wrong. It was discussed as a misconception. Even though foreign presenters may come and even show it to us or even if such is discussed at length it would not be clearly understood until and when we ourselves do the experiment and experience it for ourselves. I went home and did this experiment and I saw that water from the lowest
point did not shoot the furthest. So I was able to understand exactly what was said only after I experienced it for myself. Until then I cannot explain this phenomenon to the student. I myself have to comprehend it first. As a result I don’t have to learn stuff by rote, there is no need to do so.

That is what is hoped through constructivism, the ability to construct new knowledge based on past experiences.

Yes this is a very easy method. There is no need to memorize and remember pictures by-heart and facts by rote. I feel that this is the best way to teach students: to use a practical approach and in doing so to use simple and familiar material. I did the ping-pong ball and statically charged balloon experiment in the classroom. It is not prescribed in the syllabus. However I just did it and the students enjoyed it a lot. They watched me do it and then attempted it on their own. The whole class derived great pleasure from it and I am sure they also learnt a lot form it. It is true that is was not relevant to a prescribed lesson, but it was science and they learnt a lot from it which they could relate to other scientific phenomena as well.

Q4. You have clearly mentioned that the workshop presented numerous avenues for professional development, so finally I would like to ask what aspects you perceived to be short-coming or in other words what areas would you like to see further developed in such professional development workshops of this nature in future?

I really don’t have any short coming to remark, but would like to add that I was amazed at the amount of preparation that the presenters had put into it. They had beautifully organized the whole workshop. They had brought enough materials for all the participants and most of all I liked the way that they communicated. It was very informal and friendly, especially the way they complemented one another in their conversations. It was very friendly and enjoyable.

However, there is one thing I must note, there were only few teachers from Colombo schools present at the workshop.

This was to with the organization. NSF had asked NIE to invite teachers for the workshop and they had invited NIE zonal teacher educators. As a result there were only a few school teachers let alone teachers from Colombo there. We only knew of this after we arrive din Sri Lanka. One of the short-comings with these participants is that the information form the workshop doesn’t directly flow into the classroom. It is an indirect approach, via the teachers. Also they would not be aware of the practical difficulties that are experienced by class teachers when hey have to deliver such information to the classroom. And similarly we don’t get classroom feedback from teacher educators. Thus a workshop for teacher educators needs further thought.

Did you have a problem with time constraints of the workshop, I mean was the duration insufficient for you?

To tell you truth I did not ever feel the time going by.
Really? So you did not feel that too many activities were done within a very short time frame?

Yes, there was a sense of hurriedness about the whole workshop, but since it was all so very well organized and well presented, we did not feel time pass by. We were all kept so very well engaged and absorbed in what was going on and did not feel left out. It would have been bad if it was the opposite, fewer activities with more time, I would definitely have felt bored.

Did you have a problem with the medium of communication, the language or the accent?

I of course had no difficulty with the language and understood everything very well. I teach in the English medium at school, so the language was not a problem for me. The accent was also very clear to me. Nothing confusing. I was wondering if the Tamil participants had a problem though.

I think not. However, a few others complained about not being able to understand because of the accent. Do you have to add anything else about the workshop?

I think that the workshop provided a motivational force for us to take something new to the classroom. Also, everything that was used was easily and readily available. They were simple materials. They also did not cost a lot. This was something I really appreciated about the workshop.

Having said so, did you not think of any simple alternatives you yourself could take to the classroom? Simple everyday stuff that you might find around the house?

Yes, I was thinking about the detergent and milk experiment, and was wondering that since we don’t use pasteurized milk much here at home, would it be possible to use powdered milk instead. Even the possibility of using coconut milk also crossed my mind. These are familiar and low-cost things around the house and easily obtainable. Also, the paper that was used to observe the scattering of light; I tried it out with normal cellophane paper and it worked. The students were very thrilled about it. It is very simple and the children loved it.

I agree, when things are simple they are easy to understand. It also makes it clear that we don’t require beakers and pipettes to learn science.

I think the scattering of light as we did in class was so good because I felt that the students understood the concept better than if they had attended a lecture on it. It was a very inspiring workshop. Please let me know if there are any future workshops like this in future.
(30.05.06) Queensland (Ayr and Charters Towers) teachers’ focus group (9 teachers)

Q1. What do you think about the simple activities used in the workshops to demonstrate forces?

I think that they have been terrific. I think that they’ve really demonstrated the concept easily and you can see it very clearly and it has also given us a lot of ideas that we can take back and use in the classrooms, because they are simple and use simple materials. So I think they have been terrific in that respect.

Easy going, like Penny just said the materials are readily available and very applicable to everyday situations so it is a good thing.

I like the hands on nature of it. The accessible materials certainly good for schools and some of them are pretty impressive with what you can do.

The laser pointer one impressed me. The laser pointer was a blow away thing. The viscosity one with plasticine and the oil, that was cool, that was pretty impressive too. So if put together in the schools it would be really brining out this style.

I’ve started using some of the things already this week, because we’ve just started pressure.

I was particularly impressed with the explanation they gave us on buoyancy force. I’ve seen many many before and I am certainly the activities they have given here.

Q2. Did you feel there was a difference in the apparatus that were used last week when compared to the week before? Which did you find more challenging?

I think the first week was where we had the little train and the fan.

Yes toys and patty cups etc.

I still think they are readily available. We were asking where to buy things where you could get them and they were telling us where to get things. They weren’t something that we might have in the school.

Yes the second week had stuff like pullies and stuff like that, but that is pretty accessible. Yes we have got them, pretty accessible stuff.

I saw the first week as straightforward devices: toys, and stuff like that. Where as the second week was assembly of that kind of things.

Yes, but they are fairly simple.

I think I noticed the similarity between the first and second week was quite impressive. The fact that, I mean, apart from demonstrating principles there was an element of surprise it.

Yes.

I am a prac teacher basically and when I look back 25 years when I finished my degree. We didn’t have computers. We had couple of lab sessions with fairly rigorous whiteboard instruction, you know sit down learn the theory, the concepts, the problems, where as this is **** by the teacher. You do something that surprises the kids they know that something is not what they quite expect. Like the train.

Yes the train that even stumped us for a while.

I didn’t actually use that. That’s the sort of thing that really captivates, and I think actually hey would be interested. The other thing that impressed me about teaching. The job that I was doing previously managing programs for DEST, I think kids they need to learn science, maths and physics, but the thing with some of these projects is that kids are bored. They want to see practical stuff that they can use, they can try and make a link to what they are doing.
I’ve teaching science for 13 years and this probably one of the best PDs I’ve every been on, in terms of getting ideas for the classroom, and clarifying my own thoughts and concepts. Because I can’t **** manner. And I realise that reading the text book is probably isn’t enough in some respects, you got to play with it **** ****. Although even I did physics in my degree it is still very different to what we learn in this.

Why do you saw it is very different?
Well what we did in physics was a lot more theoretical at university and a lot of *** hardly any practical stuff at all. Well trying to apply the stuff that was theoretical, trying to apply them practically we can struggle sometimes. There just wasn’t that link made. So really I am find that I have to learn it all here.

So when this link was not made, as a teacher before you went for PD sessions, how did you cope with the challenges of teaching?
Well generally I haven’t had to teach much physics and when I did, I was at the college for a number of years before going into high school, and I taught the middle level physics and I found that that wasn’t the case. But when you are looking at the really basic things, I know that it sound sad but, the simple action reaction type things, that I didn’t really understand, even though I had been teaching that sort of thing. It was the middle level physics that I was teaching not the higher level physics. So I think that was the difference, well because there was a lot more project work. And it would be simple things like, we get remote controlled cars, trains, or whatever, we get skateboards, watch the speed, the acceleration, that sort of thing. So it didn’t really matter. I didn’t seem to struggle with it so much as I do now.
You really got to get down to the basics of it and ask the simplest question and they are the hardest ones to actually explicate. I think the action reaction pair stuff was really good, because you never ever tire of going over that sort of stuff when your teaching. (No, exactly). So it always important to spend time with the basics.
And that’s what I meant, the biggest things in these workshops is that, going back to the basics, looking at the experiments and activities that we can take back to the classroom, that demonstrate the basics very well.
The other thing is that in science, particularly physics, it’s really hierarchical, am I right? When you go into a history class if you don’t have to start from ancient history before you start teaching another aspect of history. (Yes, like building blocks). So you need to see how those early concepts are required in a practical sense for some sort of visualization when teaching future lessons.
Probably I think that’s the crux of it. I think at university I probably rote learnt a lot of it, guessed a lot of it and being able to do maths that was fine. But the link to the practical aspect was difficult to make.

Q3. How comfortable would you be to introduce these activities into the classroom?
Well we have to do to so we do it, but there are some subjects you feel more comfortable with after all.
Teaching I find is a reasonable amount of risk taking anyway. I can remember one of my colleagues, he was having disastrous practicals: every time everything he tried in the class wouldn’t work. And he was always bagged by his students. I find that rather, I’d rather address something or teach something that would rather not bother me at all. I’ll rehearse or go through it, check it over and make sure I got it right before I go into the classroom.
Because I got to have an understanding before I can speak to my students to understand. A little bit of hit and miss in science, unless you do it, it’s like typing, touch typing not even look at the keyboard. When you don’t use it each day you have to go back, go over it again, try it out, take some measurements. Once you feel comfortable you go in and give it the best shot.

It’s like being a prac teacher seeing whether your prac really work. I spent 2½ hours the night before working out a prac that we teach in motion. And I said this time I’m going to throw away the text books and work out something that’s hands-on, creative and ****. Two hours lying in bed, writing ok I’ll do that. So the next day I got all the materials together, we went outside, a beautiful day, kids got engaged and they were taking measurements, bringing the data back. Now working on a computer on how to get that data in and deal with spreadsheets and stuff like that. So there you go.

I’m trying to think of a prac as well. I’d just go and check a website. www.physicsteacher or something like that, there’s a lot of stuff that you can get. There’s a lot of stuff. (There is also heaps stuff. You can just even get ideas and modify them to what suits you). I saw variations of several of the work we did last week. It gives the materials and details like how to cut the little bit of sail. (What would teachers do without the internet).

Yes I agree. As a teacher you have to build a link from what you understand and how best to develop a link which the students would relate to. So it’s building on your knowledge and at the same time seeing how students see it as well.

Yes and we are always thinking. Sometimes I’m just shopping I’ll see something and think I can use it with the kids or we can use that in the prac, so it is always in your head, trying to think how best to teach. It doesn’t just end in the classroom.

Unfortunately sometimes you wake up in the morning and you find yourself, I am not in school but I am think about it.

Q4. How do you think your students would feel/react if they were given a similar opportunity to play with toys and simple stuff in the classroom?

Oh they loved it. I set up stations around the room and we did all sorts of pressure activities at each station and they had an absolute ball. These students they are level 1 students and hey are actually not used to that sort of teaching, used to more chalk, talk so it has taken them a bit of time to adjust to my style, but doing the stations and doing the simple things that’s got marshmallows, balloons, they had a great time. I had to get them to stop and pack up. They really didn’t want to they simply wanted to keep going. They were really engaged; even the students who sometimes aren’t interested, they were having fun using the stuff as well.

I have had this input that simple materials bore high school students. What do you have to say about this?

It was great they were into them.

Yes I think you are right. You’ve got to give some science to make them enthusiastic. You cannot just give them toys to play with.

Yes you cannot just give them each a balloon to play with, but if it done properly in a suite of things, I think it makes a big difference. And it’s simple.
It also seems to be one of those things that students have to do in groups and they like to work in groups. Give them something to do on their own. In groups they work things out by themselves. They also will chat, but that is good.

I did a survey this year and one of the questions was ‘what things help you learn?’ and one of the biggest things was group work. They like working in groups because they can talk to each other, exchange their own ideas. So I think group work is awesome.

I think also when they talk they make familiar referencing, like talking about the footy or something. So it makes it more comfortable for them. But you have to check that they don’t talk too much about footy and ignore the science.

Q5. Looking at what Sue, Mike and John do and say in these workshops, has it affected the way you think about science and science teaching?

I think they’ve got it easy, because we are adults and we have some understanding, through our prior experience and knowledge, whereas we as teachers with kids who have probably not had any hands on experience with what we are trying to teach. They did a good job, but I suppose they’d appreciate having an adult class who could basically listen to some of their explanations of what is happening. They are not sort of having to run around saying ‘do it this way’ and do explanations at the same time.

I feel that a bit though. We are all sitting here and what’s going on and they come round and help us.

I think it was good for them to see us actually engaged in dialogues and trying to work out what is going on here. And last time we were talking about something that wasn’t hitting the nail on the button, and he came in there and just cemented it and saved it. So that was really good. So that cleared any misunderstandings we might have had.

*I agree they have a slight advantage over teachers in the classroom.*

Oh for sure, no behaviour problems for a start.

What I like is the little slights, that they make things much easier to remember and take home with you. The wings on place for instance, that was a winner. Everybody makes paper planes. So I like those little slights. (Yes the subtleties) yes, from there experience and at another time I like teaching, because that is really important.

It’s harder than it seems in the classroom. Much different to what we assume in our kids. Most of them want to get out as quick as they can form the classroom. But in our case we are here because we want to learn.

Yes getting teachers enthusiastic hope that will relate on to our kids. If the kids see you enthusiastic about things they tend to come on board. But if you come in and look dull and drub and use chalk and talk and one monotonal, they just switch off.

Yes coming at them with a bit of enthusiasm, you can get somewhere.

*In a certain sense you too are here after a long day of work, do you feel they have anyway of motivating you in the way they talk and present apart form the props and equipment they use?*

Oh yes, they are very entertaining and they have a lot of stories.

Probably, the whole thing about bringing out a discussion, is probably something that wakes us all up. Asking questions and predicting answers, isn’t it?

Probably. Actually the change in presenters. That means who speaks, who goes first and the interaction they have. How one person come in while the other is speaking.

Yes things that are subtly put and very spur of the moment.

*Like the instance Mike spoke about the lever, what do you think about that?*
That’s one bit of information we all heard together. Yes we were talking about that the next day. We remembered that the next day so I think that was really significant. It is nice to see different people with levels of expertise from different areas interact like that.

_I am mainly looking at the communication at these workshops, so do you have anything you would like to add on here?_

I think you got a good mix here, three people. They all come from slightly different backgrounds. And Arden also throws his knowledge around when he describes, what is really currently happening that sort of thing. So you’ve got three different people and they are quite happy to get up there and interject and pull the other person back. I like that sense of corporativeness and the sense that if I make a mistake someone is not going to pull me outside because I am not taking it too seriously. Often we are alone in the classroom and when I make a mistake I feel bad. Just do. It would nice to have a couple of people around who would say ‘hey hang on, you got that wrong’. And we’d have that corporation/team sort of thing in the classroom. There used to be the case where you could do that sort of thing. Doesn’t seem to happen terrible much these days. The places I’ve been for 8 month training have been a pain in the neck in a lot of cases because of noise issues, but then there was a lot of understanding. You weren’t just out there. There were other people around and there were people talking and walking in on you. You felt ‘well I am part of a group, I’m not just by myself’. People pitching in and saying ‘do it this way, change that’ and so on. But I think that has changed and teaching has become a bit more isolating. I’d like to see a threesome or the twosome or whatever it is in the classrooms again. Yes, I like that style of group teaching.

It’s hard with govt trying to cut off on staff I wonder if the class will have one teacher at least.

I felt pretty sad recently when someone said ‘we can do more efficient with a class without teachers’. Don’t give them ideas. Probably they will be using computer to teach in future. I think also that these guys are very passionate about what they do and that becomes infectious. Engages us more I think rather than standing there lecturing for 2 hours. What I find interesting too to see that is the peer critiquing. It is humorous, but also very professional.

Obviously they’ve got a very wide knowledge base and they are able to communicate the theory behind what’s going on very easily on a level that we’ll grasp at straight away. Also we are able to relate to the kids as well. They could go on a very theoretical level but they choose not to.

The level of dialogue seems a good mix of academic but at the same time what a general lay person can speak. So when you are talking about a concept or principle you can speak from an academic standpoint or you can speak as they do back up by examples. _I agree, the workshops give you knowledge that you could build on. Very constructivist._

(Late comer) _Did you notice anything different between the first week and second week?_ I am so thinking back to the toys and things in the first week and last week was simple machines and buoyancy. Yes, my students love it, they enjoy it. The more imaginative the more interesting.

_Do you find the need to balance toys and simple stuff with conventional lab equipment?_
Yes definitely. Because I think the kids are very familiar with toys. They can relate to it much better and they don’t get put off and they just don’t go off the topic. When they see hardcore equipment they think that’s boring, that’s hard, that doesn’t make any sense and they just get off the track. The other day we had very simple stations put up and this workshop reinforced the concept of work stations. It worked very well. And also with simple equipment they can take the equipment out. They can take it home and show their friends and show their family. They actually understand it. A simple thing like a balloon. Let go of the balloon and see the direction it will fly at. They wouldn’t have been able to explain why that actually happened if you just explained it to them or gave them problems they had to discover. But why it actually happens they may never know? They can actually take it home and actually explain it to their parents and show off that they actually know the stuff.
I think everyone is quite fascinated with toys.
I liked that one. The simple one. The caterpillar. Our group had huge discussions about that one. Small things amuse me. Well the thing is that am fascinated by all sorts of these things. I can still spend a long time watching them and playing with them. And trying get the kids to a point where they actually see things and they actually do these things, it’s a beautiful challenge. A lot of them see these things but they don’t make the link to the learning. They are not really making critical observations, between that and physical principles. To get that connection together you got to make them see crystal clear as you can, to make it self evident. To watch and really see what’s going on.

As adults and teachers you already have that clear link at the back of your mind, when you see the toy. But when you show the student that toy they don’t have that link. So how do you set that background?
I just did the punch thing, which we did here and I was not quite sure how to link it and the kids went ‘that’s cool, miss have you seen pirates of the Caribbean?’ and they went on to that and related it to the movie and were asking ‘if a boat capsizes upside down can you really survive it?’ they related very well. So they could not understand the link between that. So probably seeing something and that question mark staying in their head, probably the visual effect is really great. A lot of them linked it to the pirates of the Caribbean. That was really good. Yes some sort of story, some suitable aspect of the real world helps to make links to science.
I think a lot of those toys as well remind you of your childhood. As children we have been fascinated with how they work and having the chance to link action reaction pair and understand how they work makes a link between science and the real world. And it is great to see toys that work without a battery. Because kids today it the battery is dead and the toy doesn’t work they just toss it away.
I was listening to song lines that is actually trying to bring music into kids lives and I could see that in a way that entertainment is presented to them. Kids have become more passive in that regard. They don’t have to derive entertainment and I guess that is why they find it difficult to link what they see with what they need to learn. Constructing and deconstructing.

Yes I see you are speaking about this planned structured system that is prevalent nowadays. So even education they think should be present to them and don’t need to actively engage in learning.
Which is bad, because most people don’t go to the national gallery to get entertainment, they need to observe the pictures and get something out of it. Even university education is very structured in that way. Not many go into have fun and learn, many have a definite plan.

(15.08.06) Launceston teacher individual telephone interview

What is it that you enjoy most about teaching science?
I enjoy seeing students find out about things and helping them…and students finding out things about how the world works. I really enjoy the experimental part of science. And I enjoy helping students understand the way in which science works.
So it is an inquiry approach you adopt to teaching science, helping students understand things they don’t know and come to terms with things that are natural phenomena, am I correct?
Yes.

In doing so have you experienced any frustrations in teaching science?
I have had lost of frustrations teaching science at various stages.

In this role that you described earlier about the teacher providing a basis for students in an inquiry approach, how do you see your role as a teacher in this whole process?
In an ideal situation as the facilitator, providing opportunities and giving background and demonstrating various practical activities so students can see how things work. Keeping students safe. Guiding them in their inquiry process.
So you see yourself as a guide and a facilitator?
Yes.
Going back to your question on frustrations, I don’t find however, that the above necessary works all the time. So I feel frustrated and when it doesn’t work.

Why do you think it doesn’t work? Do you see it as a problem form the students point by them not wanting to accommodate this approach?
Well yes. The reason I am not keen on answering your question is that I am not able to say whether the problem lies with me or whether the problem lies in terms of me expecting students to be too independent too quickly. Because I have had substantial time in year 11 and 12, I think my expectations are a little too high and particularly the last 4 years I’ve been teaching may be grades 7 and 8, and perhaps as I have said my expectations are too high, in terms of their ability to organise themselves, even with guidance.

You mention you don’t know whether the frustration is a result of your expectations or the students. Do you personally feel that teachers should be prepared to answer all student questions or if they should just go with the flow of the classroom? What do you feel about that challenge?
I think that teachers have to do both of those things. I think they have to have backups ready for them, in case things aren’t working and at the same time they need to go with the flow, and that’s what I think that makes it really difficult, particularly with younger students. It is a huge challenge to manage that dynamic of teaching.
Do you remember the CPAS science teacher workshop in Launceston that you attended in December 2004?
Yes I certainly remember the workshop.

What do you remember most from the workshop that day?
I was somewhat involved in organising the place and the material. Probably I remember that organizational aspect. But in particular I remember Sue and Mike gave the group material they had developed on using the Movie Titanic, as a way of describing buoyancy. I was quite keen on that and I started to use it the next opportunity I had, although I didn’t get to complete that unit, since I was away for some of the time. However, I thought it was a really good idea and I like some of the things that they use to connect to that particular sort of stimulus.
So you believe that they pitched the information in a way to create a learning environment relevant to the teachers?
Yes.

Why do you think that particular activity interested you?
I think they took a topic that had a lot of potential for interest. Well I made me think how would I get into this to make to real to the students. It gave me a way that I could make it real to the students. Rather than it just being some interesting activities.
Creating a personal appeal, a relevant context, is that what you mean?
Yes.

What do you feel about using simple and familiar materials to teach science?
I certainly think it is a good idea, particularly for primary school classes, it is excellent to use simple materials. I think it’s also handy to have some of those sorts of activities up your sleeve in secondary school classes, but I am very aware that a lot of the students, particularly in the school that I am a teacher, they are looking to actually have more different things. They don’t just want to see stuff that you see around all the time. That would be a bit frustrating. You think that you are doing something that they can relate to, because you are using simple materials, and then they say ‘ah we’ve seen this…, we can do this…’,
That is a very interesting observation. I have not heard that before. I was thinking that the objects are familiar they would relate to them better, but they really want something novel. Yes they do, but I am not positive whether that applies to other schools or not. It may just be the school that I am teaching at.

Did you have any specific expectations that you hoped from the workshop?
No not really.
Ok, so you came with an open mind and wanted to take anything that was offered.
Yes.

Do you agree with me if I said the workshop provided you with some useful information?
Yes

After attending the workshop did you feel that it had an effect on the way you teach science?
Well, I cannot say that it had a huge effect on my manner of teaching. It gave me some extra ideas to use, but I don’t know if it affected my manner of teaching particularly.
When you say extra ideas, so it was the bag of tricks? Yes, but a lot of the other material they were using, I had already seen.

Apart from teaching strategies, did you receive anything else professionally through the workshop experience? Did you feel empowered or motivated in any aspect, as a teacher, after the workshop? Specially with regard to the challenges you mentioned earlier about teaching.

I think we may be going a bit too far back to feel if I felt particularly empowered.

Do you think these workshops should be repeated on a regular basis?

Oh yes, I definitely think they are valuable. I think we just really don’t get enough opportunities to have workshops from people who give us different ways of looking at things. I am not just speaking about myself, probably when I was asked to organise that workshop, was because I was already involved in doing some professional learning facilitating as part of the job that I’ve had for the previous 2 years. So, as it was my job to go around and do those sorts of things with teachers I was very aware of how many teachers don’t get that sort of opportunity very often. So yes, every opportunity that could be given I think is good.

Are there any shortcomings in the workshop that you would like to mention?

I felt this is not a shortcoming, as much as.. I think I heard a couple of comments from some people that they got the idea form Mike and Sue that because this was Tasmania, we weren’t doing anything in Tasmania, and therefore, anything that was presented to us would be new and wonderful and they would love it. Really, Tasmanians do quite a lot. I think perhaps sometimes when people bring stuff to Tasmania, it might be a good idea to find out what is going on in Tasmania and not just assume, that.. I am sure they would have done lots of preparation, but as I said, some of the activities they had were ones that we have seen round for a number of years, and unless they are given a slightly new perspective, people will tend to say ‘we know that, we’ve seen that’. It’s like the kids isn’t it? So I mean to some extent Mike and Sue overcame that by presenting it in a context of that Titanic material, so that was good. It is not a criticism, but just that…

No not at all this is wonderful feedback and thank you.

Where to go from here…, I think where we are at the moment in Tasmania is we need more of that suggesting really rich ways of incorporating things that we do in science into context. The more we can have of that the more different perspectives that they can bring to it, the better.

I understand what you are saying. We all got concepts like abstract bits of information and need context to set in within.

(17.08.06) Charters Towers teacher individual telephone interview

What is it that you enjoy most about teaching science?

Just giving the kinds new ways of thinking about what they are learning about. And giving them a way of testing their theories. They come up with all sorts of things you haven’t thought of.

So it always keeps you thinking on your feet.

Yes that’s right.
You mentioned that having to deal with several age groups simultaneously was a challenge, apart from that do you have any frustrations about teaching science?

With me personally, my science experiments never work. But that’s ok. Because we talk about what worked and what didn’t work and how they can make it work better. So I guess that is my frustration.

The other frustration is that we don’t often have the resources in a small school. We don’t often have the many good science equipment that we need to do the some really fantastic stuff like some of the bigger schools, have got the budget to buy things and they can also access the other high schools to lend material. We don’t have that opportunity. So we have to scavenge around with what we have got.

*It must be quite a restriction.*

Specially for the grades 6 and 7s who really want to some really good chemistry stuff, we don’t have that opportunity here.

*That must be frustrating.*

We do kitchen chemistry. Which is all the stuff you find in the kitchen.

*So you make use of kitchen stuff to teach chemistry?*

Yes, like what chemical mix, like, does yeast and sugar dissolve in hot water or cold water better: kitchen chemistry stuff. And we found what works best for rockets: alcasela tablets and lemonade or alcasela tablets and vinegar. Which works best, but it is all kitchen stuff, something that you can find in the kitchen.

*So it is necessarily using simple materials to teach science.*

Yes.

*This brings me to a question that I hoped to ask later. If you remember form the CPAS workshop they discussed a lot of materials that could be used to teach science. What is your students’ take on the use if simple materials? Are they happy with it?*

I think they are fairly happy with it, because they don’t know anything about fancy lab equipment. But what we do to show them what else is out there, is we invite JCU lab on legs, from Townsville. We invite them down depending on what unit we do. So the kids do get, at least once a year, to see what equipment is out there and how it works.

*So they do have exposure to lab equipment?*

Yes.

*But they are happy to experiment with kitchen stuff?*

Yes they love the kitchen stuff here, because they can go home and try it.

*That’s what I thought too, but I heard that students at higher grades don’t relate well to simple equipment and I was wondering if you had the same experience too?*

No my kids, are quite happy as long as they can mix things together and see what happens. We are little innocent country kids here.

*That is also good, because if things don’t go the way they did you can always talk about why it didn’t happen they way you expected.*

That’s right, and that usually what happens to my experiments here.

*Drawing on that point again do you think that teachers should be prepared to answer all student questions or if they should just go with the flow of the classroom?*

Definitely learn along with the students, because students have to know that teachers don’t know all the answers all the time. So it is a case of where can we find the answers. So I think that’s what a teacher’s role is. It is not to know all the answers, but where can we find the answers. Who can we contact to get some answers from. So it is not always that the teacher knows everything. Cos that is not true is it?
So this is the environment you create for your students, a very inquiry based, thinking on your feet kinds of place.
Yes it has to be when you teach grades 1 to 7 in one classroom. You can’t do it any other way. Because the knowledge I can give the upper school is not going to be as valid for the little kids. And what the little kids get out of a science experiment is not, is beyond, is too simple for the upper kids. So you have to pretty much give them the material and ask them what can we learn form that.

Going onto the CPAS science teacher workshop in July 2005? I wanted to know do you remember the workshop?
Yes I do.

What do you remember most from the workshop that day?
The actual hands on science experiments. The sea diver in the bottle and the clouds were really good.
Any particular reason that you found them interesting?
I just liked that hands on equipment. Hands on things that you actually see what happens. I don’t learn very well from people giving me information or facts, that doesn’t actually stick in my head. When you can actually see it, it’s much better. And I think that’s same with the kids. They can see it happening, it seems to make much more sense to them that when you are trying to explain it to them.
So you have this same learning environment in the classroom where it is very hands-on?
Yes.

Going back to the workshop, was there any other activity that appealed to you that you would remember?
It was a long time ago, but I remember the compass one with the ping pong balls. That was pretty good too. Can’t remember much about that but I can remember doing the activity.
That’s interesting how many teachers relate to the hands on activities as not knowing but knowing where to look.
Going on a bit further, did you have any specific expectations before you came for the workshop?
No, I don’t really have a scientific brain so I came along to see what else is possible, what else can I do as a teacher to help my kids in science.

Did you find that the workshop catered to your needs?
Definitely, I learnt a lot. Specially with the material that you guys used. It shows again that you don’t have to have the expensive labs. That you can do the experiments none the less.

Did the workshop affect on the way you think about teaching science?
No I don’t think that’s changed. Because I’ve always had that open ended and hands on approach to teaching anyway.

You mentioned that you appreciate knowing where to look and whom to speak to. Did the workshop provide you with any professional support through contacts, a teacher network, etc?
Yes, because I got some e-mails and websites. I haven’t used many of those. That’s probably time restrictions for me. Yes and always working with the other teachers is really good.
Do you think these workshops should be repeated often?
Yes definitely.
How frequently?
I think every couple of years, because you’ve always got new teachers. Then you’ve always got teachers who are coming back off leave. And then there is always people who forget: oh what do we do then and how is it done: who want refresher courses, so I reckon every couple of years.

Are there any shortcomings in the workshop that you would like to mention?
No I don’t think so. The parts that there was telling us all the information there was really nothing for me, because I can look up information as and when I need it. But all that background information I thought it was all about magnets and magnetic fields.
The history you mean?
Yes I haven’t remembered much of that because I wasn’t going to use it this year anyway. And a lot of that information I can look up when I need it. So a lot of that information stuff is not very much useful for me, but, I don’t know if there is a bank of websites or a bank of connections that we could take with us. So when we do do experiments along these lines, we can access those websites or contact people when we get to it. A little telephone book of websites I suppose.
(Perhaps a portal site)
So do you feel having more hands on activities during the time of information sessions would have been more useful?
Or even just, if we can see some student friendly sites in action, like science web quests, and how they work. Because in a small school like us I often got my big kids, what I’ve now got running, is a virtual classroom. I have my 5-7 in a virtual classroom for maths and language. So if I can put some bigger kids in virtual classrooms while I teach the little kids. If I had some kid friendly sites to learn from, or interactive websites, or something, but I am not familiar with such web-quests, so something like that. But to actually see what I should do and how I should access this site, would be a useful aspect for these workshops to consider.

(28.08.06) Hobart teacher individual telephone interview

What is it that you enjoy most about teaching science?
I don’t know exactly. I guess helping students.

Do you have any frustrations about teaching science?
No not specifically science.
Do you have any frustrations when teaching in general?
Yes sometimes I get pretty frustrated with hierarchy.
With management, but there isn’t anything to do with the teaching that frustrates you?
Some times I think we focus a bit too much on knowledge as opposed to skills.
Do you find this very common in teaching science?
No I guess not.
Just to clarify, you believe that teaching should focus more on skills than on knowledge? Is that the perception you have?
Just science skills; knowing how to research, knowing how to conduct an investigative experiment, I think that is more important than actually knowing your periodic table.

So do you think teachers should be equipped with process skills to find out facts or do you think they should be prepared with all the answers when students ask them questions? No I think the teachers be good at, should be there to teach, to show students how to find out.

Do you remember the CPAS workshop that was done sometime back? Yes, bits and pieces of it.

Good, do you remember any specific part of the workshop from that day? Yes, we went through some experiments and things like that. And talked about how science, needed to sort of, how science is important part of school.

Do remember any specific activity that was done that day? Yes, there were some experiments we did (sigh). We made a cloud in a pet bottle. I seem to remember doing some buoyancy experiments with paper clips in a blue jar of water. Yea, there was making a rocket out of a can of photograph film, with vinegar and baking powder.

Wow you remember quite a lot, that’s quite impressive. What is it about these activities that made you remember them so well? They were simple and effective. Another thing that I felt good about was that there was more focus to debunk some (don’t know if debunk is the right word), but to get kids to have a look at what concepts they understand and challenge them by showing different experiments and saying ‘then explain this’, I thought that was a good approach.

Let me get that right, so you are saying that using the same concepts with different experiments, is that it? Yes.

So is this the use of Gardener’s Multiple Intelligences, that you are speaking of? Definitely yes.

What do you feel about using simple and familiar materials to teach science? Yea it is quite good.

What is the students’ take on using simple materials to teach science? Yes they like it.

How do you senior students at high school appreciate the use of simple materials to teach science? Do they bored with it? We use both. We don’t just use simple materials. I don’t think they would.

Did you have any specific expectations that you hoped from the workshop? No because it was something we sort of did for PD n preparation. I teach in middle school so I look after the grade 7 class a little bit more like a primary school situation. We obviously know a high school environment. So just probably the head of science though it might be worth for us to attend that, give us something to pick up, to help us with the science teaching the next year so that was good.
So were you able to pick up anything?
Yes

So were there any activities that were incorporated into the syllabus this year?
Probably we have yes some of it. But we are actually looking at how..ahm, another we have used this year is we use plasticine and try and make a..make a piece of plasticine buoyant. By moulding it into different shapes?
Yes.

Do you think the workshop was relevant to your needs and the head of science’ needs?
Yes, yes in some ways it was good. I took something out of it.

Was there any information that made personal sense from the workshop for your profession as a teacher?
Yes.

You seem to be a teacher who focuses on science process skills so can I ask if the workshop had an effect on the way you teach science?
I think so, I mean I guess so. I don’t know if it affects you, it depends in your focus as a teacher, you can adopt it either way.

Do you think these workshops should be repeated often?
Yea, I don’t think they hurt anybody.

How frequently do you think such workshops should be taken to teachers?
In a ideal world they can do it once year, would be good. But the logistics of that are a little bit difficult from a school point of view.

Are there any shortcomings or areas the workshop could have improved on?
No not really. I guess I am not coming from a lot of science teaching experience at that stage to make that judgement. No it seemed to serve its purpose from my point of view.

The Titanic lesson plan that was discuss that day, was it of any use?
No I don’t seem to remember, I remember that vaguely. I think I still got that handout. I got that somewhere.

(21.09.06) Hobart teacher individual telephone interview

Do you enjoy teaching science?
I do enjoy it. I think it’s the most rewarding thing I find about teaching science is the imparting knowledge on to the kids, and as they say watching the putt drop, so when they actually understand it. It’s rewarding anyway and obviously I keep learning things, I didn’t know previously so, that’s what I like about it.
So you agree that you as a teacher learn along with the teaching process. Yes.

Are there any frustrations that you encounter when you teach science?
I guess probably one of the most frustrating things is the amount of work that’s required to teach science. I think that it comes along with it. Probably, the assignment marking and all that. But if you organise it, it shouldn’t really matter. But I think the added requirements of the teaching profession in general is becoming a little bit too much and that’s probably the frustrating thing I find I feel.

What are these added requirements you mention?
There are programs that are required of you, added responsibilities are placed upon you. Not just being a science teacher being generally anything. That’s the only thing. In terms of actual science by itself, no I don’t have any frustrations really.

From your point of view how do you see science teaching science? How do you see role as a science teacher?
My role is not to impart knowledge, it’s not really for the students to gain the knowledge when I actually give it to them. It’s more actually about the skills about how about on what we teach, is what I’m trying to get across to the kids. The skills that they are going to take into their later life. Not necessarily the content that we actually give them. That’s what I see myself as, like a facilitator of their learning that’s all that I want them to take into later life.

So you focus is more on the process skills rather than the factual knowledge.
Yes, obviously the factual knowledge is an added bonus and it depends on what they want to do, depends on how much they want to get out of it. First and foremost is probably the skills that they get from it.

Do you remember the CPAS science teacher workshop you attended in a few weeks ago?
Yes I do.

From the activities that were done what do you remember most?
The hands-on ones. Just about all of them actually, because I thought that they were all very interesting. The first day was about the toys and there was a bit of a chat to begin with and they described certain principles, like the Archimedes Principle and so on, and then we got to play around with the toys. So it was rather interactive which I found excellent. The second week was about the levers and forces and how the forces are applied, I think. The third one was more theoretical and I thought they were all beneficial.

Was there anything that you found particularly interesting?
I personally found them all interesting. I couldn’t really pick out one saying ‘that one was the best one’. I found them all good.

What do you feel about using simple and familiar materials to teach science?
I found the materials that they used were excellent, because we are able to transfer that into the classroom and the students are able to take that home, that knowledge that they have gained from what we do in the classroom to home as well, and they can impart that knowledge on/show their parents what they’ve learnt in class. And the materials they use are readily available, we don’t have to purchase equipment, it’s just little odds and ends I find around the home or classroom so, I found them very useful.
You said that it is easy for your high school students to take this knowledge home. From their point of view, how receptive do you feel they are about using simple toys and household materials as opposed to conventional equipment to teach science?

Well if the set up is quite intricate kids don’t really understand the relevance and they can’t connect it with real life situations. But if you using equipment that is readily available and what they’ve used before, for example the toys, they’ve used it before, and they just watch it. And they just watch it operate. But then you are explaining why and how it operates. Then they would get a much greater understanding from it rather than a really intricate apparatus set up.

So you say they appreciate the use of simple toys?

Oh yes definitely. Toys and very simple machines that are able to demonstrate the principles that we are learning or we are trying to get across.

So students don’t get bored with simple toys?

I think they actually benefit, it helps them a lot more because they are easily able to connect with the toys, this is what I find, rather than some apparatus. Obviously you are going to have some intricate apparatus set up to explain some of the principles in greater detail, but generally you can use the simple ones, simple machines.

After attending the workshop did it have any effect on teaching?

Unfortunately I have not been able to transfer that knowledge as yet, but I was planning on doing it this morning, but the class wasn’t here. But yes it has benefited me because, obviously there were a few things that I didn’t quite understand or ideas on concepts on actually how I am going to get across the information to the kids. And those workshops have given me the tools I guess to be able to transfer that knowledge to the kids.

Can I ask what activity had you planned today for the class?

I was going to use the balloon rockets, I was going to do the dropping of the patty pan as well. Just the forces that affect them and so on.

You also mention that these workshop gave you tools, apart form the notes that you received at the end of the workshop was there any professional empowerment that you received?

Like they did in the workshop, just a brief explanation, like little stations set up, just so that the kids can go around. Its more self discovery with a bit of guidance with a sheet of information on the tables, and the way the instructors gave across information, I found really useful. I wrote down basically a lot what they said and I am able to obviously transfer that across. And they used very simple language as well. They mixed it up a little bit for us, they used quite theoretical language, compared to what we would probably use and we were able to gain an understanding from that and able to transfer it across.

So you think you saw something different in the way that they were communicating science, for example the short activities, the way they spoke?

Yes.

Do you mind expanding on that a bit, you said you took down notes.

Like, from Archimedes Principle and from those things like how did they build the pyramids, the drag effect on aeroplanes, all of the levers, and the vector forces on different objects and different situations.

What do you think about the interaction among the four presenters?
I thought it was very good. What would have helped a little bit more I think is if we had just a few more. Because the three poor instructors were going around at times and they were caught up with the groups. There were some group however we found that if we had one..(let me start again) it was sometimes good to just to be by ourselves and just to discover. Whenever we needed assistance someone wasn’t far away, which was fine. Obviously to promote quicker understanding I guess if one person could come round with us, but then again it’s a double edged sword, whether you want them all the time or you don’t. We prefer to have someone there just to ask whenever we needed. Which was fine and they did that really well. They were interacting with each other and disagreeing with each other and we found that quite interesting as well. I think anyway.

*How do you think you could convey this type of communication style with the limitations in your classroom?*
What I find is you have it pretty structured. You say ‘kids you’ve got a certain amount of time between each station and you got to move on’ and you give them a sheet that they can complete for each station. You are not going to address every kid, that’s pretty much a given thing, some kids might switch off. It depends on the ability of the class. And obviously you’re going to have to suit the type of equipment and the objective of the lesson to suit the actual level of the class. You are not going to a higher order thinking skills with a lower ability class. You’ve got to suit the kids. And once you’ve done that most of the kids, especially with this type of work that we are doing, will get them engaged and that should keep them interested, because as I said before, it’s objects, it’s machines, it’s pieces of equipment they’ve used before but they haven’t really thought about how it actually works. But now they are able to learn that from these activities and it’ll keep them engaged. I think anyway.

*So you it’s about pitching it to the audience, is it?*
Yes, you have to teach your audience, because you can’t go above the head of lower ability classes. They are just not going to be able to understand it. And you’re going to have to be there with them all the time to prod them along. So as long as you make it suit the level you should be alright.

*How do you propose the workshops should be followed up? How could they ensure they continuity of this professional development that they initiated?*
If they can do other branches of science as well of physics, I reckon it will be fantastic. One of my fellow teachers said that he would like to do some electromotive force in terms of electronics. Just a follow up. Even if they can explain, or if we can go into depth more of other Newton laws or just keep on going along the track they are going, I reckon it’s fantastic.

*So how do you think this should be done: internet forum, follow up workshops?*
Yes definitely interactive workshops, I find very rewarding.

*I know that there were several teachers form your school at the workshop. Do you think this was an added advantage and that future workshops should insist on such peer groups as well?*
Yes I believe you’d need at least a couple form your school, at the least. And I find that when we were doing, because we went around as a group basically as a faculty going around to each of the tables doing the activities, and we were bouncing ideas off and now when we come to a classroom environment where we are unsure of something we can at
least go an ask one of our colleagues ‘hey do you know how this happens’ or ‘what the explanation of this happening’. I find that very beneficial, not as a resource and just not only as someone to help you when you are doing activities.

Did you find any shortcomings in the workshop that you think should be addressed in future?
I think there was one. I was interested in all the activities that were going on and all the station we had. I think there was one time we had over thirteen stations and I didn’t have enough time to go through them all because I was pretty engaged in the ones that I did do. Perhaps a little bit more time, but then again offering that time from 4.30 to 6.30, it is pretty limited amount of time, but perhaps a little bit more time, perhaps an extra half hour would help.
Do you think the timing should be also changed, like to a weekend/morning time?
Oh no. I didn’t mind after work. I find that fine. Obviously some people are unable to make it, but that’s just the luck of the draw really. Some people will be reluctant to give up there weekends I think to go to it, if they are teaching. But I found the afternoons were fine.

(21.09.06) Launceston teacher individual telephone interview

It is advanced science that you do with them?
We don’t really do advanced science here. Because the groups that we have especially in grade 10, are, they are a mixed ability, and in the past we have run an extended science class. And we hope to do it again next year but, the more in-depth science happens in Tasmania in grades 11 and 12, and that happens at sort of a year 11 and 12 college.

So needless to ask you X, you do you enjoy teaching I presume?
Oh I do yes, sometimes other things get in the way of it being a good lesson, but underneath that, I am still teaching after 25 years and I still do enjoy going to my lessons.
When you say other things coming in the way, what do you mean by this?
Oh behavioural issues, and eh, sometimes timetabling factors and things that are not necessarily related to science, but often kids come into classes with a different agenda and with baggage and they are disruption because of whole school programs happening and you have a class that may not necessarily be, have everybody there, because there is something else happening on that day, so, you know you might want to introduce some new work, but you have to put it on hold, because you think like I would everybody to be here. So, you know, how you sort of plan doesn’t necessarily isn’t necessarily, how you act.
Yes I understand, these management issues as I would think impact also on the way that you would have to arrange your lesson plan. It is more than thinking on your feet about how to teach, but also how to go about the lesson in the first place.
Yes that’s right and, you have to cater for a wide range of abilities. Even within a standard grade.

That is very challenging, Apart from this do you experience any other frustrations with teaching?
Yes I do. In Tasmania in particular we are, going through some fairly major curriculum changes at the moment. And that has put a lot of pressure on staff. In especially teaching the core disciplines, which I believe that science is a core discipline. And that had made it,
when you know, one year we might be told that our time allocation is been chopped in half basically. And are going to have to give up some time to things like trans-disciplinary subjects where, there will be, some of our subject will be taught as part of a big, sort of integrated trans-disciplinary subject. It’s frustrating and then you sort of put up with that sort of change and adapt and sort of get a handle on this and it changes again. And it’s all politics. And so we are constantly struggling to hang on to what we believe in and that is an effort, and it’s tiring and it is stressful and you know you get a bit down sometimes, because you think oh hang on a sec, we really know what’s best for the kids not somebody else making those decisions. And we know what the kids want. I mean we are talking to the kids everyday. We see how they respond.

It’s sad when decisions aren’t taken from a bottom up by getting teachers input and feedback, instead of implementing something from top.

Yes that’s right and are last sort of curriculum initiative has been basically a top down one. Not form the universities, because if we went with what the universities wanted we’d still be teaching a fairly structured, you know, decent styled course. But the previous change with our government change down here, and the new minister has decided that things have to change in a way that probably a lot of us are more are more agreeable with and it makes a lot more sense. His approach is to talk to the teachers and to put the kids in the middle of it, in the centre of it, and we are hope that might have some positive change. You know for the better.

I wanted to ask this before, what is it that you enjoy about teaching?

That’s a hard one some days. Um, I like getting the kids enthusiastic. I like it when the kids come in and think ‘great science’. You know what are we going to do today. And I like to see them sort of develop that understanding, you know, some of the kids you have trouble with, but other kids, we can see them coming in and they are really receptive and they want more. And they want more of, they want the next part of the story sort of a thing. And when kids do a good job of something, you know when you plan something you think I hope this works, and it does work really well. And some of the kids rise to it and get a lot out of it, that’s the sort of enjoyment I get. But I just don’t like sitting in a classroom up the front and just sort of um, handing kids out work and telling them to get on with it, actually I like being involved with them while they are working too.

So you see your teaching role as a facilitator?

A bit of both, there is a bit of a balance. Sometimes I think you need sort of up front, sort of information for the kids and that information sometimes needs to be deconstructed by you and made sort of palatable. But I also increase them to become independent themselves, and to take more responsibility for their own than just be the gofer. And get the stuff that they need, and perhaps guide them a little bit, but not to perhaps put too many answers in their heads.

That’s a very difficult balance to strike isn’t it?

Yes, our kids aren’t mature enough and independent enough learners for me to facilitate, you know. Because they still at that age where are a lot of other distractions so I actually do need to keep them pretty well structured sometimes, and some kids do respond better. Other kids can’t cope if they are given time to do it themselves.

Teaching is always full of challenges.

Yes.
I think we spoke about this before. When students ask questions in the classroom how do you feel? What is your approach to answering them? Do you think that the teacher should be prepared with all the answers or is it alright for the teacher not to know?

No I often say look I am not really sure of that but you try to find that information or I’ll find out something, or I will tell you how you can find that information out. Or where would be a good place to get some information, but I tell them I don’t know about certain things or I don’t know everything and that I’d like to know about it if they can find me out some more information or you know, I tend to just sort of do it that way.

So do you adopt thinking on your feet as you go along with students in your classroom?

Oh yes, and I’ll respond to student interest and student need as well. You know if I sort of think that we are on bit of a roll with something, and the kid are really interested, I’ll think well what the heck let’s just go with this. Because to me that’s where they are going to learn and the things that they are interested in, and I can’t always predict what sort of thing they are really going to be interested in. But if they are still using all their scientific skills then it doesn’t really matter what the content is.

So as you see it, it is training the skills that is important.

Do you remember the CPAS science teacher workshop?

I do yes.

What is it that you remember most from that day?

This is the one with Mike Gore and Sue Stocklmayer?

Yes.

I really liked the hands on approach. The fact that we did lots of really good effective little experiments. And many of them that we have used quite a lot. And the kids really enjoy them, because they are sort of bit of fun, but they are also, they do provide a good lead into some, some good science. And probable the fact that there were a few of us there from this school, so we were able to sort of talk about it afterwards and sort of share what, who done what, and what worked and that sort of stuff with our kids and where we were going to apply it. So over the last two years we’ve probable used that buoyancy unit, that sink or swim unit, quite a bit.

You mentioned that the ideas that were presented that day were ‘effective’, do you mind to expand on that?

Well they were ‘effective’ means that they were pretty child-safe, the kids could so them, and we could demonstrate them or um, or because we’d seen them when Sue and Mike demonstrated them to us, they were really clear on how to do it. They didn’t need complicated apparatus or anything, there might have been one that was a bit complicated but, the rest were all really straight forward and the kids could do them with out much difficulty and they didn’t need sort of complicated equipment, it was just pretty easy stuff to hand out to kids and recycle and all that sort of thing. So it wasn’t expensive either.

So what’s your take on the use of simple materials?

Well we try and use them as much as we can because we only have a limited budget and we try not to, we try to bring stuff in from home like we, you know sort of yoghurt containers and all these sort of tubes and cardboard, bits and pieces from here there and everywhere. There are obviously things that are going to get used once and have to be chucked out but there is much of the other stuff that we can recycle and sort of put aside for certain tasks, then we do it that way and it you know makes us a little bit better if have to go shopping and buy other more perishable items for various particles and things.
How do you feel your students appreciate the use of simple materials? Are they reluctant? I don’t think so. And I think often the simple materials that they are using they might use in construction tasks. And I love construction tasks. And so they are quite familiar with these materials. And they’ll know that they are always around and they can work with those. There are time when you want something a bit more complicated but to have a whole class set up things that are complicated, often you are looking at things not working properly, or there not being enough to go around, and that sort of thing. Whereas they will always know that there will be enough of everything if they are simple, relatively inexpensive materials.

From the workshop that day do you remember any activity that particularly got your attention? I think one of them I can remember is that the coke bottles that were filled with blue dyed water and we had to just put paper clips in it, to see how many would actually fit into it before they over flowed. The kids really liked that one. They even, we sort of do like drops of water on a penny or a coin sort of practical. But they liked that because it completely throws them, because they got no idea that they can actually put that many in that little space. I really like that exercise too, because it gives an idea that nothing is permanent and there is still room for change.

Before you attended the workshop, did you have any specific expectations for that day? I knew it was going to be fairly practical, because, I’d seen Mike Gore before, when he did the Galileo stuff. And we have that video here, and I remember seeing that. And so I knew that would be none of this us sitting/listening stuff, but that it would be pretty hands on. It was presented pretty well to us as well. I mean it looked like it was going to be a really practical, hands-on, very sciency thing using simple materials and that was what we hoped for and that was what we got.

Sorry to go off track but you mentioned that you saw Mike’s Galileo show. I am working on that at the moment. Can I ask what made the show so appealing to you? I think the simple way of him showing some of the experiments. It’s such a simple but quirky as well.

After the workshop did you feel that your expectations were met? Yes I did, I came away with a really good package of stuff. And that wasn’t just sort of in the hand, in the head as well.

This package of stuff, did it have an effect on the way that you taught after the workshop? Um, yes and no. It made me appreciate the effectiveness of little short sharp demonstration examples. Things that kids can do to just reinforce, emphasise or to make them to make some predictions and some observations out of. So they were really good. Um, simple ways of showing sometimes things that are a bit hard to explain to kids.

You mention deep, sharp and short exercises, do you use a lot of these exercises in the classroom? It depends what topic I am doing and you know there are obviously some instances where that’s more appropriate than others to do. But often I’ll do it as an introductory task, or something like that just to get kids interested, or I know that there is going to be a lesson it a bit fairly sort of working with paper and books. But I like to break it up with something that is a bit more visual just that so that all of them are getting the opportunity to learn.
something a bit more in another different way. Or just to emphasise something or illustrate something.

And do you find these short boosts being dispersed throughout a lesson effective as well? I wouldn’t do too many of them because it’s a bit disruptive, but I would use it either at the start, the middle or the end to try and emphasise something or introduce something that way. Or sometimes a really simple experiment like that allows you to get the kids to practice their writing up their scientific method because it’s simple you get some good results but you can get it done in sort of a short time, it’s not something that drags on for ages.

And also the thought process is stimulated, that’s how I see it.

Yes, you have a chance to discuss different ideas and different sort of ways in which kids are perceiving it and that’s really good, because it gives the kids confidence that you know they can be heard and that it doesn’t have to be right or wrong.

Do you think workshops like this should be repeated?

Oh yes.

How frequently?

I think they should be on offer each year. Because each year there are different groups of staff available, it would be valuable for them to experience that. I too along a teacher who wasn’t a trained science teacher but he had actually been teaching some junior science. And it was really valuable for him to sort of see how science could be and it didn’t have to be how he might have done it at high school. It could be packaged slightly differently.

Did you find that the workshop had any shortcomings or areas that you would like to discuss?

I probably don’t focus on that sort of thing after this period of time. I don’t really think so. I think it was really well catered for. I think everybody had access to materials we weren’t short of anything. The food was good. It was at a different place, so that you know, so we could just forget about our normal, where we normally operate. But I can’t really think of anything that I thought was, you know, a negative.

(25.09.06) Charters Towers teacher individual telephone interview

What is it that you don’t enjoy, your frustrations about teaching science?

Mostly difficult students and at times the frustration of curriculum that doesn’t really suit the needs of specific student groups.

Would you like to elaborate on that?

Some of the more disengaged students who have greater learning needs and for whom I feel a priority should be learning to really be able to read more effectively, write more effectively, communicate more effectively and being ask to them chemical equations is to me a waste of their time and my time, because they have more urgent needs.

That issue has been raised by many teachers, about curriculum needs not addressing student needs.

That’s right

From your point of view, what you do think teaching science is about?
To me teaching science is actually teaching a way of thinking and a way of existing in the world as if. It is beyond a behaviour, it’s incorporating a way of viewing the world, assessing what going on around you, being able to communicate with facts, being able to test ideas, and not rely on what other people tell you but being able to assess things for yourself and draw conclusions based on what you’ve experienced and the information you’ve been able to gather. A sense of independence of knowledge is a good way of describing it.

*What is the role of the teacher in this process you describe? How do you see yourself?*

I think it really varies from student to student. There is no one method that works for all. Depending on the group of students and the class that you’ve got, sometimes you need to guide them step by step, sometimes you can just give them challenges and let them move forward and just re-direct a little bit when you feel that they’ve lost their way. It really depends on where the students are up to. So to me it’s really facilitating from the point students are at to the next level they can reach.

*You mentioned that you would like students to be independent seekers of their own knowledge. So you wouldn’t want to give them precise answers, etc. and that you would be taking them through a self-discovering process.*

Definitely, the methods of teaching that I’ve been using in the last few years, and I’ve actually find that they work with all levels, is really more open-ended investigations where I’ve asked students to think about the unit we have to cover, what aspects they were interested in and then taking that and helping them design different questions that they can explore, whether that be through researching on the internet and books etc., or through researching and carrying out experiments. A lot would depend on the topic area and students in question, but either way they are starting to develop an ability to find information that interests them, assess that information and start to draw conclusions from it.

*In this process do you see yourself as a knowledge-seeker? How would you for instance see yourself at a block and your students come to you for an answer and you don’t know it? Doesn’t worry me and doesn’t phase me at all. It’s not uncommon. My response is usually is that ‘we can explore that’. If they are particularly interested I can ask them to explore it at another time. Sometimes I’ve said ‘that is very interesting and very important so I’ll see what I can find for you’, depending on their level. And sometimes if it’s been thrown at me to try and distract me ‘well you look that up and find the answer and bring it up b ask’. Or it might be something we cover further down the track and I’ll get them to ‘we are going to cover that further down the track, let’s explore it then’. So it does happen and it doesn’t phase me at all because I can’t know everything. And another answer is of course the fact that between breakfast and morning tea they discover more information per day they knew when I was born. So there is not way of knowing everything.*

*What activities interested you most during the CPAS workshop?*

What attracted me most about all of them was just the simplicity of the equipment that they used to display the concepts. There was nothing complex there really at all. As I just looked across all of them, that’s really what struck most. Particularly the use of paper clips to hang things on and rulers with tiny little holes in them to help measure. It was just all very simple.
You mean not only the equipment but also the set up was very simple.
Yes.

How do you think students would feel when they have to use such equipment as opposed to conventional lab equipment?
So long as you pose some enough interesting questions to explore, they are not going to be the least bit concerned. In fact, they’d feel empowered by it, because it’s all equipment they know they could get hold of at home and explore things at home further, if the wanted to.

Do you think the CPAS workshop presenters pose that context of questions that you mention?
They did have some questions. But I feel you are often better trying to get students to come up with the questions. Because otherwise you are still dictating to them. If they come up with the questions, then they have a little bit more ownership over what they are doing.

What do you remember most from the workshop that day?
As a convenor for the workshop and as a participant, do you think the overall expectations were met by the workshop?
I don’t know that I had any expectations to tell you the truth. If anything they were higher, because I’ve had a lot of positive feedback from teachers. So yes the workshop definitely met them and higher.

What do you think about the communication that was used by the workshop presenters?
I felt that it was fine. I did appreciate having Aden showing me the mathematical equations, because for some reason I had to see the mathematical equations before it was clarified for me. Somehow it needed to have the bridge, from ‘yes I can see it all happening’ but I just needed it explained in that mathematical way so that I could make connections mathematically in my mind, to truly feel that I had a full understanding of what was going on.

So you thought that inter-presenter interaction was very useful?
Yes I felt so. I think that a lot of them preferred not to use the mathematical equations at that stage. But I felt that for some of the teachers who are working with college students, that it did need that mathematical link.

Did you notice any other aspect of effective communication?
I liked the dialogue aspect of it all. I felt that was valuable because we felt a part of those discussions, even if you weren’t contributing you were listening and picking up different people’s ideas, what you didn’t pick up form one you’d pick up form another.

How would you propose that these workshops should be followed up?
That’s really once again like the students who really depend on the teacher, and where each different teacher is at. May be it need to have some which are specifically set for college level. And some which are specifically set for teachers with little or no experience with teaching physics.

Are you proposing web-forums for teachers with more experience while more follow-up workshops for teachers with less experience?
Yes and they’d probably need to look at may be some other areas, other subject areas in physics.
So do you propose a more interactive element rather than CD roms? 
Personally yes, because, my experience as a teacher is that by the end of the day you are so 

tired that you’re just not going to put the CD rom in and watch it or listen to it. It could be 
useful as a resource. Teachers might look at something like that as a resource to help them 
go back and teach certain aspects if it is six months down the track. But in terms of 
continuing their understanding then I like to be interactive, because it provided networking 
among other teachers as well. So that there is a chance that they can talk with other teachers 
who are teaching physics and that can help build their confidence as well.

So you see peer networks as important? 
I think all peer-networking is important in amongst science teachers, because often you are 
working in the largest faculty would be about five or six teachers and sometimes teachers 
are working with only another one or two. So I think that networking is valuable. 
The teachers who had peers from the same school acknowledged the same. They said they 
had the chance to go back and discuss the workshop and set it in the context and learning 
needs of their students. So do you think that such peer networks should be supported and 
further facilitated?
Yes I agree that could be quite valuable. I think it also doesn’t involve not a lot of driving 
to have to do. And I can thank about that as part of my role.

Are there any shortcomings in the workshop that you would like to mention? How do you 
think they could be best addressed in future? 
One of the things was getting hold of the sheets but they were given out at the last session. 
That was addressed there. It would have been good to have all those experiments and the 
equipment etc, available so teachers could take that and set them up themselves, but that 
did happen. Also given the materials out at the end of each session so if teachers are 
actually covering the unit of work, they could try them out and come back with further 
questions if they have them.

I agree that would support this peer network we were talking about earlier. 
Yes. 
Anything else that you felt the communication at the workshop could address further?
May be a little more description in the advertisement about, what it is and how it’s going to 
help. To possibly encourage more people and make sure it’s directed at the right level of 
teachers, so they know whether it is suitable or not, because that was sort of the questions 
that came up.

Were there other shortcoming teachers raised with you? 
No I don’t think so, I did notice that some didn’t come back so that indicates that perhaps 
they felt that it wasn’t the right level for what they were trying to do and so it would be 
better to try and get people who are the right level and gain the most form it.
Section (A): Identifying if conceptual change has occurred?

Q1. Has the last week changed or had an effect on your ideas about teaching science that you had so far?

It has been fun, entertaining, amazing. It has given us more pangalaman. For example about the candle. When we thought of a candle burning before, we thought that it was the candle that was getting burnt, but now we understood that there is a state change and that it is actually the wax in vapour state that is getting burnt. Activities done in this workshop have made scientific concepts much clearer to us and our misconceptions have been corrected.

We normally directly use formula and text book explanations to teach scientific concepts. But here on the other hand, at the workshop they demonstrated to us how to teach the concepts and thereby understand the meaning of the formulae and definitions, etc. They used simple examples get the concepts across to us. I guess the development of teachers’ competency (viz. teaching efficacy) should come through the development of the way we think (viz. conceptualization) rather than through factual knowledge. The way we teaching in Indonesia is usually by giving factual knowledge rather than by introducing concepts. This leads not only to a lesser quality of awareness but also to students’ lack of creativity.

Q2. How do you feel about using simple activities and materials to teach science? (Would you be more comfortable using conventional methods and textbooks to teach science?)

The simple stuff is easy to get and they are cheap. The materials that we used here is not normally use din Indonesia to teach science.

Q3. Do you think you could use the activities from this workshop back home in Indonesia? Would you need to modify them to suit Indonesian context?

Yes we think it is possible. But up till now we have not been aware of such teaching techniques and therefore, are not familiar with the use if simple materials to teach science in our classrooms. Also our lack of creativity limits us when we have to decide and incorporate such strategies. Yes we like to teach without having to think too much. It is easier that way, with just textbooks and sticking to the syllabus. Here there is a lot of independence involved in teaching. Teachers prepare their own materials to teach lessons, but back home we simply use pre-developed props and aides to teach. There is a preference to this latter style of teaching where we rely on textbooks and other pre-set activities. When it comes to some sophisticated teaching apparatus etc that are costly and come from factories this becomes a problem. Also complete consignments of laboratory equipment are not available in every school. But there are some simple materials that we can obtain easily and use to teach science, like plastic bottles, balloons, etc.
But could you use these materials directly from the workshop in your classrooms or would you have to modify these simple equipment to be relevant to your classrooms?
Yes some of the activities would need to be modified, provided we have the creativity.

Now we have an opened mind towards teaching. We need not always have sophisticated/complicated equipment to teach science, we can use simple materials. These workshop activities have made us more open minded to creativity and broadened the way we think.

Q4. Would your students be comfortable with these new teaching methods?
Yes the students would be happy. They would be more interested in science. They would learn while they are playing and play while they are learning.

But would your high school students appreciate simple activities, wouldn’t they prefer more conventional laboratory experiments instead?

No they would like these kinds of simple experiments that convey basic scientific concepts. Like the experiments that include guessing (viz. POE) where the answer is not what you expected, like the one where the string was cut and we expected it to be in 2 pieces but it was actually one piece.
We think that students in general enjoy practicals in generally. They like it even if it simple. But they need to be structured. Activities for high school students need to have an aim. For example like the experiment to find wavelengths that was done here. It had a good aim. So even though this activity was simple it is god for high school.
The most important thing in learning/teaching is motivation. Teaching should provide students with a motivation to study: why something happens the way it does. These simple experiments provide such a motivation. When you have incited students’ interest to one thing you can guide them to other things. But it is important to start with basic concepts.

Section (B): Was the communication effective to cause the above change?

Q1. Was the lack of Bhahasa a problem for you during the workshop?
No it wasn’t. We know enough English to understand what was said. Also the body language, gesture, the way they moved their hands and their facial expressions (Indo. Isharath), with these things the message got through.
True, but with the more complicated concepts, we had a bit of trouble understanding. But, if it is followed up by practicals/experiments it helps up to understand.

Do you think it would have been helpful if there was a translator? (Q3. Due you think there should be an interpreter, if there are future workshops of this nature?)

Here is the thing. Not only do the presenters use spoken language they also use body language which helps a lot. So better than a translator it would be good if we got a summary/handout of each activity before they spoke to us about it. So that we can first read it and understand it first, or at the end immediately give us a conclusion/summary, before they move to the next activity (viz. written communication to separate oral communication). (Yes, but they gave us handouts). Yes I know, but this is just a suggestion. (This week there has been no problem because Mike has already made
handouts)? But in the case of others, where there was lack of body language and where they spoke fast, it was difficult to understand. But Mike and Sue were ok.

Why do you think they are ok? Mike has a broad accent and Sue has a different way of communicating when compared to Mike. So what do you think they communicated ok? (Q2. What do you think about the presentation styles used Sue, Mike and the other presenters? (Were they clear about what they were saying though they didn’t know Bahasa?))

Because they used body language, controlled the speed of their speech. For important things they stressed, emphasised the meaning and said the thing repeatedly, over and over again.

So do you feel comfortable when they repeat the same things to you?
Yes very comfortable.

Ok, so these examples they spoke to you about when discussing scientific concepts, were they relevant to you, did you find the examples familiar?
Some were some weren’t, some were new. But it is amazing the way they introduced, the explanations they used for some things.

Q4. How do you propose CPAS should follow this workshop? (i.e. Should they use internet discussion boards, e-mails, another workshop in Indonesia/Australia?)
Yes e-mail would be better.
Can you meet after this workshop and have peer-networking?
No we are from different parts and live far away from each other so we can’t have meetings. It is good that we meet like that every year.
But we have annual workshops/training for teachers to, like this one, run by a teachers’ organization.
Perhaps Mike and Sue can come to Indonesia to refresh us about what we have done here (jokingly). Now after this workshop we will try to implement it into our teaching for our students. Perhaps Mike and Sue could evaluate us whether we are becoming better Indo: is it developing). If this PD programs (P3G?) stops here, well I think there is no use. There needs to be continuation and follow up.

Ok, not only back home, but during the workshop, back at your hotel, did you speak with one another and try to clarify points that were not clear to you?
Yes we discussed. If someone didn’t understand or had misconceptions we corrected them. If someone didn’t understand we could explain it again.
Yes we had to make reports of this workshop, so we discussed about the workshop each night.

Do you plan to have cascading workshop for teachers in Indonesia who couldn’t make it to this workshop?
We have come here from a teachers association in Indonesia. Every week we have a meeting for each subject. Mathematics one day per week, biology one day per week. In the meeting we talk about how to increase our teaching skills in the subject. o There are teachers associations where we meet and develop
Appendix 7: Transcripts of Workshop Facilitators’ Interviews

Transcript of interview with Facilitator 1

Q1 What your understandings of Constructivism are?
What we try to do in the workshops is to implement our understandings of Constructivism. So I think it is very important if you are attempting to teach in any way through a constructivist framework that you do understand that you have to have to build on existing knowledge. Now, in teaching teachers that may seem fairly simplistic, because you may assume that they have the existing knowledge that they need to forward into a different view of how they teach, but in fact it has proved not to be the case. And so one of the things we do is to try to establish what their existing knowledge is so far as we can, without too much probing and effort that disturbs the teachers. But we do need to recognise, I think, very clearly that there are misconceptions within the teachers body of knowledge, that we cannot assume everybody shares the same scientific understanding. So my understanding of Constructivism is building very carefully on existing knowledge so far at it can be established, and allowing exploration on the part of the students (i.e. the teachers in the workshops), to explore the topic in a very free way. To feel very comfortable about asking questions so that they feel very safe. So that they can explore their own knowledge in an environment that is not very critical and which allows them to go laterally as well linearly into a topic, and to understand themselves more.

Q2 Are Yager’s recommendations for conceptual change part of the CPAS workshops?
I would like to think they are. An important element of the workshops from our perspective is a very good understanding of where teachers are coming from, not only what their background may be, but also what constraints they have in the classroom. So what we try to do is locate the various activities in that double framework of the teacher’s own world and the world of the classroom that they will be implementing later on, what they have learnt in the workshop. So I think that, we are to some degree teaching for some degree of conceptual change. It may not be radical change in some cases it may in others. But we are certainly applying intelligibility, plausibility, feasibility, fruitfulness ideas of conceptual change theory, and I think if you set up an environment where there is a lot of open discussion, where people are not afraid to say what they think, then you would improve the likelihood that people will indeed move towards a deeper understanding of a topic. And I think that is very important because our experience shows us that within one room of teachers you are going to have quite a variety of understandings in a particular area. And you do have to allow teacher to teacher discussion as well as teacher to facilitator discussion to bring out those differences in understanding.

Q3 Does the workshop address teachers’ understandings individually or as a group?
I think in the end it comes down to individuals. I think that in these workshops it is less of an issue because what we are about there is modelling good practice, as much as we are about the concept itself, and so even when we get teachers who understand the concept very well, so times they haven’t thought of good ways of modelling that good practice. And very often we have very experienced teachers say “this is the first time I’ve really had to think about this at this level” and that’s really good. That act of reflection is encouraged not only through careful exposition of the activities but also through the interaction of the teachers I their groups. And we try to keep the groups small so that in that level of exchange of ideas and knowledge is maintained.
Q4 What is the basis for designing the activities?
The easy place to start is the misconception literature, because that is an area that teachers must address in any topic. So if you can device activities that can expose the misconception and enable people to talk about it and address it then you can hope they will promote conceptual change. That’s a very easy one. But not all our activities in that category. Other activities are there to illustrate other things that we believe is very important in teaching. One of those is to use simple equipment. Another of those is to model good group interactions in learning. Another of those is to understand that other elements such as history of science, use of humour, various elements we believe are important in science communication translate into the workshops themselves. Now that’s not as ad hoc as it may appear because we do have a very long and strong history of hands-on and science shows here in Australia on which to build those kinds of understandings. So we have drawn very much on the science centre tradition here, which is a science communication tradition rather than a teaching tradition, to understand what makes science engaging and accessible and to some degree entertaining. So we’ve try to combine those two traditions of: an understanding of the research in the formal sector and an understandings of what it is that makes science accessible and appealing and put those together so that each activity we do is carefully structured to model some element of that. In some cases more than one element of that. That’s quite overt in our design. It’s not haphazard at all. Each activity is chosen with something in mind.

Q5 So is this element explicit or implicit to the teachers?
We usually mention what we think is important abut the activity. We may not labour the point. We do certainly say at some point in the prior advertisement or some point of the workshop itself that the activities are designed to model good teaching practice. We do try to make it clear to the teachers what we are about, that the activity has something beyond the simple use of the thing. I think that is important too because if teacher can see a rationale for doing something beyond simple activities I think that the transferability of the idea is enhanced. I would like to think that these workshops are not a set of activities and when they are done that’s the end of the matter. I would hope that’s not the way it works.

Q6 Take me through the design of an activity.
I’ll take the simple case of a misconception and knowing what the misconception is, and then what we would probably do is to try to show them that such and such is not the case. So we would look very carefully at the misconception literature so we understood what the problem was and then at the physics texts to make quite sure that we understood the source of the problem, what it was about the presentation in traditional physics or chemistry that was not illuminating this concept properly…try to understand form where the misconception was arising, so that we have a handle and can communicate with the source of the misconception. Next, we have a vast amount of activity books, so would scan those first, and if we think there is nothing suitable there to take or adapt to illustrate the problem, we would then have to design from scratch. That would be probably a minority case where we absolutely start form scratch. Most of the time we do get inspiration form other sources. Most of the time we don’t take the activity directly. We would say “that one is in that area, can we now work with that design to modify it, change it in someway, so that we can use it to clearly illustrate whatever it is we are trying to show… It is very often with the application of the science that we can find a way of showing something important. So where in the real world, because that is an important element of Constructivism: relevance, where this thing applies in the real world, so what we try to do is to draw on those various
knowledges to locate the activity first of all in the area of real world relevance, then to look at the science behind it, then to point out where students and often teachers, are likely to not understand or to misunderstand, and then to workout with the teachers ways to re-illuminate their understandings. Real world application is an important element. That I think is a really critical elements of the things we do. The buoyancy shows are a classical example, of taking one single principle and working through 20-40 minutes showing where the concept applies. So it is not haphazard. As a model I think it really points to the fact that professional development have to do two things: to understand the classroom environment and what is useful and what constraints teachers are under and difficulties they face and what their background is. The second thing is to be able to draw on a range of knowledge which the teacher could access, but to access that takes a lot of time and knowledge teachers don’t have. So you are bringing things that their training has not really delivered for them… So when we are giving the workshops, what we are trying to do is to simplify the process for them. To help them, how to get these other pieces I’ve mentioned integrated into the activities in a way that makes sense to them and will make sense to their students. If you don’t, what you are doing is repeating what is known in the teaching domain, and so you are not actually bringing in a new means of their becoming better at the job, because you are only drawing from what’s already available. I think that’s the difference: communicating it is the key but communicating it in a way that relates to the general communication of science not the communication of teaching science, but the communication of science as a whole.

Transcript of interview with Facilitator 2

Q1 What is the basis for designing the activities?
Think of an activity and then introduce the concept. Textbooks are absolutely full of activities, small experiments and things. The teachers quite often go out and buy activity books. And then they do the activity and it doesn’t work, the way it is supposed to work. And they immediately come to the conclusion that what is wrong is them. We say no and show the examples. Look the lemon battery they say… you put a piece of copper in you put a piece of aluminium in, the you connect wires to then and you connect it to a 5 volt globe and it’s supposed to light. The picture in the book shows it lighting. But it doesn’t light. One thing we’ve learnt form that is we come to the conclusion that people who write activity books don’t actually check out what they are writing about…Teacher say “I assumed it was me that was wrong”. I’ve spent hours sometimes tying to get things to work like in the book.

Q2 Take me through the design of a workshop activity.
This particular demonstration was to get round the problem that when you ask a child “why does something float?” they say “because there is air in it”. It in fact is not the only reason. In fact sometimes that can be wrong. What you get is one of those old ball-cocks you used to get in toilets. They float on the water with an arm and as the water level inside increases, it turns the switch off. In the olden days those were made of copper… hollow copper balls… This activity from a particular book said, if you drill a hole where the rod fits the ball, and you put a thread in so that you can fit in a high pressure valve from a bicycle, you can then pump air into it, and of course because of the bicycle valve the air will go in but it won’t come out… it’s a very tricky experiment to do. I did it one day. You actually put lead shot in the ball… until when you put the ball in the water only the top part of the valve
floats above the water. In other words, it only just floats. You then take it out and you screw the valve in and you say “now, if I put more air in, it should float higher, it should float better”. And the kid says “yes, right”. So you pump air in… Now of course what everybody knows is air has a particular weight… so you are increasing the weight of the ball. So what the demonstration is getting at, is when you put the ball back in the water, it should sink… I made a ball and put air into it… and do you know what happened? The ball didn’t sink, it actually floated higher, supporting the misconception it came up… It took me about an hour to work out what was going on. I put about 200 puffs of air in there, so there was quite a large volume of air in there. So it should be a lot heavier. Indeed it was. But the pressure inside that copper ball had increased quite a bit, just like pumping up a bicycle tyre… In fact the pressure caused it to get bigger. As a result when it went into the water, it displaced more water and increased the buoyancy force, so it came up. Yes, it did weigh more, but the buoyancy force increased due to the fact that it expanded, due to the increased pressure… I saw in a flash that the person who had written the experiment had actually never done the experiment. If he had he would have observed exactly what I had observed. And I tell this to the teachers… I’ve done that many times, and they say “that’s amazing”. And they say “now actually I fell much better. The next time the experiment doesn’t work the way a book says… I won’t automatically think it is me.” The come away quite empowered by the workshop, not so much about the science, but what it does is to communicate science, the science of the real world. What they really feel good about is that they don’t need to know everything about every question. They feel confident, that if they don’t know the answer to say “let’s go and find out”…

Q3 Is there anything else you would like to share?
One things that has been very important… we actually, not only get to talk about the science, and what’s involved, and how it connects with the everyday, but we are able through these workshops to give the teachers confidence. We point out to them, that quite often, many times textbooks are wrong. They print things which are just not right… these errors go down through the years. Many teachers believe implicitly in these books: they can be wrong. We say “occasionally they are” and we show them examples. And they “really”… One of the problems teachers say they have is “we can’t answer all the questions”. We say “nobody has all the answers to all the questions”… the important thing is finding out how to find the answer. So one of the things we try to do in these workshops is to give them confidence.