

**Learning about Astronomy: a case study
exploring how grade 7 and 8 students
experience sites of informal learning in
South Africa**

Anthony Douglas Lelliott

**A thesis submitted to the Faculty of Humanities, University of the
Witwatersrand, Johannesburg in fulfilment of the requirements of the
degree of Doctor of Philosophy.**

Johannesburg 2007

Table of Contents

Abstract	i
Keywords	ii
Declaration	iii
Acknowledgements	iv
Table of Contents	v
List of Appendices	ix
List of Figures	x
List of Tables	xii
Abbreviations	xiv
1 Introduction to the study	1
1.1 Introduction	1
1.2 Background and Rationale for the Study	1
1.3 Research Problem and Research Questions	4
1.4 Conceptual Framework	6
1.5 The Researcher and Positionality	6
1.6 Structure of the Thesis	8
2 Literature Review	10
2.1 Introduction	10
2.2 Research in Science Education	10
2.3 Astronomy Education	15
2.3.1 Research in Planetaria	23
2.4 Informal Learning	25
2.5 Edutainment or Entercation?	28
2.6 Science communication and science literacy	31
2.7 Learning in museums and science centres	33
2.8 Theoretical Framework	37
2.8.1 The Contextual Model of Learning	37
2.8.2 Human Constructivism	39
2.8.3 Conceptual Change	45
2.9 Summary	47
3 Research Design and Methodology	49
3.1 Introduction and Overview	49
3.2 Methodology	50
3.2.1 Paradigms of Research	50
3.2.2 A Case Study	51
3.3 Research Instruments	54
3.3.1 Personal Meaning Mapping	55
3.3.2 Interview Schedules	59
3.3.3 The pre-visit interview schedule	59

3.3.4	The post-visit interview schedule	61
3.3.5	Interviews	61
3.4	Data Collection	62
3.4.1	Selection of the Study Sites	62
3.4.2	Selection of the Participants	64
3.4.3	Triangulation	67
3.5	Ethical issues	68
3.6	Issues of credibility and trustworthiness	71
3.6.1	Validity	71
3.6.2	Reliability	72
3.6.3	Reflexivity	72
3.7	Reflection	73
4	Setting the Scene – a narrative of the visits	74
4.1	Introduction	74
4.2	A visit to Hartebeesthoek Radio Astronomy Observatory	77
4.2.1	Before the visit	77
4.2.2	“Planets and stars and like, well, space”	79
4.2.3	The Sun, Whispers and Rockets	82
4.2.4	Break with Gravity	87
4.2.5	Taking the Solar System for a Walk	89
4.2.6	Landing on the Moon	91
4.2.7	The Telescope and Control Room	93
4.2.8	After the visit	95
4.3	Discussion	96
4.4	A visit to the Johannesburg Planetarium	99
4.5	Discussion	106
5	An Analysis of Collective Learning	108
5.1	Introduction	108
5.2	The Research Sample	108
5.3	Learning in Science Centres	111
5.4	Big Ideas	113
5.4.1	Gravity	113
5.4.2	Stars and the Sun	116
5.4.3	Solar System	118
5.4.4	Size and Scale	119
5.5	Significant Ideas	120
5.5.1	Day and Night	120
5.5.2	Phases of the Moon	122
5.5.3	Dominant Artefact: Parabolic/Satellite Dish	122
5.6	Coding for Big Ideas	123
5.6.1	Helen and gravity	126
5.6.2	Helen and stars	128
5.6.3	Helen’s conception of the Sun	129
5.6.4	Helen’s conception of the solar system	129
5.6.5	Helen’s conception of size and scale	130
5.6.6	Helen’s understanding of day and night	130
5.6.7	Helen and the phases of the Moon	131

5.6.8	Sipho and satellite dishes	132
5.7	The Extent of Learning	133
5.7.1	Preparation for, anticipation of and knowledge regarding the visit	134
5.8	Knowledge about Big Ideas in astronomy prior to the visit	138
5.8.1	Gravity	138
5.8.2	Stars and the Sun	143
5.8.3	The Solar system	146
5.8.4	Size and scale	147
5.8.5	Day and Night	150
5.8.6	The Moon Phases	155
5.8.7	Parabolic/Satellite Dishes	156
5.9	Summary of collective learning	157
6	A Human Constructivist Analysis of Learning	160
6.1	Introduction	160
6.2	Human Constructivism and Conceptual Change	161
6.3	Cognitive Domain	163
6.3.1	Addition	163
6.3.2	Emergence	165
6.3.3	Differentiation	166
6.3.4	Discrimination	167
6.3.5	Recontextualisation	168
6.3.6	Superordinate Learning	169
6.4	Affective Domain	171
6.4.1	Enjoyable	171
6.4.2	Germane	171
6.4.3	Salient	172
6.4.4	Wonder	172
6.5	Conative Domain	173
6.6	Coding for Human Constructivist categories	175
6.7	Problems encountered with the coding process	175
7	How individual students learnt about astronomy (1)	178
7.1	Introduction	178
7.2	The Schools	178
7.2.1	Balfour Forest School (BFS)	178
7.2.2	Lourdes Girls School (LGS)	179
7.2.3	Achievement School (AS)	179
7.2.4	Bokamoso School (BS)	179
7.3	Big Ideas and Individual Learning	180
7.4	Use of Astronomy-Related Vocabulary	185
7.5	The Students	187
7.5.1	Portrait of Nonkululeko (swo26)	188
7.5.2	Portrait of Botho (tsw04)	195
7.5.3	Portrait of Neo (swo42)	202
7.5.4	Portrait of John (vho 16)	211
7.6	Discussion	221

8	How individual students learnt about astronomy (2)	223
8.1	Introduction	223
8.1.1	Portrait of Fatima (scf15)	223
8.1.2	Portrait of Brenda (swo70)	231
8.1.3	Portrait of Helen (scf11)	240
8.2	Discussion.....	248
9	Discussion and Implications	251
9.1	Introduction	251
9.2	Big Ideas in astronomy	252
9.2.1	Gravity.....	252
9.2.2	Stars and the Sun	253
9.2.3	The Solar System.....	254
9.2.4	Size and Scale.....	255
9.2.5	Day and Night	256
9.2.6	Moon Phases	256
9.2.7	Satellite/Parabolic Dish	257
9.3	How Learning Occurs.....	258
9.3.1	Cognitive Learning.....	258
9.3.2	Affective and Conative Learning	262
9.4	Methodological Findings.....	265
9.4.1	Issues in Interviews	265
9.4.2	Personal Meaning Mapping as a technique for data collection	269
9.5	Misconceptions.....	271
9.6	Science Literacy	275
9.7	Role of Vocabulary.....	275
9.8	Critical Reflection of the Research Process	276
9.9	Conclusions and recommendations	277
9.10	Future Research	280
9.11	Endpiece	281
	References.....	283
10	Appendices	297

Abstract

All students are able to learn something about astronomy when they participate in a school visit to a site of informal learning such as a science centre. I examined how children from four schools experienced presentations and participated in activities about astronomy during a two to four hour visit to either the Hartebeesthoek Radio Astronomy Observatory or the Johannesburg Planetarium in South Africa. The case study involved observing thirty-four 12- to 14-year-old students at the science centre and interviewing them about astronomy concepts including those based on personal meaning maps they drew prior to and after their visit. The data were analysed using a human constructivist framework to determine both what and how students learnt during their visit.

Despite a lack of teacher involvement I show how students collectively and individually learnt about concepts in astronomy, which I categorised into a set of seven Big Ideas: gravity, stars and the Sun, size and scale, the Solar System, day and night, Moon phases and parabolic dishes. Collectively, there was an improvement in their knowledge of Big Ideas dealt with at the study sites, including gravity, stars, the Sun, size and scale, and parabolic dishes. The students showed little change in their knowledge of day and night or the phases of the Moon. Individually, all students learnt principally by incremental addition of knowledge, while some students also demonstrated greater knowledge restructuring. Students with the least prior knowledge added additional basic facts to their repertoire, while those with greater prior knowledge were able to reorganise their knowledge and achieve greater understanding. All students also showed that the affective domain (for example enjoyment and wonder) contributed to their learning by encouraging interest in astronomy. Some students demonstrated examples of conative learning in which their experiences prompted them to further action after their visit. While the visit changed the misconceptions of some students, it made little difference to others, and promoted misconceptions in a few. Methodological findings included the value of using personal meaning maps, the importance of using models during the interview process and observations of how students used language in their description of astronomical processes.

The study suggests that students learn best from a range of activities clustered around a central theme, and that enjoyable activities appear to enhance learning. I recommend that the astronomy presented at the centres focus on a limited number of concepts in astronomy, and that presentations and activities be structured around those Big Ideas. Science centres

should provide teachers with guidelines for their visit. I also propose that activities aim to recall students' prior knowledge and provide situational interest to encourage motivation in the topic of astronomy and the subject of science. Finally I suggest that science centres should combine cognitive learning with affective fun, as recommended by students participating in the study.

Keywords

Astronomy, Astronomy Education, Constructivism, Human Constructivism, Informal Learning, Museum, Planetarium, Science Centre.

List of Appendices

Appendix A	298
Appendix B.....	299
Appendix C.....	302
Appendix D	305
Appendix E.....	308
Appendix F	309
Appendix G	311
Appendix H	312
Appendix I.....	313
Appendix J.....	314
Appendix K	323

List of Figures

Figure 1.1	Current foci of research into visitor studies (Rennie, 2001).....	5
Figure 2.1	The Contextual Model of Learning (Falk and Dierking 2000).....	38
Figure 2.2	Concept Map of Human Constructivism (after Mintzes and Wandersee 1998).....	42
Figure 3.1	A Personal Meaning Map constructed by Bhekiwe.....	56
Figure 3.2	Example of initial PMM drawn on chalkboard	58
Figure 3.3	The sequence of events in data collection	67
Figure 4.1	The Turntable.....	80
Figure 4.2	Moon Phases	82
Figure 4.3	Projection of the Sun	83
Figure 4.4	Sundial	84
Figure 4.5	Whisper Dish and Telescope	85
Figure 4.6	Launching Rockets	87
Figure 4.7	Coke cans and gravity.....	88
Figure 4.8	Cosmic Pinball.....	89
Figure 4.9	Taking the Solar System for a walk: the Sun	90
Figure 4.10	The Second South African in Space	92
Figure 4.11	The radio telescope at HartRAO.....	94
Figure 4.12	Zeiss star projector in the planetarium.....	100
Figure 5.1	Student preparation for the visit (n=34).....	136
Figure 5.2	Student anticipation of visit. Some students gave more than one purpose, so the totals do not add to 100%	137
Figure 5.3	Students' conceptions of gravity (Pre-visit: n=28; post-visit: n=27).....	140
Figure 5.4	Students' ideas of gravity on Jupiter (n=24).....	142
Figure 5.5	Students' ideas of gravity on the Moon (n=25)	143
Figure 5.6	Students' conceptions of stars (n=34).....	144
Figure 5.7	Students' conceptions of the Sun (n=34).....	145
Figure 5.8	Students' conceptions of the Solar System (n=8).....	147
Figure 5.9	Students' conceptions of size and scale.....	148
Figure 5.10	Students' knowledge of the size of the Sun and Moon (n=34 pre-visit, n=29 post-visit).....	150
Figure 5.11	Students' conceptions of the cause of day and night (n=34)	151
Figure 5.12	Students' explanation of Moon phases (Pre-visit n=34; post-visit n=19)	156
Figure 5.13	Students' conceptions of parabolic/satellite dishes (n=26; only HartRAO students).....	157

Figure 5.14	Summary of percentage changes in levels for 5 Big Ideas.....	158
Figure 5.15	Summary of percentage changes in levels for significant ideas and dominant artefact.	158
Figure 6.1	Part of Brenda’s post-visit Personal Meaning Map.....	164
Figure 7.1	Scattergram of students’ pre- and post-visit mean scores	181
Figure 7.2	Graph showing students across the range of learning about whom portraits are written.....	183
Figure 7.3	Nonkululeko’s pre-visit Personal Meaning Map.....	190
Figure 7.4	Nonkululeko’s post-visit PMM	192
Figure 7.5	Botho’s pre-visit PMM	197
Figure 7.6	Botho’s post-visit PMM	199
Figure 7.7	Neo’s PMM (pre and post)	204
Figure 7.8	John’s pre-visit PMM	214
Figure 7.9	John’s post-visit PMM.....	216
Figure 8.1	Fatima’s PMM (pre- and post-visit)	226
Figure 8.2	Brenda’s PMM (pre and post)	234
Figure 8.3	Helen’s PMM (pre and post)	243

List of Tables

Table 1.1	Research avenues as proposed by Rennie and colleagues (2003) that I used in my study.	3
Table 1.2	School groups as a fraction of total child visitors.....	4
Table 2.1	List of peer-reviewed studies of astronomy education research since 1975...	16
Table 2.2	Numbers of articles related to planetaria in databases.....	23
Table 2.3	Wellington’s (1990) classification of learning	26
Table 3.1	Key concepts in astronomy identified at each study site	60
Table 3.2	Participant schools in the study	66
Table 3.3	Informed consent returns	68
Table 4.1	Relationship of data sources to criteria for constructing narrative	76
Table 5.1	Demographic information on sample of students.....	110
Table 5.2	Big Ideas used in my study	113
Table 5.3	Criteria for assigning students to knowledge categories for Big and Significant Ideas and the Dominant Artefact.....	124
Table 5.4	Responses to Question B1 and B2: Where are you going/did you go on the forthcoming visit? What subject and topic area is/was the visit related to?	134
Table 5.5	Purpose of visit: Responses to Question B3: What do you think is/was the purpose of the visit?	135
Table 6.1	Knowledge Construction categories defined in my study	162
Table 7.1	Categorisation scheme for students (n=34) based on their pre- and post-visit knowledge of Big Ideas concepts.	184
Table 7.2	Categorisation scheme showing student numbers from each school.....	185
Table 7.3	Summary of increase in astronomy-related vocabulary shown by students (n=34)	186
Table 7.4	Mean number of astronomy-related words used by students in the pre-visit and additional words used in post-visit PMMs categorised by Big Ideas scores	187
Table 7.5	Students selected for whom portraits were written, using the categorisation scheme of students developed in Chapter 6.	187
Table 7.6	Position of Nonkululeko on Big Ideas classification table.....	188
Table 7.7	Nonkululeko’s knowledge of Big Ideas.....	188
Table 7.8	Frequency of Human Constructivism codes for Nonkululeko	194
Table 7.9	Position of Botho on Big Ideas classification table	195
Table 7.10	Botho’s knowledge of Big Ideas.....	195
Table 7.11	Frequency of Human Constructivism codes for Botho	201

Table 7.12	Position of Neo on Big Ideas classification table	202
Table 7.13	Neo’s knowledge of Big Ideas.....	202
Table 7.14	Frequency of Human Constructivism codes for Neo	210
Table 7.15	Position of John on Big Ideas classification table	211
Table 7.16	John’s knowledge of Big Ideas.....	211
Table 7.17	Frequency of Human Constructivism codes for John.....	220
Table 8.1	Position of Fatima on Big Ideas classification table.....	223
Table 8.2	Fatima’s knowledge of Big Ideas	223
Table 8.3	Ways in which Fatima changed her ideas about concepts.....	227
Table 8.4	Frequency of Human Constructivism codes for Fatima	229
Table 8.5	Position of Brenda on Big Ideas classification table	231
Table 8.6	Brenda’s knowledge of Big Ideas.....	232
Table 8.7	Ways in which Brenda changed her ideas about concepts	235
Table 8.8	Frequency of Human Constructivism codes for Brenda.....	239
Table 8.9	Position of Helen on Big Ideas classification table	240
Table 8.10	Helen’s knowledge of Big Ideas.....	240
Table 8.11	Frequency of Human Constructivism codes for Helen.....	247
Table 9.1	Summary of cognitive learning by case study students.....	258
Table 9.2	Summary of affective and conative learning by case study students	263
Table 9.3	Activities at HartRAO which resulted in affective learning.....	263
Table 9.4	Presentations at the planetarium which resulted in affective learning.....	264

Abbreviations

AS	Achievement School
BFS	Balfour Forest School
BS	Bokamoso School
CCM	Conceptual Change Model
CML	Contextual Model of Learning
GET	General Education and Training
HartRAO	Hartebeesthoek Radio Astronomy Observatory
HC	Human Constructivism
HSS	Human and Social Science
HU	Hermeneutic Unit
IK	Indigenous Knowledge
LGS	Lourdes Girls School
MLC	Museum Learning Collaborative
NARST	National Association for Research in Science Teaching
NASA	National Aeronautics and Space Administration
NRF	National Research Foundation
NS	Natural Science
PCK	Pedagogical Content Knowledge
PMM	Personal Meaning Map
RNCS	Revised National Curriculum Statement
SALT	South African Large Telescope
SD	Standard Deviation

Chapter 1

1 Introduction to the study

This chapter provides an overview of the study, why it was conducted, how the research questions are framed conceptually, the researcher's positionality and the sequence of the chapters.

1.1 Introduction

Astronomy can be regarded as a relatively familiar discipline for students and their teachers, as it crosscuts the subjects of science, technology, geography and history and can be used as a unifying theme for project work in schools. For some phenomena, such as day and night, star constellations, the seasons and the phases of the moon, direct observation is simple and practical. However, what makes the study of astronomy more challenging are the non-intuitive, relatively complex and abstract explanations needed to elucidate the observations. A further attraction of astronomy as a discipline is the fact that it asks some of the 'big questions' in science and philosophy, such as "Are we alone?" and "Where do we come from?" While the asking of such questions is sometimes encouraged by more innovative teachers, astronomy is a topic which lends itself to practical and out-of-school approaches where children can experience the study of the universe or the force of gravity in a more authentic context than that of the classroom. This thesis explores what processes of learning take place when a school student goes outside the classroom and experiences the presentation of astronomy concepts in an informal setting. What does she learn? How does he learn about it? How does their prior knowledge influence their learning?

1.2 Background and Rationale for the Study

Many children's natural interest in space and the stars has been identified as a way of encouraging them into the sciences (e.g. Jarman & McAleese, 1996). However, participation and achievement in science at secondary school level in Southern Africa are not as high as education authorities, employers and institutions would like (Department of Education, 2000). As the history of science education research shows, understanding learning and developing better pedagogy to assist in the learning of the sciences has been a major aim of science educationists over the past twenty-five years. As I demonstrate in the

literature review in Chapter 2, most research in astronomy education has examined students' conceptions and misconceptions. The aim of the empirical study described in this thesis is to understand how children learn, not in the classroom, but in the informal settings of a planetarium and the visitors' centre of an observatory. The research falls within the general frameworks of visitor studies and learning at museums and science centres, which have developed over the past thirty years. Research into this type of learning is particularly important in South Africa for a number of reasons. First, very little research has been carried out in South Africa on visitor studies. Secondly, if science and technology are to develop in South Africa as envisaged by the government (Department of Arts Culture Science and Technology, 1996), then both the Public Awareness of Science and the attraction of larger numbers of school children into science-related subjects are high priorities for research. Thirdly, scholars such as Gardner (1993) suggest that present day formal schooling has become less significant for the majority of young people. Although this may not be as true in South Africa as it is in the USA, the kind of informal learning that takes place in a planetarium, museum or science centre is important to study precisely because such institutions can provide motivation for students and can engage them in the kind of 'big ideas' in science referred to in Chapter 5. Interest in learning in science centres is gaining a higher profile in South Africa, as the number of science centres increases, and both the government and donors question the impact that such science centres can make.

In Southern Africa, astronomy is important for other reasons. Due to the fact that we are situated in the southern hemisphere, have wide sky coverage, lie longitudinally close to the Greenwich meridian, have relatively sophisticated communication facilities, and have relatively low levels of light pollution, we are positioned favourably to contribute to the science of astronomy on a global scale (Square Kilometre Array, nd). The establishment of the South African Large Telescope (SALT) at Sutherland in the Northern Cape Province and the current bid for the Square Kilometre Array (a massive radio telescope) are both examples of recent initiatives by government and the private sector which highlight the country's commitment to astronomy. Political commitment has been forthcoming too; in his speech opening parliament in 2004, President Thabo Mbeki referred to the development of Southern Africa as a global hub for astronomy, space science and technology, while the Minister of Science and Technology has mentioned important developments in space science and astronomy in his budget speech in 2006 (Department of Science and Technology, 2006). Together, these activities and

undertakings reflect a growing profile of astronomy within South Africa which provides further motivation for conducting research into astronomy education.

Over the past decade, museum practitioners and scholars have attempted to define an agenda for research at sites of informal learning. Leona Schauble and colleagues at the Museum Learning Collaborative (MLC) have proposed a sociocultural agenda (Schauble, Leinhardt & Martin, 1997) for ‘general’, non science-specific sites, while others have suggested a science-specific framework (Martin, 2001, 2004). However, a number of informal learning researchers have proposed a wider agenda based on the National Association for Research in Science Teaching (NARST) Policy Statement on Informal Science Education (Rennie, Feher, Dierking & Falk, 2003). This wider agenda embraces other theoretical frameworks for research in addition to the sociocultural approach espoused by the MLC. Rennie and colleagues identify six avenues for future research, and when planning and conducting my research I broadly aligned my objectives with three of the avenues proposed in the Rennie agenda to ensure that my study was both relevant and current. Table 1.1 shows the three avenues together with the respective NARST policy statements and how I addressed the issue in my own study.

Table 1.1 Research avenues as proposed by Rennie and colleagues (2003) that I used in my study.

Research avenue	NARST policy statement	My study
Examining the precursors to the actual engagement in learning.	Out-of-school learning is self-motivated, voluntary, and guided by learners’ needs and interests, so certain aspects of learning are critical to investigate.	I examined how students’ interests, prior knowledge and beliefs affected the learning experience at the science centre – see Chapters 7 and 8.
Investigating the process of learning.	Learning is both a process and a product so we need to investigate both the processes of learning as well as the products.	I examined <i>what</i> students learnt about astronomy (see Chapter 5) as well as <i>how</i> they learned (see Chapters 6 to 8)
Expanding the variety of methods used to carry out our research.	Informal learning requires multiple creative methods for assessing it. ...Innovative research designs, methods, and analyses are critical.	I used Personal Meaning Mapping as one research tool, analysed my data qualitatively using the software program ATLAS.ti and used narratives and portraits as ways of sharing my findings.

Most of the current research into museum and science centre learning takes place in developed countries, where interest has focused on general visitors, family-group learning, and to a lesser extent school visits (Falk & Dierking, 2000). Table 1.2 shows approximate percentages of child visitors in the form of school groups from museums and science centres in Europe, the USA and New Zealand compared with three sites in South Africa, two of which were the locations for my study. The table shows that the proportions of children visiting in school groups in South Africa are much higher than overseas. I therefore considered that school groups, which would include a broad spectrum of children representative of the demographics of the population of South Africa, would be the most appropriate sector in which to target my study.

Table 1.2 School groups as a fraction of total child visitors

Location	Percentage of total children in organised school groups	Source
Natural History Museum, London, UK.	10	(Hawkey, 2001)
Jodrell Bank Visitors' Centre, UK.	23	(Chaplin, 1997)
Observatory Science Centre, UK	33	(J. Harris, pers. comm.)
Exploratorium, San Francisco, USA	<25	(Exploratorium, 2006)
Stardome Observatory, NZ	50	(A. Buckingham, pers. comm.)
SciBono Discovery Centre, Johannesburg, SA	75	(SciBono statistics 2005)
Johannesburg Planetarium, SA	75	(Johannesburg Planetarium statistics 2000-2004)
Hartebeesthoek Radio Astronomy Observatory, SA	89	(HartRAO statistics 2002-2004)

1.3 Research Problem and Research Questions

At school level, basic astronomy has traditionally been taught as part of geography in the old curriculum (prior to 1990), and later as part of Human and Social Science. With the advent of the new curriculum introduced in 1997 and its subsequent revision as the Revised National Curriculum Statement (Department of Education, 2002) astronomy was transferred to the learning area of Natural Science, and given a more prominent place in the

curriculum as part of the ‘Our Place in Space’ in the ‘Planet Earth and Beyond’ knowledge strand. With the change in curriculum being such a recent development, there is little or no published research concerning how astronomy is being currently taught and learnt in South African schools. When teaching astronomy, some teachers have opted to run a school field trip to a science centre which covers the topic, either as a support or a replacement for their own teaching. When developing my proposal for my doctoral research I was interested in how both students and their teachers gained from the experience of visiting a science centre related to the topic of astronomy. I developed research questions to investigate the extent to which learning takes place at such centres, and how what is taught relates to the school curriculum. As the research progressed, I realised that most teachers who arranged a visit for their students did not themselves participate to any great extent in the teaching and learning process either before, during or after the visit, and I decided therefore to focus on learning by the students only (see Section 3.4.2).

Science centres are a specialised form of museum in which interactive displays are arranged thematically (McManus, 1992), and fall under the broad area of museum or visitor studies. Within this field, my area of study is visitor learning, as shown in Figure 1.1

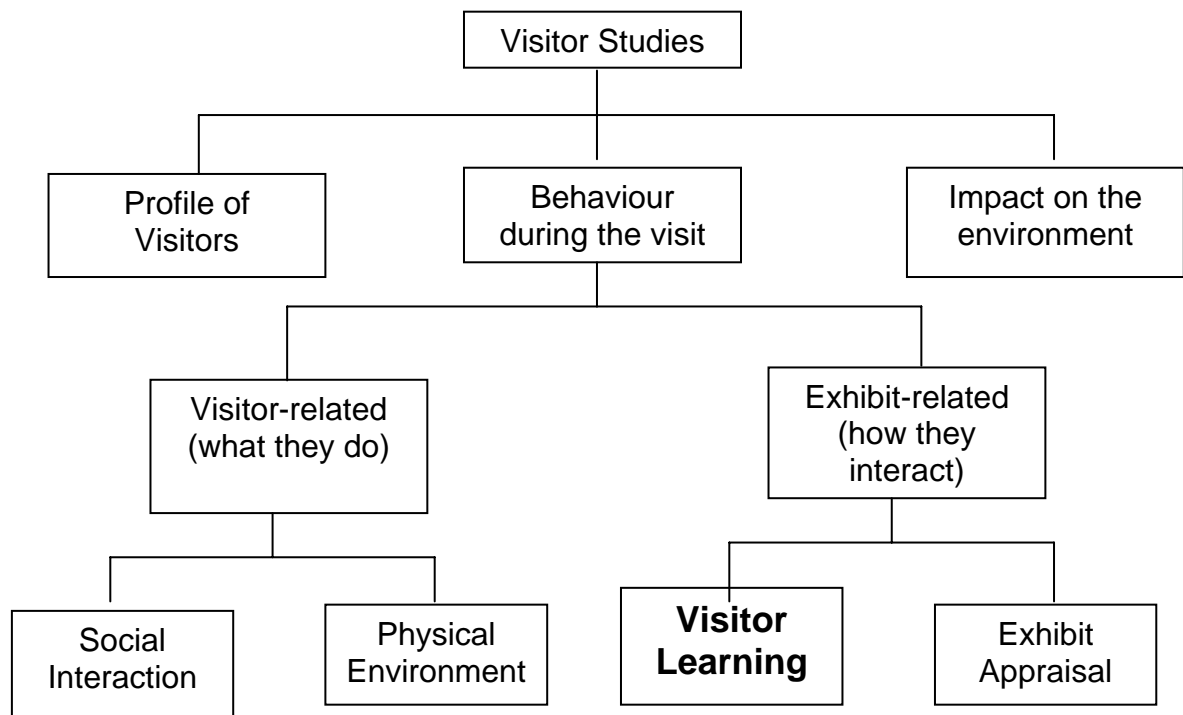


Figure 1.1 Current foci of research into visitor studies (Rennie, 2001)

The learning sites that I chose were the Johannesburg Planetarium on the campus of the University of the Witwatersrand, and the Hartebeesthoek Radio Astronomy Observatory some 50km West of Pretoria, South Africa.

My final research questions were defined as follows:

1. To what extent do students learn in the process of a visit to a planetarium or the visitors' centre of an astronomical observatory?
2. How is the content of astronomy communicated to students?
3. What are students' individual experiences of the visit?
4. How do students construct knowledge during and after the visit?
5. How do students' interests and prior knowledge affect the learning experience of a school visit?

1.4 Conceptual Framework

The study is informed by the notion of informal learning as involving an out-of-school, unstructured, voluntary activity (Crane, 1994). It is further informed by John Falk and Lynn Dierking's Contextual Model of Learning (Falk & Dierking, 2000) that identifies the personal, sociocultural and physical contexts as significant features of the environment which interact to influence learning in museums. I also use the concept of human constructivism (Mintzes, Wandersee & Novak, 1997) as a theoretical construct in which to embed the research and to explain how children learn at sites of informal learning. Although based on constructivism, I adopt a 'modest realist' stance (Osborne 1996), which I elaborate on in sections 1.5 and 2.2. Modest realism combines the advantages of a constructivist theoretical framework in the area of student learning, while at the same time recognising that there is an ontological reality, which has been established by scientists by repetitive and routine confirmation. It is this reality that students are learning about in science, assisted by their visit to the science centre.

In Chapter 2 I show that despite the considerable research into astronomy education and informal learning over the past thirty years, no studies combine the two fields, and my use of a human constructivist theoretical framework focusing on student learning makes my study both unique and an important contribution to the literature.

1.5 The Researcher and Positionality

The research I conducted falls within a qualitative, interpretivist paradigm (see Chapter 3). According to qualitative researchers such as Tobin (2000) and Henning (2004), it is

important in interpretive research for the researcher to provide a clear account of who he or she is, and how he or she has influenced the results by engaging in the research process. Positionality is defined as the “knower’s specific position in any context as defined by race, gender, class, and other socially significant dimensions” (Maher & Tetreault, 1994 p. 22). The following paragraphs portray me as the researcher, and attempt to show how my positionality may have interacted with the research conducted.

I am a white male living in Johannesburg, South Africa. Born in the United Kingdom, I have always been interested in amateur astronomy, and, along with many of my generation, the Apollo missions fired my imagination regarding space travel and research. However, my main interest as a youth was a passion for ornithology. Together with two friends, I would spend hours visiting sites of ornithological interest, recording the number and types of birds seen, and we would compare notes with other enthusiasts. Although an obsession during my teenage years, by the time I went to the University of Durham, I had decided to pursue Geology as a degree. One of our courses was in lunar geology, and it was very exciting to see the recently acquired moon rocks with which some of the professors were working. After leaving Durham I worked as a ‘conservation geologist’ for six months before leaving for Nepal, where I studied Himalayan Pheasants as part of a conservation project there. I wrote up the results of this study as a Masters thesis when I returned to the UK and subsequently completed a teacher training course. I taught in a Sixth Form College in Essex for three years before applying for a job teaching in Botswana.

I lived in Botswana for 10 years, married there and worked in the area of science teacher education in a rural college of education. I moved to Johannesburg in 1995, a year after the end of apartheid, and took a job at the University of the Witwatersrand running teacher upgrading programmes. With an education grounded in the sciences and teaching in the disciplines of geology, biology, environmental science and science teaching methodology, my outlook has been strongly influenced by positivist science views. However, since teaching in a university I have been able to interrogate these to some extent, as my teaching style has always been broadly constructivist, attempting to determine what prior knowledge students possess and scaffolding their learning towards the goals of the course. My basic premise is that in science there is a real world out there which can be investigated, so I would regard myself as a ‘modest realist’ (Osborne 1996). While I accept the relativist position of constructivism can assist students in learning,

whereby the teacher needs to work with learners' views, I would still maintain that some of those views might be misconceptions, and part of the teacher's role is to move those conceptions towards more scientific ones. How this is done is crucial for the learner, and some of the discussion in this thesis examines ways in which misconceptions can be used positively as a basis for a progression towards a more scientific understanding of a concept.

My modest realist stance means that I have some misgivings about embracing views of indigenous knowledge (IK) and worldview theory currently popular in the literature. While I consider it important to value and acknowledge indigenous knowledge as part of what has historically been developed and used in South Africa, IK should not be confused with science, which has completely different standards for verification and theorising. The values of openness and peer review in science are very different from the often secret traditionally-communicated means by which IK is transmitted. For this reason I did not choose to investigate students' cultural or religious beliefs about astronomy in depth, even though they may affect learning. I accept that my values are therefore very much consistent with a White Anglo Saxon Protestant upbringing, and are not currently politically correct. My values colour the interpretation I bring to the data in the thesis, as I presumably am trying to search for a 'truth' in the learning by students visiting science centres. However, I feel it is important to search for that truth using qualitative rather than quantitative approaches, as only the former are able to obtain rich detailed data on students' ideas. I need to accept that when I interviewed students during data collection they would have seen me as an authority figure, not dissimilar to some of their teachers, and what they told me would have been in the light of their perception of what I wanted to hear. Some of these issues might be threats to quality and trustworthiness of the findings, and it is important for the reader to know these upfront, so as to be able to better determine the quality of the thesis.

Despite these constraints, I consider that my research has been able to investigate children's thinking about astronomy and at least to some extent provide insights into what and how they learnt at a science centre.

1.6 Structure of the Thesis

My thesis consists of nine chapters, starting with this introduction to the research. In Chapter 2 I selectively review the relevant literature of astronomy education and informal

learning which form the background to the study. Acknowledging that much of the previous research has lacked a theoretical basis for the claims made, I introduce the theoretical framework of human constructivism as a pertinent conceptual basis for my study. Chapter 3 describes my research methodology, case study design, my research instruments and how the data was collected, as well as addressing issues of ethics and rigour. Chapter 4 is the first of the 'finding's chapters, and consists of narratives describing students' visits to Hartebeesthoek Radio Astronomy Observatory and the Johannesburg Planetarium. This is followed by Chapter 5 which summarises learning about Big Ideas in astronomy by the 34 students in my study. Chapter 6 provides greater detail about how a Human Constructivist theoretical framework is used to analyse learning by individual students, while Chapters 7 and 8 provide seven portraits of students who showed differing degrees of learning at the science centres. Chapter 9 completes the thesis by summarising the main findings of the study, relating them to the literature and discussing their implications in the field of informal learning.

Chapter 2

In this chapter I review a selection of the literature related to science education in general and astronomy education in particular, as well as the literature on informal learning pertinent to the study. In the light of this review I then present theoretical frameworks in the form of human constructivism and conceptual change, which underpin the study.

2 Literature Review

2.1 Introduction

A student who visits a science centre such as the Johannesburg Planetarium or Hartebeesthoek Radio Astronomy Observatory (HartRAO) visitors' centre participates in an experience which has been influenced by a varied body of work. The major influence is probably the popular articles of the newsletters and journals read by the practitioners of museums and science centres. However, the activities that take place at astronomy science centres have their roots in the field of science, science education, astronomy education and the literature of informal learning.

This research study draws upon three fields of research: the prolific literature on science education in general, the extensive literature over the past thirty years in the area of astronomy education and, most importantly, the museum and informal learning literature. As the focus of my study is *learning* in the science centre, the literature reviewed in this chapter concentrates on articles, books and other resources which highlight learning.

2.2 Research in Science Education

Scholars of science education research claim that during the first half of the 20th century, science teaching as well as learning theories associated with science education were predominantly positivist (Poole, 1995) and behaviourist (Duit & Treagust, 1998) in nature. Over the past twenty years, there have been various attempts to review research in science education and its development, and to place the various theoretical orientations into a framework. Eylon and Linn (1988) identified four research positions:

- the ‘developmental perspective’ which was heavily influenced by the theoretical work of Jean Piaget, and encompasses research into how mental reasoning in science develops over the school-going years of a child;
- the ‘differential perspective’ which examined the relationship between instruction and learners’ individual differences in ability and aptitude, and how they can explain conceptual change;
- the ‘concept learning’ perspective, consisting of the conception/misconception¹ and conceptual change research of the constructivist school; and
- the ‘problem-solving’ perspective which covers research into the science problem-solving processes employed by learners

While the first two positions have long histories, overlapping with much of the behaviourist work earlier in the twentieth century, the latter two are based on studies conducted since the 1960s. In a lengthy analysis and using representative studies, Eylon and Linn compare the perspectives with each other, and propose an integrated perspective on science education. They note that the large number of studies has provided somewhat fragmented knowledge of the science learner, and that collaboration across the perspectives would provide the more coherent picture that the field requires.

Ten years after this review, Duit and Treagust (1998) report that there has been “an encouraging tendency towards an ‘inclusive’ view of science learning which brings together approaches of different theoretical orientations” (p.8). They conclude that conceptual change strategies based on social constructivist views of learning may help in providing an inclusive framework for future research.

While Eylon and Linn use a perspectival approach in their analyses, Erickson (2000) takes a programmatic approach which uses Lakatos’ analysis of scientific progress as a lens to examine science education. Erickson identifies three ‘research programmes’ within science research over the past 25 years: the Piagetian, the constructivist and the phenomenological programmes. Erickson considers that while the Piagetian programme has had a major influence on science education over the past 30 years, it peaked in the late 1970s and is now waning, with a considerable decline in the number of studies since the

¹ In this thesis I will use the term ‘misconception’ to cover the various terms used by different authors, including ‘alternative conceptions’, ‘preconceptions’, ‘intuitive conceptions’ and ‘alternative frameworks’.

1980s. In contrast the constructivist research programme has become dominant in the student science learning literature since the mid-1980s. Erickson's own research fits within the phenomenological programme, and he provides a useful summary of recent research in the area. Although Erickson's approach is valuable in that it provides an alternative view of science education research, he provides little evidence that the phenomenological programme is likely to become as dominant as either of the other two.

An examination of any of the major science education journals demonstrates that the current predominant theory of pedagogy within science education is constructivism. As a basis for pedagogy it has few rivals, despite possible contenders such as the history and philosophy of science school (Matthews, 2000). Constructivism can be regarded as having two major strands, radical constructivism and social constructivism. Radical constructivists maintain a basic assumption "that reality exists but cannot be known as a set of truths" (Tobin, Tippins & Gallard, 1994 p. 47). Within the overall strand of radical constructivism are views of constructivism in which an individual builds up his or her own view of the world from personal experience. This 'personal' constructivist school developed from the work of Piaget's developmental theories and has given rise to a small number of related views of learning.

One of these is the human constructivist view of learning developed by Joseph Novak and others (e.g. Mintzes *et al.*, 1997; Novak & Gowin, 1984), which incorporates both the theory of meaningful learning advanced by Ausubel and collaborators in the late 1970s, and views of constructivism that involve a radical restructuring of knowledge (Mintzes & Wandersee, 1998). In human constructivism, learning is regarded as being sometimes slow and incremental, resulting in a 'weak' form of restructuring of knowledge, while at other times, particularly during 'aha' experiences or 'insightful moments', it is rapid and involves a complete reorganisation of concepts already acquired ('strong' knowledge restructuring). This theory of knowledge acquisition has important implications for my own study, and I use it as a basis for my theoretical framework (see section 2.8.2). Learning in museums and science centres has the potential for both weak and strong knowledge reorganization, due to the way in which the knowledge is presented, both using innovative presentation methods (such as in a planetarium dome) and as hands-on, interactive exhibits. It is important to note that the human constructivists are realists, at least to the extent that Osborne (1996) defines the 'modest realist' position. In his critique Osborne shows how the principal strength of constructivism is in its use as a pedagogical

method, taking into account learners' prior knowledge and treating learners as active participants in the construction of knowledge. Osborne maintains however, that constructivism fails to provide any mechanism or processes to assist learners to judge whether one conception or theory is better than another, and move beyond a common-sense view (which in the case of much of science is not the *scientifically-accepted* viewpoint). Osborne suggests there is a clear role for "telling, showing and seeing as methods which enable the construction of new knowledge" (Osborne, 1996 p. 66). He advocates that science educators and researchers adopt a 'modest realist' epistemology, which accepts that there is an ontological reality which scientists investigate. A version of that reality can be constructed by students both from their own experiences of the world and from formal (and informal) instruction.

In contrast, 'social' constructivists have used the work of psychologists Lev Vygotsky and Jerome Bruner to show that knowledge is built up by social interaction between individuals. Social constructivists argue that knowledge is created and shaped by human discourse, and that science education is a process of enculturation whereby "novices are introduced to a community of knowledge through discourse in the context of relevant tasks" (Driver, Asoko, Leach, Mortimer & Scott, 1994 p. 9). Recent developments related to the social constructivist paradigm are the notions of situated cognition, border crossing and world views.

Situated learning or cognition (Brown, Collins & Duguid, 1989; Lave & Wenger, 1991) refers to knowledge being shared or distributed across physical, social and psychological contexts. Lave and Wenger have examined how learners can act like apprentices, participating and increasingly taking on critical tasks of their masters in authentic situations. Aspects of situated learning are relevant for my study, in that when visiting Hartebeesthoek Radio Astronomy Observatory, students are seeing an authentic site of science investigation. However, for visitors to become apprentices in the sense used by Lave and Wenger, they would need a more prolonged engagement with the science centre and associated observatory than a single visit.

Aikenhead and his collaborators (Aikenhead, 1996, 2000; Aikenhead & Jegede, 1999) take a different approach to constructivism: they postulate that learning science involves students crossing cultural borders from their own subculture to that of (what is currently predominantly Western) science. They postulate that the crossing of these borders can be smooth or hazardous. Students in the latter category avoid assimilation into

the 'school science' subculture, and either fail or pass science courses without true comprehension of the science involved. Again, the concept of border crossing has some relevance to my study: when students visit either of the study sites, they could be regarded as crossing a border between their own subculture and that of 'Western Modern Science'.

The world view hypothesis (Cobern, 1991, 1996) and its African variant (Jegede, 1995; Jegede & Okebukola, 1991; Ogunnyi, 1996) suggest that concepts covered in the science classroom will be assimilated into a learner's belief system only if it corresponds with his or her world view. Although this idea might be appealing in a study such as mine, which includes the influence of students' beliefs during the learning experience, a small number of researchers (e.g. Dzama & Osborne, 1999; Rollnick, 2000) have questioned the world view hypothesis. In a quantitative study, Dzama and Osborne demonstrate that traditional beliefs and attitudes account for only a small proportion of the variance in achievement in a test on electricity. They suggest that other factors such as the "absence of supportive environment for serious science learning" (Dzama & Osborne, 1999 p. 401) are more likely to explain success in science, or lack of it. Marissa Rollnick (2000) suggests that situated cognition (which at the time had gained greater acceptance in the mathematics education research community) might provide a "more coherent view of culture" (p. 99) whereby the science learner becomes a participant in the social practice of science. There are implications here for my study: students visiting a science centre, especially an authentic context such as a radio telescope, may gain entry to the community of science through such a visit. However, as in the case of Lave's apprenticeship model, for such entry to be gained it is likely that there needs to be a sustained series of visits over a period of time. My study did not examine such a situation, as in South Africa school visits to science centres normally take place only once in a year, due to financial and curricular constraints.

Cliff Malcolm and Busi Alant provide a detailed, if somewhat one-sided, review of science and mathematics educational research in South Africa since the early-nineties (Malcolm & Alant, 2004). Writing from a critical paradigm and despite providing the reader with many examples, they disapprove of much of the Southern African science education research into learning and teaching over the past 15 years. They regard much of it as involving what they term 'mechanistic' and 'technicist' cognitive approaches, and are more complimentary of the mathematics education research. The latter, they claim, involves more appropriate exploratory methodologies to investigate the complexity of the

social and political environment. Malcolm and Alant maintain, using examples from language, African worldview theory, teacher education and policy studies, that there is a need for emphasis on critical participatory studies which address more closely the context of South African society.

Broadly, my study is grounded in the theory of constructivism, and would likely be regarded by Malcolm and Alant as a ‘mechanistic cognitive’ approach, as it involves trying to determine what and how children learn over a relatively brief time period. I would however, defend my approach as being appropriate for the context of my study into how individuals learn during a science centre visit. Extensive research has demonstrated that, as a theory of learning constructivism can explain how knowledge is acquired. In my study I use human constructivism as described by Mintzes and Wandersee (1998) and Mintzes *et al.* (1997), and as used by Anderson (1999) and Anderson, Lucas, & Ginns (2003) in their study of learning in a science centre in Australia. In addition, in order to encompass the affective aspects of learning science, which are not as clearly identified in human constructivism, I use a variation of the Conceptual Change Model (CCM), originally developed by Strike and Posner (1985). Alsop & Watts (1997) have taken David Treagust’s framework of the CCM (Tyson, Venville, Harrison & Treagust, 1997), and argue that informal learning contexts should take into account issues of affect, conation and self-esteem, and I have adopted their suggestions. Both the human constructivist and conceptual change model positions are addressed in more detail in the theoretical framework in sections 2.8.2 and 2.8.3.

This first part of my review has examined research into science education in general and has identified how theory can inform the analysis for my own study. As my study investigates learning about astronomy, I believe it important to consider how research into the learning of astronomy has been conducted during the 20th Century and in the early years of the new millennium. Section 2.3 examines pertinent research into astronomy education.

2.3 Astronomy Education

As a preface to this section, I provide a summary of the peer-reviewed products of empirical research into learning about astronomy over the past 30 years (Table 2.1). I chose to focus on peer-reviewed articles for the summary as they are likely to demonstrate a greater degree of rigour than other products such as conference papers. However, Dunlop

(2000) provides a useful review of additional articles in conference proceedings and other journals. The majority of studies have been in topics related to the Earth-Sun-Moon system such as the cause of day and night and the seasons (Table 2.1). Other popular topics have been the Earth and the Moon phases while gravity and the remaining topics have been the subject of fewer studies. Although I have included nine gravity studies in the table, most of them were in the subject of classroom/university physics experiments, and not related to astronomy. As Bailey and Slater (2003) noted in their review of astronomy education, the topics of current astronomy, such as stars and the universe, have hardly featured as subjects of study for educational researchers, even though teaching these topics has been espoused by astronomers themselves (e.g. Pasachoff, 2001, 2002), although not all astronomers agree (Sadler, 2001; 2002).

Table 2.1 List of peer-reviewed studies of astronomy education research since 1975

Astronomy Topic	Total number of studies
Day and night	16
Seasons	15
The Earth	13
Earth-Sun-Moon system	13
Phases of the moon	13
Gravity	9
Stars and Sun	4
Solar system	3
Attitudes	3
Worldviews	3
Other	3
Size and scale	1
Total	96

Jean Piaget made the first scholarly studies of how people, particularly children, conceive of astronomical phenomena in the 1920s. In his two books *The Child's Conception of the World* and *The Child's Conception of Physical Causality* he describes children's ideas about a flat Earth and the cause of day and night, and refers to previous psychologists' work on similar conceptions (Piaget, 1929, 1930). Piaget identifies three stages of

development of conceptions regarding the origin of the sun and moon. The first stage regards them as being made artificially by God or humans, the second stage ascribes them as being partly natural, while in the third stage they are regarded as having nothing to do with human activity. Piaget's work was both pioneering and very valuable in presenting children's mental constructs. However, subsequent research has shown that children's conceptions are dependent not only on age (i.e. cognitive development), but also on context and content (Bliss, 1995), and Piaget himself made no claims in using his research to assist in student learning.

Wall (1973) summarises research related to astronomy education in the USA over the period 1922 to 1972. He reviewed 58 studies, of which 54 were doctoral and master's studies, and only 13 were published in the research literature. Written from the viewpoint of astronomy as an earth science, Wall produces a rather pedestrian list of reports grouped according to elementary, high school and college level. The studies consist of experimental projects which compare different methods of instruction or teaching resources, as well as surveys and development of curricula for astronomy teaching. The final two decades of Wall's review was a great age of space exploration, and space science features heavily in the studies described. Historically the article is a useful record of research conducted prior to and during the era of the space race, and Wall concludes with a list of eight recommendations for further research which reflects the priorities of the time, such as "the effectiveness of audio-visual materials on student achievement" and "the effects of student variables (such as sex, IQ, ...etc.) on student achievement" (Wall, 1973 p. 665).

Since Piaget's studies, much of the research in astronomy education has mirrored the changes that have taken place in science education generally over the past four decades, summarised in section 2.2. In the 1970s researchers such as Nussbaum and Novak (1976), Nussbaum (1979) and Mali and Howe (1979) worked from what Eylon and Linn (1988) would identify as the 'developmental' perspective. Using clinical interview techniques, they identified Piagetian constructs held by children regarding the Earth in space.

By the late 1980s the constructivist programme in science education was well established, and astronomy education studies focused on misconceptions and conceptual change. Numerous studies of this nature were conducted throughout the last two decades of the twentieth century, both in developed and developing country contexts. These included those of Gunstone and White (1981), Klein (1982), Baxter (1989; 1991), Vosniadou and

associates (Vosniadou, 1991; Vosniadou & Brewer, 1992, 1994), Sharp (1996), Fler (1997), Kikas (1998a; 1998b) and Sadler (1998). Examining different conceptions held by children over varying ages and across different cultures, these studies form part of the vast number of misconception studies carried out within science education during this period. Like those summarised in Table 2.1, most studies concentrated on the relatively accessible concepts related to the Earth-Sun-Moon system, such as the Earth in space, phases of the moon, ideas about day and night, and ideas about the seasons. Similar research projects have been conducted with pre-service and in-service teachers, principally in the UK and the USA (e.g. Atwood & Atwood, 1996; Barba & Rubba, 1992; Summers & Mant, 1995). Such studies show that the majority of teachers, particularly at the primary level, hold misconceptions similar to those of the students they teach. All these studies could be classified as belonging to the ‘concept-learning’ perspective (Eylon & Linn, 1988).

Two papers provide very detailed accounts of pre-service primary teacher trainees’ conceptions. Parker and Heywood (1998) examine pre- and in-service primary teacher trainees’ conceptions of night and day, the seasons and the moon. What makes this paper different from others I have cited are the implications the authors identify for the key features of the learning process and the trainees’ Pedagogical Content Knowledge (PCK). PCK (as discussed by Shulman, 1986) refers to the ability of teachers to represent ideas being taught in a way that makes them understandable by students. It is particularly important for teachers to be able to explain difficult three-dimensional concepts such as those involving the Earth-Sun-Moon system. Another key paper is by Trundle *et al.* (2002), who examine American pre-service primary school teachers’ conceptions of the phases of the moon before and after instruction. They cite previous studies carried out in the USA, most of which involve multiple-choice items in the methodology, but themselves use interviews (together with the manipulation of models) to determine students’ conceptions. They demonstrate that instruction results in students being much more likely to hold a scientific conception on the cause of the moon phases.

The plethora of studies on misconceptions has continued into the 21st century, even though there is now a substantial body of research which shows that both students and teachers hold beliefs and misconceptions which are resistant to change. Interesting studies include those of Dunlop (2000), Trumper (2001a; 2001b), Comins (2001), Roald and Mikalsen (2000; 2001) Dove (2002) and Agan (2004). Others, such as Diakidoy and

Kendeou (2001), use instruments with such ambiguous multiple choice answers² that any claims regarding post-instruction learning are difficult to evaluate.

Although my study did not set out to examine misconceptions, the data I collected did demonstrate that several of the misconceptions identified in the literature hold for South African students. This in itself is a finding, as very little research has been carried out on this topic in Southern Africa. A typical misconception held by the 12 to 15-year-old students in my study relates to their understanding of gravity. While 79% of students were able to give a partial scientifically acceptable definition of gravity, a third of the students specifically stated prior to their visit to the study site, that there is ‘no gravity in space’ (Lelliott, Rollnick & Pendlebury, 2006). This misconception has been identified by Borun *et al.* (1993) in the USA, Bar *et al.* (1997) in Israel and Sharma *et al.* (2004) in Australia. It is likely to be widely prevalent, given the frequency of images of astronauts ‘floating’ in freefall on the International Space Station or space shuttle. Similarly, 5 students out of 34 (15%) thought that the phases of the Moon are caused by either the Earth’s shadow or something such as another planet coming between the Earth and the Moon. Again, these are common misconceptions found in the literature (e.g. Engeström, 1991; Trundle *et al.*, 2002), showing that my own research mirrors some of the findings from elsewhere. Comins has established a website (www.physics.umaine.edu/ncomins/miscon.htm) listing the astronomy misconceptions identified in his book (Comins, 2001), and regularly updates it. Bailey and Slater (2003) note that several of the misconceptions referred to by Comins are not true misconceptions, but merely factual errors which “might simply be correctable with traditional lecture-based methods” (Bailey & Slater, 2003 section 2.6). This may be true for some of the factual errors I identify in my own research, which is why I am more interested in *how* students learn about astronomy rather than *what* they learn. For example in Chapter 7 I show that two students learnt about sunspots; Nonkululeko just remembered that there are black spots on the Sun which she did not discuss further. Neo developed an understanding, albeit flawed, about the spots, their relative size and their relative temperature. These issues are discussed further in Chapters 7 and 9.

In the late 1990s Albanese, Neves and Vicentini (1997) carried out a critical review of several internationally published research papers over the period 1976 to 1994 on the

² e.g. Question 1 from their questionnaire: “What do you think the earth looks like? (a) a square tray; (b) a round tray; (c) a fish bowl; (d) a basketball; (e) a round loaf of bread”. Options (c), (d) or (e) could all be regarded ‘correct’ to some degree.

Earth and its place in the universe. Approaching the field from a 'history of science' viewpoint, they conclude that while the research is valid regarding children's conceptions on the shape of the Earth, the research-questioning used did not relate the children's empirical observations to abstract models of the Earth-Sun system. They are particularly critical of Baxter (1989), Klein (1982) and Vosniadou and Brewer (1994), stating

Apart from the obvious conclusion that children may learn an abstract model without questioning the reasons of its validity, no other information may be derived from the research, or implications drawn for didactic practice (Albanese *et al.*, 1997 p. 586).

Although Albanese and colleagues are harsh in their criticism, a similar argument could be put forward for much of the alternative conception research in astronomy education to the present date. Out of the numerous papers on children's alternative conceptions cited here, less than a quarter theorise how the understanding of the alternative conceptions can be used to promote improved learning. This is important for my study, as it indicates the relatively atheoretical approach that has been taken to astronomy learning, and the need for theory to inform learning, as I attempt to show in Chapters 6 to 9. Other authors (e.g. Malcolm & Alant, 2004) have said much the same for the alternative conception research which has been so prevalent in the science education literature over the past 25 years.

A study in a similar context to mine was by Falcão and colleagues, in a Brazilian astronomy museum (Falcão *et al.*, 2004). Focusing on four exhibits depicting astronomical cycles and using a modelling approach, the researchers found that different types of teaching models were of value in enabling visitors to understand such cycles as day/night and seasons. An interesting and relevant study which included some fieldwork in South Africa was a teaching intervention conducted by Schur (1999). Using an experimental research design, this study combined a constructivist and mediated learning experience approach. A teaching package, the Experimental Astronomy Curriculum, consisted of engaging students in a "thinking journey to the moon" in order to enable 14- to 15-year-old Israeli students to change their conception of the Earth. Although this study examined the effect of a teaching intervention over an extended period of time, its relevance for my study is that it identifies students' understandings of gravity, one of the foci of my examination of students' learning. Recent papers on astronomy education have appeared as conference presentations in Southern Africa (e.g. Clerk, 2006; Mosoloane & Stanton, 2005), and it is likely that this is a growth area for research in the region.

A small number of studies have examined indigenous knowledge in relation to astronomical and everyday phenomena (e.g. Cameron, Rollnick & Doidge, 2005; Jegede & Okebukola, 1991; Lemmer, Lemmer & Smit, 2003; Mohapatra, 1991). Such studies are conducted partly from the point of view of scientific misconceptions, but relate student understanding to culture, religion and the worldview hypothesis. I decided not to take this route in my own study, as I found in my pilot questionnaire that 12- to 15-year-old students in urban schools did not tend to have strong cultural traditions associated with astronomy.

Some of the most interesting reports of research on learning about astronomy do not appear in the ‘traditional’ science education journals. A newly established on-line journal ‘Astronomy Education Review’ has begun to provide a variety of papers within the field (e.g. Agan, 2004) as well as a very useful review of astronomy education research over recent decades (Bailey & Slater, 2003). However, from the point of view of relating astronomy learning to theory, there are two key studies which appear to have gone largely unnoticed by researchers. The first, by Engeström (1991) examines a common misconception prevalent among both children and adults (and reported extensively in the literature) that the phases of the moon are caused by the Earth’s shadow. Engeström uses a notion of ‘synthetic stupidity’ developed by Wagenschein to account for this misconception. Wagenschein suggests that as a result of misapplied learning from either the classroom or textbooks, people do not relate the model of the Earth-Sun-Moon to the real moon they see in the sky. Engeström suggests that the textbook diagrams bear no relationship to real scale, and are part of the cause of synthetic stupidity. Such diagrams, as well as the complete lack of problematisation of moon phases versus lunar eclipses, are the principal culprits in the “empty sentences” that people use when asked about moon phases (Engeström, 1991). Several other authors (e.g. Ojala, 1992; Trundle *et al.*, 2002; Vosniadou, 1991) identify textbooks and their two-dimensional diagrams as promoting misconceptions in astronomy. Engeström however, then uses activity theory to propose an ambitious new model for learning in schools. Building on the Legitimate Peripheral Participation theory of Lave and Wenger (1991) Engeström shows that in order to counter misconceptions such as the moon phases, a completely revised approach to learning is necessary in schools. Engeström’s work is relevant to my study in that the notion of ‘synthetic stupidity’ was identified during the analysis of some of my data, and is discussed in Chapter 9.

A second study, based in Sweden (Schoultz, Säljö & Wyndhamn, 2001) is important as it questions the basis of one of the principal methods used by many researchers in the field: the interview. While a large number of studies in astronomy education have been based on multiple-choice tests and questionnaires (e.g. Dove, 2002; Dunlop, 2000; Trumper, 2001a), several studies have used interviews to elicit views from students (e.g. Sharp, 1996; Vosniadou & Brewer, 1992, 1994). Schoultz and colleagues introduced a globe into the interview process, and found the responses of quite young children were very different from those obtained by other researchers. Based on these responses, they argue that the presence of the globe allowed the subjects to conceptualise their understanding very differently than if the prompt had not been present. Schoultz *et al.* go on to theorise that the interview is a situated event, and the responses obtained by researchers such as Vosniadou and colleagues do not represent children's underlying 'mental models', but are merely reflections of the nature of the interview. Similar findings (without theorising about the event) have been noted by Trundle *et al.* (2002), and it appears that the availability of 3-dimensional models has a significant effect on respondents' thinking. While the sociocultural approach adopted by Schoultz and colleagues appears to cast doubt on many of the findings of misconception studies, Vosniadou has sought to defend her cognitive position. In a recent paper (Vosniadou, Skopeliti & Ikospenkati, 2005) she replicates her previous work from the 1990s as well as that of Schoultz and colleagues. Her findings suggest that only the older children (7- to 10-year-olds) can use the globe effectively, and that sometimes children base their answers on the globe and sometimes on their prior knowledge. Further, the children do not know when they are making inconsistent responses with respect to the globe and their prior knowledge. Vosniadou maintains that a combination of cognitive and socio-cultural approaches is important in this type of research, and that purely discursive analysis is not appropriate. As I will attempt to show in Chapters 7 to 9, my own research demonstrated that the introduction of a model had a strong effect on a student's ability to explain the cause of day and night. Like Vosniadou, I would argue that a combination of approaches is the most appropriate way to explain the interaction between interviewer and interviewee when a model is introduced into the discussion. These recent studies by Engeström, Schoultz and Vosniadou would be classified as being part of the constructivist programme of educational research (Erickson, 2000). I consider them key papers, as they provide important insights into the use of models in astronomy learning which many researchers

have declined to use in their studies, basing their findings on questionnaires and written tests instead.

2.3.1 Research in Planetaria

In contrast to the substantial volume of astronomy studies, there is limited recent literature on research into learning at planetaria. The modern planetarium was invented in 1920, and the earlier studies can be found in Wall's review, but are difficult to obtain. An accepted technique for determining the prevalence of research in a particular field is to make searches through databases of abstracts (Lucas, 1991; White, 1997). A search for the terms 'planetarium' 'astronomy' and 'education' using key words from summaries in the ERIC and the NASA Astrophysics Data System (ADS)³ databases is summarised in Table 2.2. Unlike White's method on science trends which presents the proportions for the target word per 10,000 articles, Table 2.2 shows simple counts for the terms of interest, by publication date, and grouped at 5-year intervals for more recent years.

Table 2.2 Numbers of articles related to planetaria in databases

Interval	Term: 'planetarium and learning' ERIC		Term: 'planetarium and education' ERIC		Term: 'planetarium and education' ADS		Term: 'astronomy' and 'education' ERIC
	Number of abstracts	%	No. of abstracts	%	No. of abstracts	%	No. of abstracts
Pre-1970	1	3	5	5	2	2	47
1970-79	17	47	47	51	5	5	>540
1980-84	7	19	25	27	2	2	330
1985-89	4	11	6	6.5	5	5	212
1990-94	5	14	6	6.5	17	18	176
1995-99	2	6	4	4	32	34.5	279
2000-04	0	0	0	0	30	32.5	97
Total abstracts	36	100	93	100	93	100	1681+

³ This consists of 3 bibliographic databases covering astronomy, astrophysics and physics based at Harvard. See <http://adswww.harvard.edu>

Table 2.2 shows the relatively limited extent of the abstracts involving planetaria in educational journals over the past 30 years. The ERIC database shows a peak in the 1970s and early 1980s, with only 10 to 20% of the articles published since 1990. The ADS databases show a different trend, with over 80% of planetarium-related abstracts ‘published’ since 1990. However, it is important to note that most of the planetarium-related abstracts cited in the ADS databases are in fact abstracts from the American Astronomical Association meetings, and do not get published. In contrast, the ERIC abstracts relate mainly to articles published in educational journals, such as *Journal of Research in Science Teaching*, and *Science Education*, as well as books, conference papers and official documents. Also shown in Table 2.2 is a summary of astronomy education-related abstracts for the same time period. Although it shows a peak in the 1970s, probably related to the Apollo missions, it does not show the same drop-off in research that is indicated in the case of planetarium education. This begs the question: why has there been so little educational research carried out related to planetaria since the 1980s? I posed this question to an Internet listserv of about 1,200 planetarium directors and educators in 2003 and again in 2006. I had three replies in 2003 and seven in 2006. A general concern raised by most respondents was that in order to survive financially, planetaria have to stress the entertainment aspects of their shows rather than education. Numerous planetaria have closed over the past two decades, and there is debate as to whether this is due to the move towards entertainment and the attempt to compete with I-MAX and Disney-style theme parks, or a general loss of public interest. A very recent example is the London Planetarium which closed its doors as a planetarium in May 2006: the owners blame a lack of interest by visitors, while astronomers identify the move towards entertainment as the reason for its demise, citing other successful planetaria run by astronomers elsewhere (Bale, 2006).

Riordan (1991) provides a useful review, which includes a brief history of the planetarium as an educational presentation and a summary of research over a period of about 30 years. In common with research in science education described in section 2.2, research into the effectiveness of the planetarium as a teaching tool was mainly quantitative, using experimental and quasi-experimental methods, during the 1960s and 1970s. By the 1980s, more participatory planetarium presentations were gaining in popularity, and although some research showed no significant differences in learning achievement, other studies demonstrated improved learning gains using a planetarium.

Riordan's overall conclusion can be summed up early in the review, that "the effectiveness of the planetarium as a teaching/learning device is yet undetermined" (Riordan, 1991 p.19). Much of the research presented in the review shows contradictory results, and the great majority focuses on the attainment of behavioural objectives. Since Riordan's review, occasional studies reporting the use of planetaria have been published (e.g. Rusk, 2003; Urke, 1993), but they do not relate directly to my study. There have also been opinion pieces relating planetaria to museum research (Parker, 1995) as well as the entertainment-education debate (Brunello, 1992).

Although the field of astronomy education research has advanced since the days of Piaget and Novak, I consider that it became somewhat bogged down in misconception research by the 1990s, with many studies published into the 21st century which have not added to our understanding of the *nature* of learning. There is little doubt that if the classic documentary "A Private Universe" (Pyramid Film and Video 1988) was repeated now, very similar results would be obtained. This short film showed graduating Harvard students being quizzed about astronomical phenomena such as the cause of the Moon phases and the seasons. These highly trained graduates demonstrate very little knowledge about common phenomena. Clearly, a different approach to learning about astronomy is required; it may be that learning outside the classroom has an important part to play, and section 2.4 examines the role of informal learning in education.

2.4 Informal Learning

As a mode of learning, informal education is usually contrasted with the terms 'formal' and 'non formal'. According to Falk (Falk & Dierking, 2001) these terms, developed by researchers in international development, go back nearly 50 years and were later used by the museum community to distinguish between school-based learning and out-of-school activities. Coombs and Ahmed (1974) provide a distinction between the three terms, as follows:

Formal education: the highly institutionalised, chronologically graded and hierarchically structured 'education system', spanning lower primary school and the upper reaches of the university'.

Non-formal education: any organized, systematic, educational activity carried on outside the formal system to provide selected types of learning to particular subgroups in the population, adults as well as children.

Informal education: the lifelong process by which every person acquires and accumulates knowledge, skills, attitudes and insights from daily experiences and exposure to the environment at home, at work, at play; from the example and attitudes of the family and friends; from travel, reading newspapers and books or by listening to the radio or viewing films or television.

(Coombs & Ahmed, 1974 p. 8)

The category of non-formal education, although relevant to the concept of learning in museums, seems to have fallen into disuse in the research literature, where the principal distinction is now between the terms formal and informal. Wellington (1990) distinguished between the informal learning of field trips and the formal learning of school (Table 2.3).

Table 2.3 Wellington’s (1990) classification of learning

Informal learning – field trips	Formal learning - school
Voluntary	Compulsory
Unstructured	Structured
Open-ended	Close-ended
Many unintended outcomes	Fewer unintended outcomes
Non-assessed	Assessed
<i>Learner-led</i>	Teacher-led

Hofstein and Rosenfeld (1996) reject Wellington’s distinction as being too simplistic and creating a binary approach which does not reflect the true situation of reality. Instead Hofstein and Rosenfeld prefer the ‘hybrid’ approach of Crane (1994) which allows that certain ‘formal’ aspects of learning can take place under informal conditions, but that informal learning is essentially an out-of-school, unstructured, voluntary activity.

Falk (2001) identifies difficulties with the term *informal* when it is applied to the term *learning*. He maintains that ‘there is no convincing evidence that the fundamental processes of learning differ solely as a function of the physical setting’ (2001 p. 7), and postulates that children experiencing a lecture in a museum auditorium is no different from experiencing the same lecture in a school auditorium. He makes a similar point about open-ended discovery learning in the same two settings, and identifies the social context and a learner’s motivation as being more important. Falk and Dierking (2000) and Falk (2001) have therefore argued that the term *free-choice learning* is more appropriate for museum settings. The characteristics of this type of learning have been identified as being non-sequential, self-pacing, non-assessed, and often involving groups (Dierking & Martin,

1997). Although there has been some consensus for the use of this term, participants at a conference on free-choice learning in 1998 were divided as to whether it should replace the more familiar and established term 'informal learning' (Luke, Camp, Dierking & Pearce, 2001). It is also interesting to note that recent issues of science education journals (e.g. the *Journal of Research in Science Teaching* 2003 and *Science Education* 2004) have devoted issues to science learning in *informal* environments. For the purposes of my study, I will use the two terms *free-choice* and *informal* learning interchangeably, as the term informal learning has a wide usage while the term free-choice is a useful expression which is likely to gain increasing currency in the future.

Most of the recent research on informal science learning has been carried out in museum environments, with a lesser (but increasing) amount at science centres. Relatively few studies have been executed at either planetaria or observatory visitors' centres. At the latter sites, Dierking and Martin's (1997) characteristics of informal learning are less in evidence. While non-school visits to a planetarium are usually social, voluntary and non-assessed, school visits are usually compulsory and may well be assessed in some manner. Further, the visits to such institutions are usually structured, sequential and at least partly didactic. Despite these differences, I would contend that learning at planetaria and visitors' centres can indeed be classified as informal, on the basis that it is out-of-school, and, that *parts* of the programme have *some* aspects of free-choice, of being unstructured, self-paced, exploratory and non-sequential.

Unlike the astronomy education research described in section 2.3, research into informal learning has not mirrored that of science education so closely. Although research until the 1970s was behaviourist in nature (Hein, 1998; Rennie & McClafferty, 1996), and has more recently embraced constructivism, there has been much less emphasis on misconception research than in the broader science education community. Instead, we can identify the following key themes within informal learning research:

- Entertainment & education
- Science communication and science literacy
- Learning in museums and science centres

A fourth theme, which does not strictly involve research, includes issues relevant to practitioners, such as evaluation and impact studies. I now discuss each of these themes as

reflected in the literature, with particular reference to learning, as it forms the key research question in my study.

2.5 Edutainment or Entercation?

The lament of numerous museum scholars over the decades has been whether the purpose of museums and similar institutions should be to amuse or educate the public (Falk & Dierking, 2000; Lucas, 1991; Shortland, 1987). In her excellent analysis of the changing museum, Lisa Roberts devotes a whole chapter to the subject, and argues that is not a new issue (Roberts, 1997). In the early days of American museums through to the early twentieth-century, the debate was around scholarship versus popularisation as museums sought to become both professionally and commercially viable. As the twentieth-century progressed, the issue was fairly clear-cut, with ‘scholarly’ curators on one side arguing that museums were primarily important for their collections and the research that could be carried out on them, while ‘progressive’ educators on the other side maintained that such collections needed to be available for the upliftment and education of the visitors.

However by the 1970s, with the introduction of audio-visual displays, computer terminals, theatre, music and other features more associated with show business, the argument had shifted to ‘entertainment versus education’. Museums felt they were losing audiences to the leisure industry (such as theme parks) and responded by trying to provide entertaining activities within the museum to retain their visitors. Museum ‘purists’ found this unacceptable; the depth of feeling is shown by William Fagely in 1973: “the curator should not prostitute his institution by transforming it into an amusement center full of ‘fun house’ gimmicks in an attempt to win the interest of all potential visitors” (in Roberts, 1997 p. 39). Interestingly, many educators increasingly found themselves on the same ‘side’ as the curators, trying to promote serious learning in the face of ‘frivolous’ entertainment.

As the field of ‘visitor studies’ developed over the 1970s, research began to show that leisure and play were motivating factors for people’s visits to museums. Once at the museum, learning could still take place, even if learning was not ‘cognitive gain’, as it had traditionally been viewed. Research into motivation and leisure in museums has demonstrated that they are often precursors or partners in learning (Csikszentmihalyi & Hermanson, 1995; Hood, 1980 in Roberts, 1997). While some museum educators have embraced the development of entertainment activities in museums, others have resisted the

changes. Roberts suggests that “the vote is still out, however, on whether these developments are for better or for worse” (Roberts, 1997 p. 44). She notes that changes in ‘authority’ within museums, with a shift towards educators and the public (and away from curators), as well as greater acceptance that experience in museums is a wider notion than mere cognitive gain, reflect broader changes in society, at least in developed countries.

The criticisms by some, regarding ‘frivolity’ and ‘hands-on, minds-off’, have been especially severe in science centres as they have emerged over the last four decades as separate institutions from science museums. Science centres have grown exponentially, at the rate of thirty percent per year, since the opening of the Exploratorium in San Francisco in 1969 (Beetlestone, Johnson, Quin & White, 1998). Instead of displaying artefacts, science centres focus on hands-on exhibits, often interactive, which attempt to engage and educate their visitors (Rennie & McClafferty, 1996). Criticisms involving ‘sloppy science’ (Champagne, 1975), “science as simply play and innocent entertainment” (Shortland, 1987 p. 213) and “an endless series of unconnected, entertaining magical events” (Parkyn, 1993 p. 31) are just some of the disparaging remarks directed towards science centres. Although written as opinion pieces and not research-based, such critiques have had considerable influence over the years. As the body of research in these institutions increases, there is beginning to be acceptance that both entertainment and education have a role to play in science centres and museums. Studies such as those of Boisvert & Slez, (1994), Silverman (1995), Falk and associates (Falk & Dierking, 2000; Falk, Moussouri & Coulson, 1998) and Gilbert (2001) demonstrate that for many visitors, their visit to a science centre is to learn and **also** to have fun. In my own study I included a strand of questioning regarding the views of the students on learning and fun. As will be demonstrated in Chapter 5, most students regarded learning and fun as natural bedfellows when participating in a visit away from school. In an analysis relating Dewey’s work to the museum environment, Ted Ansbacher identified no conflict between an enjoyable and an educative experience; he did however caution that “an enjoyable experience can have negative outcomes and be a mis-educative experience” (Ansbacher, 1998a; Dewey, 1938). In my study I found no evidence to support this claim, but the fact that I worked with teenagers may mean that a school visit experience precludes such conflicts: every student interviewed enjoyed at least part of the visit, and each one of them learnt at least something from their experience.

In the public arena, the debate between entertainment and education continues. In 2003, I followed a fascinating discussion thread on the ASTC listserv⁴. Kurt Koller of the Pacific Science Center in Seattle, quoting Michael Crichton's views on society's "need" to be entertained, posed a question regarding the relevance of science centres in the new century: "What are the core values of science/technology/mathematics that we would want to deliver and how (well) do they intersect with contemporary interests and cultural needs"? The resulting discussion over the next few days demonstrated that science centre practitioners have strong feelings about how their institutions compare with theme parks such as those of the Disney Corporation. The central argument of the discussion was that while theme parks do entertain their visitors very effectively, managing to get them to 'suspend disbelief' as part of the experience, science centres have a different mission, much more concerned with science awareness and science processes. The following quotations demonstrate some of the tensions that science centres grapple with:

I've noticed that Disney has become a sort of icon for science center folk – for better or worse.science centers and museums should simply avoid comparison with Disney and its ilk.We're not about fairy tales, but we are about the amazing history of discovery, the uses of those discoveries, and the possibilities inherent in those discoveries. (Lisa Jo Rudy, www.lisarudy.com)

As far as I am concerned, if people leave our exhibits with a thirst (or even an itch) to learn more about a subject, then we have provided a valuable service (read: relevance). (Wesley Creel, Pink Palace Family of Museums, Memphis)

Say what you will about Disney they make money. We at science centers struggle and strain.Because the public has been conditioned to be entertained, it has now become the expectation that everything be entertaining.If you don't hop on the entertainment bandwagon, you won't stay open. But how wonderful that science centers have truly played a role in changing the way we teach and embrace science. (Marcia Hale, Discovery Center of Idaho)

The bad about Disney: I think it boils down to one "word" – edutainment. It assumes that anything educational can't possibly be enjoyable, and tries to steer us into some horrible morass. ... I would never say that science centers shouldn't be entertaining, only that we should never assume that the science we present is somehow deficient in this area. (Jonah Cohen, Science Center of Connecticut)

⁴ The Association of Science-Technology Centers is a worldwide network of science museums and related institutions. Their email listserv can be accessed at www.isen-astc-l@home.ease.lsoft.com

It appears that the entertainment vs. education debate is as strong as ever. While the issues that face science centres in South Africa may not be quite the same as those in the USA, they are broadly similar: funding and competition from ‘entertainment’ centres such as theme parks and shopping malls. My own study does not address this debate in great detail, but as Falk and Dierking suggest, the relationship between education and enjoyment appears to be becoming more complex as leisure and lifelong learning activities increase. Although neither of these activities are as prevalent in South Africa as they are in the developed world, this is likely to be a fruitful area for future research.

2.6 Science communication and science literacy

There is an increasingly extensive literature in a field which combines science communication and science literacy in relation to museums and science centres, though it consists more of opinion pieces and conceptual research than empirical studies. Science communication is a relatively new field which disseminates the processes and products of science to the general public. It includes popular science journals and books as well as websites (Gregory & Miller, 1998). Scientific (or science) literacy, although it has a longer history than science communication, is still a relatively recent discipline. Shamos (1995) suggests that the concept of scientific literacy developed in the 1950s as a rather vague term to promote a goal of “science for effective citizenship” (p. 82). After the launch of *Sputnik* by the Soviet Union in 1957, a clearer goal for scientific literacy became the actual understanding of science and technology, so that the USA could implement school curricula in an attempt to catch up and overtake the Soviet Union.

Early attempts to define the field included those of Conant (in Shamos, 1995) and Shen (1975). Shen makes a distinction between practical scientific literacy, civic scientific literacy and cultural scientific literacy. Although Shen has advocates from within the field of informal learning (e.g. Lucas, 1983; Rennie, 2001), both Durant (1993) and Shamos (1995) are very clear that any definition of scientific literacy needs to include the sense that some degree of the *understanding* of science should be implicit.

Durant’s classification of scientific literacy identifies three areas:

- Understanding as knowing a lot of science,
- Understanding as knowing how science works, and
- Understanding as knowing how science *really* works.

While the first two are regarded as degrees of scientific literacy, Durant suggests that the public needs “a feel for the way that the social system of science actually works to deliver what is usually reliable knowledge about the natural world” (Durant in Gregory & Miller, 1998 p. 91). Shamos (1995) provides a similar categorisation as Durant, identifying ‘dimensions’ of scientific literacy as levels of understanding. Dimension one consists of *cultural* scientific literacy, similar to the ‘knowing a lot of science’ of Durant, but merely at the level of vocabulary and jargon. Dimension two is *functional* scientific literacy, in which the words and definitions of the first dimension can be used in a ‘meaningful discourse’ regarding, for example, science articles in the popular press. Shamos’ highest level is “*true*” scientific literacy, in which science processes and theory are combined with the functional dimension to understand the ‘overall scientific enterprise’. Shamos suggests that this dimension is only achieved by up to 5% of the population in the USA.

Helpful as Durant’s and Shamos’ classifications of scientific literacy are, neither of them is particularly appropriate for relating to the outcomes of a visit to a science centre. The nature of learning in science centres is discussed in section 2.7, and although there is considerable evidence that learning does occur (e.g. Anderson, Lucas, Ginns & Dierking, 2000), Rennie (2001) suggests that “a deep cognitive understanding of science concepts is unlikely to result from every science centre visit” (p. 114). Both Lucas (1983) and, by implication, Rennie identify Shen’s analysis of scientific literacy as being appropriate for museums. Shen (1975) identifies three types of scientific literacy:

- Practical scientific literacy, in which a person uses their scientific and technical knowledge to solve problems,
- Civic scientific literacy, in which a person’s knowledge of science-related issues can be brought to bear on society-related issues, and
- Cultural scientific literacy, whereby the achievements of science can be appreciated (and possibly criticised). This is clearly **not** the same as Shamos’ version of cultural scientific literacy (knowing a lot of science).

Lucas considers that while museums could possibly contribute to all three areas, typical displays are most likely to develop cultural scientific literacy. It should be noted however, that Lucas conducted no empirical work of his own, and his opinion piece has not brought about research in this area.

In my own study, students were asked questions related to their knowledge of astronomy (see Chapter 3 and Appendices B and C), as identifying learning at the study site was a key research issue. While the majority of these questions could be regarded as being at Durant's and Shamos' lowest level of scientific literacy (knowing a lot of science), some questions dealt with science interest and science in the news. In addition, the use of Personal Meaning Maps (PMMs, see 3.3.1) allowed the students to express ideas that they regarded as being important within astronomy. In this manner, aspects of Shen's cultural scientific literacy can be identified in the findings.

Rennie (2001) stresses that most research supports the idea that “people [during a science centre visit] have a science-related encounter which enables them to make more sense, in a scientific way, of their experiences”. (p. 114-115). This echoes the views of Rudy and Creel from the ASTC listserv. Rennie identifies the significance of science centres for science communication as follows: as they proliferate they reach a larger audience, and they assist to engage with adults whose schooling system has not created scientifically literate school-leavers. However, her context appears to be developed countries, where family and adult visitors to science centres are likely to be in the majority. In the context of South Africa, the bulk of visitors are school parties (Table 1.2), and therefore the aims of science centres for these visitors are likely to be different to those of developed nations. Currently in South Africa there is widespread concern regarding the low numbers of school leavers who have participated in a meaningful experience of science and mathematics at school, as well as achievement at this level (Taylor & Vinjevold, 1999). The focus of school visits is therefore not only about “the nature of the scientific enterprise and the role society plays in it” (Rennie, 2001 p. 117), but also on science content knowledge, which appears to be downplayed in developed countries. For this reason, my own study focused less on student attitudes towards science and astronomy, and more on the effect of the school visit on cognitive learning that may or may not have taken place. This is an area of considerable debate in the literature, and it is to learning in museums and science centres to which we now turn.

2.7 Learning in museums and science centres

As Braund & Reiss (2004) have stated, “trying to define learning is an almost impossible task” (p 4). At a naïve level, a layperson using a standard dictionary to define the term would find an entry such as “*noun*: acquired knowledge or skill, *esp* knowledge acquired

by study or education” (Allen, 2000). The word is laden with ideas of facts and memory, probably due to its association with school and exams. Although naïve, it is probably on this premise that much of the research in the 1970s and 1980s in museums and science centres appears to show that little learning takes place (McClafferty, 1995; Uzzel, 1993). However, by the following decade it was realised that the research methodologies used, particularly experimental studies measuring particular outcomes were inappropriate for the museum environment. Researchers such as Falk and Dierking (1992) suggested that scholars were misguided in their search for narrowly-defined learning objectives, and that the learning that *was* in fact taking place was not being identified.

If we take a broader view of learning, as more than just an increase in knowledge, a definition such as the following might be more appropriate:

Learning is an internal change in a person – the formation of new mental associations or the potential for new responses – that comes about as a result of experience (Rennie, 2001 p. 112 after Woolfolk 1987)

In this case, there is reference to the psychological view of learning (“new mental associations”) as well as the fact that such associations are due to experience. However, for the purposes of my study, a richer and more elaborate view of learning is important to reflect the relatively complex world outside the school environment. Such a definition might be:

Learning is a process of active engagement with experience. It is what people do when they want to make sense of the world. It may involve the development or deepening of skills, knowledge, understanding, awareness, values, ideas and feelings or an increase in the capacity to reflect. Effective learning leads to change, development and the desire to learn more (Braund & Reiss, 2004 p. 5 after Campaign for Learning)

Such an explanation is very broad, capturing experience, meaning making and feelings, as well as a range of more ‘traditionally recognised’ aspects of learning, such as knowledge and skills. Similar attempts at providing a stipulative definition of learning are made by museum researchers. Allen (2002), in her study of visitor talk in an exhibition on Frogs, described a framework for defining learning. This included reference to Bloom’s taxonomy, the use of a sociocultural perspective, a de-linking from formal learning assessment, yet a relatively narrow definition of learning as “discussion of the exhibits and the exhibition”.

Interestingly, in their book on museum learning Falk and Dierking (2000) do not provide a definition of learning. Instead, they stress repeatedly that learning is a series of processes dependent on three contexts, the personal, the sociocultural and the physical. I elaborate on Falk and Dierking's contextual model of learning in section 2.8.1. Such a broad, all-encompassing view of learning is however not without its critics within the museum community. Allen chose her relatively narrow definition of learning so that she should make stronger claims about learning as a response to the view "Yes, visitors have fun in museums, but what do they really learn?" (Allen, 2002 p. 262). As a museum practitioner, Ted Ansbacher argues that because learning has multiple meanings, and is interpreted differently by different people, we should avoid the term altogether (Ansbacher, 1998b). Instead, he proposes that we use the term *outcomes* of a visitor's experiences in a museum, and identifies a number of possible outcome categories such as 'achieve understanding', 'develop physical knowledge' (a Piagetian term) and 'change feelings or attitudes' (Ansbacher, 2002a). Ansbacher's critique has been countered by Dierking and others who maintain that while outcomes are a useful measure for expressing what an individual has experienced during a museum visit, the term learning *is* still appropriate. Dierking *et al.* (2002), citing evidence for learning in museums over the past 20 years and accepting that there are different views of the word *learning*, argue that it is an appropriate umbrella term as long as it is "broadly and clearly defined and emerge[s] from the meaning the visitor makes of the experience" (p 2).

My study examines *learning* at two out-of-school sites. I have cited this exchange of views in some detail to demonstrate there is not consensus within the museum community on what constitutes *learning*. However, I consider that to abandon the term *learning* and instead use *outcomes* is not a progressive step. The fact that there are differing understandings of 'learning' is in itself not a convincing argument that use of another term will result in clarity. For the purposes of my study, I will therefore continue to refer to 'learning', and use Braund & Reiss's description (2004) as a stipulative definition of learning in my context.

Learning is a process of active engagement with experience.

In a visitors' centre (such as at HartRAO) there is ample opportunity for students to engage with experiences made available, such as water rockets, whisper dishes and other smaller exhibits. In the planetarium there is less opportunity to do so, although the unusual setting and quality of the presentation can enable active engagement.

It may involve the development or deepening of skills, knowledge, understanding, awareness, values, ideas and feelings

The focus of my study is on the deepening of knowledge and understanding, and to a lesser extent awareness and ideas (of the solar system and universe). At this point I should clarify what I see as the difference between knowledge and understanding, at least within the context of my study. In common usage, knowledge and understanding can be used synonymously in the sense of a person's awareness and comprehension of an artefact such as a house. There are also numerous situations where they are used in slightly different senses, for example where a person knows what a television is but has no understanding of how it works. Since Tennyson's distinction between declarative knowledge ("knowledge that"), procedural knowledge ("knowledge how") and contextual knowledge ("knowledge why, when and where") researchers have used his framework as a basis for classifying types of knowledge involved in learning (Tennyson & Rasch, 1988; Wellington, 1990). Most scholars would consider that the most valuable form of knowledge is contextual where a learner is able to explain why something occurs. For example, contextual knowledge of the phases of the Moon would involve not just that they occur (declarative) or that they are due to sunlight falling on differing amounts of the Moon's surface (procedural), but that the variable sunlight is due to the orbit of the Moon around the Earth. In this example, I am using contextual knowledge in the same sense as understanding, where a true understanding of the Moon's phases is synonymous with contextual knowledge. In this thesis, I will use the term *knowledge* to refer to Tennyson's declarative and procedural knowledge and *understanding* to refer to an ability to explain fully a phenomenon at the contextual level.

Effective learning leads to change, development and the desire to learn more

In Chapters 5 to 8, using the post-visit interviews and Personal Meaning Maps, I will demonstrate that students have changed some of their knowledge, understanding ideas and feelings, and that some of them have been motivated to learn more.

So far, this chapter has reviewed research in science education, astronomy education and informal learning, and has identified some key papers relevant to my own study. Although previous research has examined *what* students learn there has been relatively little work done on *how* they learn in science centres. The next section shows how I locate my research in a theoretical framework relevant to informal learning.

2.8 Theoretical Framework

2.8.1 The Contextual Model of Learning

Prior to the 1990s, the majority of museum research was either based on behaviourist theories (Hein, 1998) or was atheoretical (Anderson *et al.*, 2003). Scott Paris suggests that the idiosyncratic nature of visitors' museum experiences has been "used as evidence that no generalizations can be made about what or how people learn" (Paris, 1999 p. 2). Over the past 15 years relatively few studies have examined science museum learning using a theoretical lens. Prominent among those that have are John Falk and Lynn Dierking, who have conducted numerous research and evaluative studies in science centres and museums since the 1980s. Their initial model of learning in museums, the Interactive Experience Model (Falk & Dierking, 1992), proposed a framework for organising how visitor learning and behaviour could be approached. In the new century they recast the model into the Contextual Model of Learning (Falk & Dierking, 2000), a more detailed and refined approach which describes how learning in museums involves the three overlapping contexts of the personal, the physical and the sociocultural.

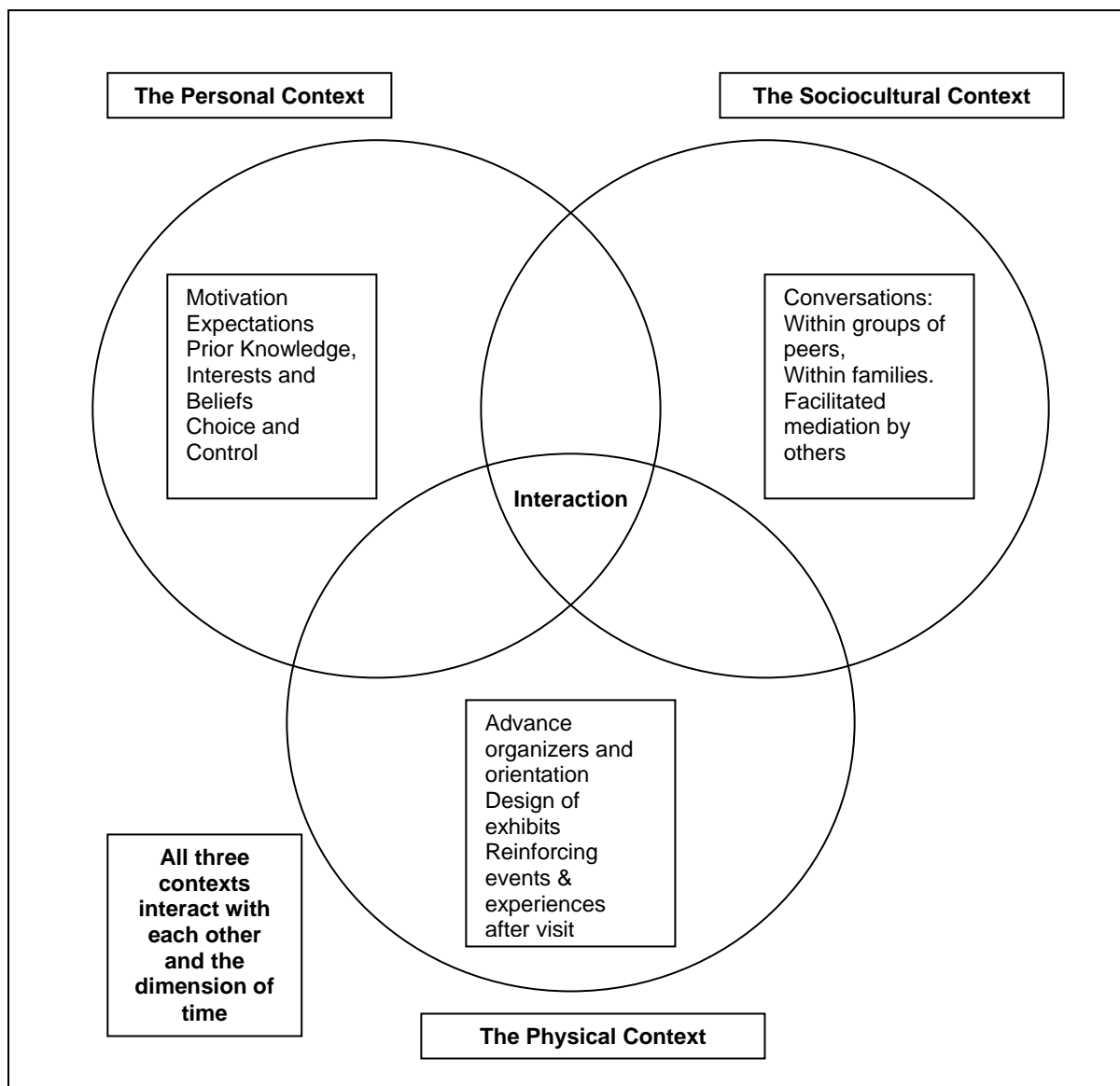


Figure 2.1 The Contextual Model of Learning (Falk and Dierking 2000)

The Contextual Model of Learning (CML) (Figure 2.1) helps researchers to design their research either to fall within one of the three main contexts of learning, or integrate across all three. In the original proposal for my study I had intended to integrate all three contexts, but John Falk, in comment on the research questions in my proposal advised that any differences I might find between individuals in the study might be obscured by too many ‘variables’. As a result of this advice, I chose the personal context as being an appropriate framework within which to base the research, and concentrated on student expectation, prior knowledge, interests and beliefs as factors which may influence student learning. Although the CML provides a model into which different types of museum and science centre learning can be fitted, and also provides a holistic way of examining such research, it does not provide a theoretical framework for the learning itself. This is an appropriate

point to revisit my research questions, as it is they which shaped the final choice of a theoretical framework. My first question is as follows:

To what extent do students learn in the process of a visit to a planetarium or the visitors' centre of an astronomical observatory?

The emphasis on learning by individuals who participate in the visit to a science centre suggested that some form of conceptual change theory might be appropriate. During my literature review for the research proposal I found that David Anderson had used human constructivism as a theory on which to base his research in a science centre. However, his study emphasised the cognitive side of learning and he placed heavy emphasis on post-visit activities carried out in the classroom after the students returned to school. My pilot studies had shown that many teachers visiting the planetarium and HartRAO tended neither to prepare their students to visit the centre, nor follow up the visit afterwards. This has also been found in other studies throughout the world (e.g. Griffin & Symington, 1997; Koosimile, 2004). Storksdieck stated "acknowledging the fact that teachers tend to not prepare or follow-up on field trips, out-of-school learning environments could also provide experiences that are valuable without preparation or follow-up" (Storksdieck, 2004 p. iv). I therefore concentrated on the students' experiences of the visit rather than incorporating the teacher into the study. In the light of this, the theoretical frameworks that most appealed to me were those of human constructivism and the conceptual change model as put forward by Alsop and Watts (1997) when studying informal learning. These are discussed in the following sections.

2.8.2 Human Constructivism

Human constructivism (HC) is a variation of individual constructivism developed by Joseph Novak and his collaborators (Mintzes & Wandersee, 1998; Mintzes *et al.*, 1997; Novak, 1985, 1988). Combining Ausubel's theory of meaningful learning with epistemological principles of constructivism that were emerging in the 1970s and 1980s, Novak developed a research programme and practical tools (such as concept mapping) that assisted students in a meta-analysis of their own learning. In his analysis of science learning Novak identified eight principles of learning together with examples relevant to teaching. While the first four principles were portrayed as being "generally agreed upon by most researchers in the field" (Novak, 1988 p. 82), from the viewpoint of this thesis it is worth briefly examining these principles to see how they have been upheld by more recent

research, and how they can be regarded as being relevant to informal learning. The first four principles are as follows:

- Concepts are acquired early in life
- Misconceptions are acquired early and are resistant to modification
- Prior learning influences new learning
- The brain's information processing capacity is limited.

Since the late 1980s there has been considerable further research evidence to confirm these four principles, notably the work of Driver and associates (e.g. Driver *et al.*, 1994), research into conceptual change (e.g. Hewson & Hewson, 1992; Strike & Posner, 1992) and neurological research (e.g. Calvin, 1996).

Novak regarded the remaining four principles as being more controversial and still open to confirmation or rejection by further research. Principle 5 is 'Most knowledge is stored hierarchically', and is one of the principal rationales for the use of concept mapping: that the maps themselves represent 'mental models' which exist in a similar form in the brain. While some proponents of concept mapping support this notion (e.g. Mintzes *et al.*, 1997; Pearsall, Skipper & Mintzes, 1997), others are more circumspect (e.g. McClure, Sonak & Suen, 1999), and still others are critical (e.g. Kagan, 1990). From the point of view of informal learning, a small number of studies (e.g. Anderson *et al.*, 2003; Anderson *et al.*, 2000) have successfully used concept mapping to determine the development of students' understanding of concepts as a result of a visit to a science centre. Subsequent research therefore, while it has not entirely discarded principle 5, has also not confirmed it, except as a heuristic method which appears to be quite valuable in research about learning. Principle 6 is 'Learners are seldom conscious of their cognitive processes' and relates to Flavell's work on metacognition (Flavell, 1976). Research studies over the last 15 years have generally confirmed this notion (e.g. Adey & Shayer, 1994) and many interventions now aim to make learners conscious of their own learning in order to improve the learning that takes place. In informal learning this is usually difficult to do in a museum or science centre setting. However, it has been carried out in studies related to the public awareness of science, and 'making learners aware of their own learning' has proved to be a useful technique in some studies (e.g. Alsop, 2000; Alsop & Watts, 1997). Principles 7 and 8 have also gained support from research since 1988. Principle 7: 'Epistemological commitments of students influence learning' has been examined from the point of view of

the Nature of Science (e.g. Lederman, Abd-El-Khalick, Bell & Schwartz, 2002) as well as conceptual change research (e.g. Tyson *et al.*, 1997) and also by Steve Alsop in the area of informal science learning (Alsop & Watts, 1997). According to evidence presented by Weinburgh in her extensive review of attitudes towards science (Weinburgh, 1995), Principle 8 'Thinking, feeling and acting are integrated' had been researched extensively prior to Novak's paper and has formed an important component of understanding learning in science centres (e.g. Jarvis & Pell, 2005; Rennie & McClafferty, 1996).

Since his 1988 work, Novak and his associates have further elaborated human constructivism and its associated pedagogical procedures of concept mapping, vee diagrams and semantic networks (Mintzes *et al.*, 1997). This view of learning is summarised in Figure 2.2, and demonstrates the relationship of four cognitive processes from meaningful learning: subsumption, superordinate learning, progressive differentiation and integrative reconciliation. I describe each of these main processes as I use them in subsequent analysis.

them (Ausubel *et al.*, 1978 p. 59). For example understanding that displaying a country's flag is an act of patriotism.

Since these original definitions, subsequent scholars have placed less emphasis on identifying different types of subsumption, and have used the model as an explanation of the gaining of new specific concepts, linked to more general and inclusive concepts within a person's cognitive structure (Pearsall *et al.*, 1997). An example of subsumption would be a student learning the names and characteristics of the nine planets of the solar system, and it is regarded as by far the most common of the four processes of meaningful learning, involving a "weak" form of knowledge restructuring in the brain, as well as an incremental change in conceptual understanding.

2.8.2.2 Superordinate Learning

Ausubel *et al.* explained superordinate learning as being "when one learns an inclusive new proposition under which several established ideas may be subsumed" (1978 p. 59). Pearsall *et al.* regard superordinate learning as being less common in school science, and regard it as "a significant and rapid shift in conceptual understanding" involving strong knowledge restructuring (1997 p. 196). The example they give is very pertinent to my own research⁵: if an individual learns that scientists have decided that Pluto should no longer be considered to be a planet (on the basis of revised scientific notions of the concept *planet*), the conceptual change required to make sense of this new information involves superordinate learning, resulting in a student's changed understanding of the concept *planet*.

2.8.2.3 Progressive Differentiation

Both subsumption and superordinate learning result in the clarification of concept meanings, and, according to human constructivism, a person's knowledge base becomes more hierarchical and complex. Such increasing structural complexity is referred to as progressive differentiation (Mintzes *et al.*, 1997; Pearsall *et al.*, 1997). In his original theory, Ausubel seems to link progressive differentiation specifically with subsumption, whereby "the process of subsumption ... leads to *progressive* differentiation of the subsuming concept or proposition" (Ausubel *et al.*, 1978 p. 124 emphasis in original).

⁵ It is also topical. As I revised my thesis in August 2006 the International Astronomical Union debated the issue of Pluto as a planet; a topic which made headlines internationally. Pluto was 'demoted' to become a dwarf planet.

However later authors such as Pearsall and Mintzes and associates indicate that progressive differentiation occurs either through subsumption *or* superordinate learning.

2.8.2.4 Integrative Reconciliation

This occurs alongside progressive differentiation, as structural complexity increases, and refers to “the explicit delineation of similarities and differences among closely related concepts” (Pearsall *et al.*, 1997 p. 196). The example given by these authors, again related to astronomy, is when students learn about similarities and differences in the atmospheres of different planets, “their knowledge structures become more interconnected, integrated and cohesive” (p. 196). Again, while later authors regard it as a result of both subsumption and superordinate learning, Ausubel’s original theory refers to integrative reconciliation occurring as a result of superordinate learning, whereby new meanings arise and conflicting meanings become resolved.

One further cognitive process is referred to by Ausubel in his original theory of meaningful learning alongside that of superordinate learning, namely combinatorial learning. In this type of learning, he suggested that the new propositions being learnt could be classified neither as subordinate (as in subsumption) nor superordinate. However, this type of learning has not been referred to by later authors, and has fallen into disuse.

I have shown how the core of Ausubel’s theory of meaningful learning has been assimilated into the notion of human constructivism, and how aspects of the original theory have been adapted as further evidence has become available. While meaningful learning has broadly influenced several researchers of out-of-school learning (Falk & Dierking, 1997; Orion, 1993), only Anderson has used human constructivism as a basis for specific empirical study (Anderson, 1999; Anderson *et al.*, 2003). In his study of a school visit to a science centre he identified seven categories of knowledge transformation, three of which he related directly to processes described by human constructivism: subsumption, progressive differentiation and integrative reconciliation. However, Anderson’s interpretation is somewhat at variance with human constructivism as proposed by Mintzes *et al.* (1997, 1998). In his concept map of HC he indicates a link showing that subsumption results in superordinate learning (Anderson *et al.*, 2003 p. 180), yet he found no evidence of superordinate learning in his study.

In my own study, the cognitive aspects of learning were examined from a human constructivist viewpoint, taking into account both Novak’s and Mintzes’ theories, as well

as Anderson's interpretation and his own categories of 'knowledge transformation'. In Chapter 6 I will show how these cognitive processes can be applied to the data collected during the fieldwork in my study.

2.8.3 Conceptual Change

My study however, is not merely a study in cognition. There is ample evidence to suggest that other processes are taking place in people's minds when they visit a science centre or museum (e.g. Jarvis & Pell, 2005; Shortland, 1987). Returning to the entertainment versus education debate in section 2.5, the affective dimension of learning has been stressed as being important by numerous researchers (Osborne, Simon & Collins, 2003). While some researchers have been concerned that 'having fun' in a science centre dominates over real learning, I have shown that there is considerably evidence that they can both occur (e.g. Falk & Dierking, 2000; Gilbert, 2001). Due to the under-theorised nature of learning in informal environments, I found a pertinent conceptual framework that includes the affective dimension of learning elusive. Eventually I discovered it in an unexpected place: within the theory of conceptual change. In the 1980s Posner and colleagues (Strike & Posner, 1985) developed the theory of conceptual change, in which they show how learners transform their conceptions during the process of learning, firstly by Piaget's *assimilation*, "where a major conceptual revision is not required" (p. 215) and *accommodation*, in which the student replaces or reorganises his or her central concepts. The same researchers also described how the features of students' 'conceptual ecology' (cognitive resources) relate to conditions necessary for accommodation to take place. These conditions are dissatisfaction with the existing conception, intelligibility, plausibility and fruitfulness of the new conception. Critique of this original theory resulted in the revisionist theory of conceptual change (Strike & Posner, 1992) to account for the roles of emotion and intuition. Further 'non cognitive' development of the model was proposed by David Treagust and colleagues (Tyson *et al.*, 1997) in which they suggested a multidimensional interpretive framework. In this model they identified three dimensions which influenced the conceptual knowledge of the learner over time: epistemology, ontology and social/affective.

Alsop and Watts (1997), in their study of adults' informal learning about radiation, have adapted the Treagust conceptual change model (CCM) to suit their research context. Alsop and Watts' revision identified four lenses (cognitive, affective, conative and self-

esteem) through which to view the science learning taking place. Their research had shown them that neither the revised CCM, nor even Treagust's further modification was entirely suitable for learning within an informal context. The cognitive lens "retained the basic elements of the Strike and Posner model" (Alsop & Watts, 1997 p. 638), namely *intelligible*, *plausible* and *fruitful*. The Strike and Posner model also included *dissatisfaction* but Alsop and Watts omit it from their framework, possibly because in an informal environment it is difficult to show that the learner is dissatisfied with his or her existing knowledge.

For the affective lens, Alsop and Watts identify three elements of how learners engage with the topic. These are *germane*, referring to personal relevance; *salient* referring to the prominence of the topic in the learning environment; and *palatable* (how agreeable the material is). Alsop and Watts stress the important nature of the affective lens and how it can affect learning. This can be in a positive way whereby learners are motivated to engage with the topic when they are interested in it. This has been demonstrated numerous times in museums (e.g. Csikszentmihalyi & Hermanson, 1995; Ramey-Gassert, Walberg & Walberg, 1994). It can also negatively affect how learning occurs, whereby learners disengage with a topic they are not interested in (e.g. Jarvis & Pell, 2002, 2005). Researchers such as Suzanne Hidi distinguish between personal interest, relating to the individual and situated interest which relates to contextual factors in the environment which promote interest (Hidi & Harachiewicz, 2000). While it is difficult to change the long-term preferences of personal interest, the context of a classroom or science centre can manipulate the environment to try to develop situational interest. Both motivation and situational interest relate to Shen's notion of cultural science literacy, where the achievements of science can be recognised.

Alsop and Watts refer to their third dimension as the 'conative' lens which relates to the ways in which a learner might take action to use the knowledge in a practical manner. They suggest that it follows from Strike and Posner's notion of *fruitfulness*, and that the learner then asks "How can I use that knowledge? Does it empower me to act?" (p. 639). Within this dimension they identify three elements: how *actionable* is the knowledge, what *control* do they have over its use, and the extent to which they can *trust* their understanding. The fourth lens (self-esteem) refers to the learners' own *confidence*, *self-image* and *autonomy* within the framework of science learning and relies heavily on meta-

cognitive views of the students' learning. My interview questions were not devised to bring this out, so I did not use it in my analysis.

The Alsop and Watts model has many advantages for a study such as mine. It stresses the affective nature of learning, but not at the expense of the cognitive, and introduces a new component: the conative aspect. However, unlike the human constructivist model I have described, it was not identified prior to the data collection, and therefore the questions asked of the students were not tailored to 'suit' the model. This has both advantages and disadvantages: an advantage is that questions asked of the students were not set up to in some way 'prove' the model. A further advantage is that the initial analysis of the questions was not biased by the model's features. A disadvantage is that some questions which might have been asked, in line with the characteristics of the model were **not** asked, and therefore some aspects of the model may go unconfirmed. However, by using this and a human constructivist framework for the analysis of individual learning (see Chapters 6 to 8) and using 'bottom up' or inductive coding to demonstrate how the students learnt as a group (see Chapter 5), I hope to show I have captured the majority of the learning that took place during the visit by the sample of students in my study.

2.9 Summary

This chapter has described the research related to science education, astronomy education and informal learning. While the section on science education set the scene for my research, findings from both the other sections of the review have a number of implications for my study. First, my analysis of the astronomy education research over the past 30 years shows that the majority of studies have examined people's views of day and night, the Earth-Sun-Moon system and the phases of the Moon. Although I included questions on these in my interview questions, the literature suggested that other, less researched areas were important for a study such as mine. Hence, I included the topics of gravity, stars, the Sun, the Solar System and size and scale as areas for investigation, and identified Big Ideas in astronomy as areas of focus.

Secondly, much of the astronomy education research reported uses questionnaires and tests to collect data from subjects. Also, much of the discussion is under-theorised, with lists of misconceptions being one of the principal outcomes. Further analysis of the findings suggests that the more interesting results which have implications for learning and teaching are where researchers have used interviews and introduced models into the

discussion. I therefore used a structured interview to collect my data, and used a model of the Earth-Sun-Moon system for clarification.

Thirdly, very little research about astronomy has been carried out in South Africa. Given the importance the government is placing on astronomy currently (see Chapter 1), it is certainly a worthwhile area of study. Related to this is the dearth of research in planetaria over the past decade; given the inconclusive results of much of the early experimental research, it should be an area worthy of further study, especially within an interpretivist paradigm.

Fourthly, although a considerable literature of studies of informal education has been published over the last 15 years, the vast majority has been within developed countries, mostly in the Northern hemisphere. Very little empirical research related to museums and science centres has been conducted or published in South Africa. The very different priorities of the South African education system compared with those of developed countries mean that research in the context of a developing country will be a contribution to the literature.

Fifthly, several studies have emphasised the importance of teachers preparing students for the visit and following up with activities after the visit. However, throughout the world this seems to happen only to a limited extent, with most outings taking place as 'stand-alone' trips. Given this reality, I therefore thought it important to determine how much learning takes place in the visit alone, with no reference to teacher input.

Finally, much of the research in museums and science centres elsewhere has been under-theorised. Models for learning have been put forward, but few have been tested empirically. Relatively few studies have examined how learning occurs in an informal environment, and my study is an opportunity to provide an empirical basis on which future research can build in this area.

Chapter 3

I present a justification for the research design of the study, the instruments used for data collection as well as a description of how data was collected. I also discuss issues of ethics and credibility, and the limitations inherent in the study.

3 Research Design and Methodology

3.1 Introduction and Overview

In this chapter, I discuss the methodology which underpins my empirical study, and show how it relates to the theoretical framework and my research questions. Further, I describe the methods used in the study, the rationale for using such methods, the data collection process, the selection of study sites and participants, the instruments used to gather data, the development and piloting of the instruments, as well as issues of ethics, credibility and trustworthiness and the limitations of the study.

Over the period July to December 2003 the Johannesburg Planetarium and Hartebeesthoek Radio Astronomy Observatory visitors' centre hosted numerous visits by school and other groups from grade R (kindergarten) to university students. Prior to my formal data collection I attended five shows at the planetarium and four visits by school groups at the observatory, made field notes and collected pilot data for the study. From 31 July to 7 November I observed and video/audio recorded seven schools visiting the study sites, and collected data from 57 students aged 12 to 15 who completed Personal Meaning Maps and whom I interviewed about their experience of the visit. Over the course of 2003 there were a few newsworthy items related to astronomy and space science that students might have been exposed to at school or in the media. The first of these was the Columbia Space Shuttle disaster of 1 February 2003, when the shuttle disintegrated on its re-entry into the Earth's atmosphere, killing all seven crew members. Later in the year (late August 2003), the planet Mars was at its closest to Earth in 50,000 years, appearing six times larger and 85 times brighter than normal. This generated considerable media attention, including several misconceptions, such as the idea that the planet would be as big as the Moon in the night sky. In October, China's first astronaut was launched into space, an event which again made it into the news headlines. A prior event, in December 2002, was a

total eclipse of the Sun visible over the northern areas of South Africa, which was visible as a partial eclipse in the Gauteng area. All these phenomena caught the attention of at least some of the students in my study, as they referred to them during their interviews.

The conclusions and recommendations from this study which I discuss in Chapter 9 are relevant to presentations at both the study sites and more generally to science centres in South Africa but are limited to similar cohorts of students to those who were the participants in this study.

3.2 Methodology

3.2.1 Paradigms of Research

Research in much pure and applied science follows a fairly consistent pattern in which the researcher sets up a hypothesis which he or she then tests by empirical means to determine whether the premise was correct or not. Perusal of science journals and higher degree theses shows that science researchers do not normally consider their own ontological assumptions. They regard their research as a means of discovering the nature of the real world, and that the role of science research is to uncover real truths. Research into learning (even if it is science learning) is usually regarded as being different from research in science (Cohen & Manion, 1994). Educational research is normally regarded as a form of social science, in which the position of the researcher has a strong influence on the claims made (Henning, 2004). Most texts on educational research methods (e.g. Opie, 2004; Tobin, 2000) therefore advise the researcher to make clear his or her own ontological and epistemological assumptions, and to explain carefully what paradigm of research he or she is working with. I gave an account of myself as researcher in Chapter 1, which laid out my views on teaching and learning.

The three principal paradigms or overarching frameworks in social science research are positivist, interpretivist and critical (Henning, 2004). They are regarded as paradigms in that they each have underlying philosophical assumptions about how the world exists. The positivist or normative paradigm regards human behaviour as being subject to rules and something that can be investigated using methods used in science, such as experimentation. In contrast, the interpretivist framework takes an anti-positivist stance, examines humans as individuals, uses descriptive methods to find out about these individuals and interprets meaning in the findings. The critical paradigm attempts to question how power relations and the political nature of human society affects

relationships. Instead of measuring or interpreting human behaviour, the critical framework works towards deconstructing and reconstructing our world, usually involving some form of critical reflection and action. My study lies in the interpretivist paradigm, as although my own positionality has been influenced by the positivism of natural science, I believe that the process of educational research involves working with people as individuals. Such persons are best studied in depth rather than by using experiments and surveys, which may only acquire data at the level of the collective rather than the individual.

Another division in social science research is between quantitative and qualitative studies, which normally (but not always) follow from the paradigm adopted by the researcher (Opie, 2004). Opie suggests that a positivistic approach taken by a researcher will tend to lead to quantitative research techniques being adopted, while an anti-positivistic approach will lead to qualitative methods. Chapter 2 described that over the past half-century, the positivistic paradigm in science education has declined, and interpretivist and critical approaches have become more dominant (section 2.2). The following section lays out my rationale for using qualitative methods.

3.2.2 A Case Study

Since the 1970s, studies of museum learning have adopted a variety of methods for examining the extent to which learning takes place in the science museum and science centre environments. In common with the rest of the science education field, since the 1990s, there has been a shift away from experimental and quasi-experimental methods towards more interpretive, qualitative methods (Rennie *et al.*, 2003; Rennie & McClafferty, 1996). The principal reason for this change in emphasis within the wider science education community has been the realisation that social and contextual issues play a greater role in learning than had been previously thought. (Duit & Treagust, 1998). Key researchers who have been influential in shifting the museum research community towards more naturalistic studies are John Falk and Lynn Dierking. They have carried out numerous studies and reviews over the past 15 years (Dierking & Falk, 1994; Falk & Dierking, 1992; Falk & Dierking, 2000), as well as collaborated with many others (e.g. Adelman, Falk & James, 2000; Falk *et al.*, 1998) using a variety of qualitative (and quantitative) experimental designs which have added considerably to our knowledge of learning in the informal environment. Other museum researchers have experimented with various visitor studies techniques such as time at exhibits, pre- and post-visit interviews,

conversations between visitors, and the like. As a result of these efforts over the past decade, special issues of leading science education journals have been devoted to informal learning (International Journal of Science Education 1991, Science Education 1997, Journal of Research in Science Teaching 2003, and Science Education 2004) demonstrating the variety of naturalistic approaches and data collection methods now being used in the field.

In line with this trend, I decided that my research study design should be along qualitative, rather than quantitative lines. According to Tesch (1990) and Henning (2004), a qualitative approach allows researchers to conduct more detailed and in-depth studies. Henning (2004) and Holliday (2002) state that a true or 'progressive' qualitative study does not use pre-determined instruments to capture the data, but instead relies upon observation (without using an observation schedule), artefact and document studies, and interviews (which may be semi-structured). Henning (2004) is wary of qualitative studies which use pre-determined instruments, such as observation schedules or questionnaires, as 'naïve naturalistic' studies, and treats them as falling between the two paradigms of positivist and interpretivist, capturing neither the numbers needed for quantitative work, nor the thick descriptions required for effective qualitative study. Other researchers dispute this, for example Gorard and Taylor (2004) maintain that it is perfectly possible, and even advisable, to combine qualitative and quantitative methods, and produce research of high quality. I decided that my own study *should* use predetermined instruments, but that these would be devised during the pilot data collection phase.

One of the features of an ethnographic qualitative research design is that it involves very small numbers of participants, who are studied in great depth (e.g. Boaler, 1998; Brodie, 2005; Wolcott, 1988). Accordingly, such a study should give rise to a detailed description and interpretation of the participants' 'lived experiences' (Henning 2004). Although this has become an accepted and effective way of carrying out research, I had to consider the fact that the 'intervention' which forms part of my study is very short, confined to the one to three hours that students spend at the study site. In some cases there may have been additional work done at school, but this was not the norm in my study. This is in contrast to the sort of intervention which is more normally studied in research projects involving students and/or teachers. In these studies (e.g. Moolla, 2003; Trundle *et al.*, 2002) the intervention can consist of a special teaching project, which is tracked over a period of weeks so that a detailed picture of students' learning (and/or beliefs, attitudes,

interest) can be built up over a period of time. A study of informal learning such as mine examines the effect of a single ‘event’ which is not necessarily related to classroom learning; I found early on in the pilot phase of my study that most teachers taking a class to the planetarium or Hartebeesthoek Radio Astronomy Observatory did not link the visit to what they were teaching in class. In my case therefore, I considered that it would be important to follow the experience of museum researchers such as Allen (2002), Falk *et al.* (1998) and Paris and Mercer (2002) who used 49 pairs, 40 and 100 participants respectively, when conducting studies. Instead of acquiring limited data in the form of a questionnaire or survey, such studies obtain detailed information by interviewing the participants. In this way, qualitative methods of analysis can be applied to the data, which can also be analysed using descriptive statistics to help confirm the findings.

My study followed a case study design (Stake, 1995; Yin, 1994). Although I was initially interested in following Yin’s model of ‘multiple’ case studies, I found his recommendations for analysis approach those of quantitative research design. Yin recommends that theoretical propositions be set up as part of initial research design (similar to hypotheses), which can be tested against the findings. Given my preference for a qualitative research design, with my research questions attempting to find out the extent of learning and how it occurs at science centres, I considered the setting up of propositions to be premature. Instead I worked with Stake’s notion of a collective case study (Stake 1995) where a number of cases are selected in order to understand a particular situation being studied. Stake regards the collective case study as a special case of an instrumental case study, in which a case (e.g. a teacher) is being studied to understand something in addition to the case itself (e.g. the way the teacher works with assessment). Stake then recommends interpretive methods of analysis to understand more about the cases selected, which may lead to limited generalisations. This, however, is where great care needs to be taken on the part of the researcher. Generalisations are usually made by researchers using quantitative methods in their research, and even then only when very strict parameters have been set up in the research design, such as randomisation of the subjects and careful attention to validity and reliability issues. However, Bassey (1999) introduced the idea of ‘fuzzy generalisations’ into educational case study research. These generalising statements are *suggested* by the results, and although the researcher cannot be certain that his or her findings are completely valid or reliable, (s)he can make such fuzzy generalisations so as to generate limited claims as the basis for future research. Stake himself prefers to limit

case study research to finding out as much as possible about the case or cases under study, with the “emphasis on understanding the case itself” (1995 p. 8), though he also accepts that assertions can result from the understandings, and possibly even the modification of generalisations.

As I will show in subsequent chapters, my own study gives a detailed look at both what and how students learn about astronomy in science centres, and fits with Stake’s description of a collective case study. In addition, in Chapter 9 I show how some of my findings result in limited claims. These claims have implications for the study sites and students who participated in my study, as well as other science centres and students more generally and therefore form fuzzy generalisations based on my collective case. My collective case consisted of a total of 34 students from four schools who visited either the Johannesburg Planetarium or Hartebeesthoek Radio Astronomy Observatory. The research instruments I used and how I selected the study sites and students are described in the following sections.

3.3 Research Instruments

The principal data collection devices I used were Personal Meaning Maps drawn by participants, field notes taken during observation of the participants during their visit to the study site, and pre- and post-visit interviews with the participants using a structured interview schedule. In addition, field notes were taken during the visits to the schools, and the class visits to the study sites were audio-recorded (planetarium) or video-recorded (HartRAO).

In the early stages of the study, I considered using questionnaires to elicit information from the participants, along the lines of many researchers in the area of astronomy education (e.g. Baxter, 1989; Jarman & McAleese, 1996; Kikas, 1998b; Lemmer *et al.*, 2003; Trumper, 2001a). I developed such a questionnaire informed by the literature (see Appendix A), and administered it on a pilot basis to school students visiting the planetarium and to approximately 90 students at two township⁶ schools. The results of this pilot survey demonstrated that several of the questions were not properly understood by the students. Many students left some of the ‘short answer’ questions blank and guessed

⁶ In South Africa, the term township usually refers to the (often underdeveloped) urban residential areas that, under Apartheid, were reserved for non-whites (Africans, Coloureds and Indians) who lived near or worked in areas that were designated “white-only” (Wikipedia, see http://en.wikipedia.org/wiki/Township_%28South_Africa%29)

at what was expected in others. These results echoed the “empty sentences” referred to by Wagenschein (in Engeström, 1993). It is highly likely that the students’ ability to understand the questions (or lack thereof) had a part to play in their difficulty with them. Several researchers in Southern Africa have shown how language issues have a role to play in learning. Rollnick and colleagues (Block & Rollnick, 2003; Rollnick, 2000) have investigated how second language learners acquire the language of science, while other researchers such as Setati and colleagues (Setati, 2003; Setati, Adler, Reed & Bapoo, 2002) have examined how code-switching and discourse-specific talk influence the learning and teaching of mathematics and science. Language was not a focus of my study, and I decided that the deeper, probing nature of interviews would be a better way of exploring students’ knowledge and understanding of issues in basic astronomy. In addition, it appeared that in doing a study based on questionnaires, I would be replicating previous research such as that critiqued in Chapter 2. For these reasons I chose to use methods more appropriate to gathering data related to my research questions, and decided on a combination of Personal Meaning Mapping and interviewing.

3.3.1 Personal Meaning Mapping

Personal Meaning Mapping (PMM) is a technique developed specifically for museum learning, in which a subject’s knowledge and views about a particular subject are investigated prior to the subject entering the museum and again after the visit (Falk, 2003). Specifically, PMM is carried out in the following manner:

1. Prior to the visit to the museum, the subject is given a sheet of paper, in which a word or phrase is written in the centre. The subject is then asked to write or draw anything that comes to mind in relation to the word or phrase. This can be factual information, ideas, beliefs, or any other related opinions, and is written in a specific colour on the paper (e.g. blue).
2. The investigator then has a short interview with the subject, and, investigates the ideas the subject has already written on the paper, recording the subject’s elaboration of their ideas in a different colour ink from the original (e.g. red)
3. After the visit, the subject is given their original paper, and asked to make changes or additions to what they have already written on the paper. According to Falk (pers. comm.) and Luke (pers. comm.), it is crucial that the original paper is given back to the subject, rather than asking them to fill a new one. It ensures that they do not feel that the investigator is ‘wasting their time’ by asking them to repeat what they have already done, and it allows them to alter their original ideas. These corrections and additions are made using another colour ink (e.g. green).

- Finally, the investigator carries out another interview, based on the alterations and additions carried out in step 3. The investigator writes these (again using the subject's own words) in a different colour ink (e.g. yellow).

A sample PMM is shown in Figure 3.1.

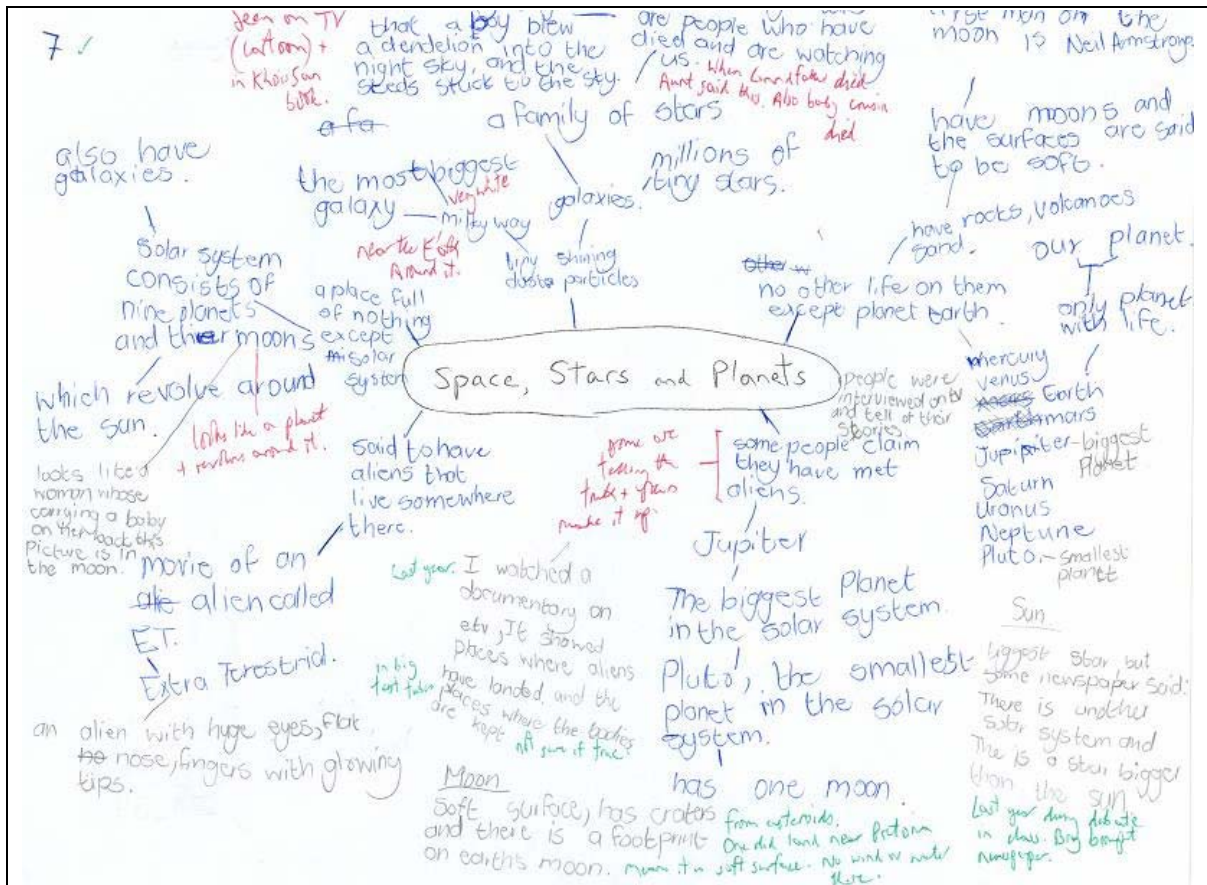


Figure 3.1 A Personal Meaning Map constructed by Bhekiwe

The technique is based on the concept maps developed by Novak and collaborators in the 1980s (Novak & Gowin, 1984). In concept mapping, a subject is taught how to map out their own understanding of concepts on a sheet of paper, and relate concepts to each other with appropriate connectors. In the analysis of concept mapping, there is sometimes a 'correct' concept map, drawn by an expert, against which the subject's map can be compared and scored. Much of the concept map analysis that has been developed over the past 20 years is based on this type of comparison (McClure *et al.*, 1999) and it has proved a useful technique for both pedagogy and the study of conceptual development, especially at the school and tertiary education level. There has been a number of variants of concept mapping since the technique was first developed by Novak. Techniques used by Morine-Dershimer (1993) and Leinhardt and Gregg (2002) are probably the closest to PMM. In a

study of conceptual change, Morine-Dershimer asked student teachers to make a concept map depicting their view of the important components of teacher preparation by providing the phrase “teacher planning”. Two semesters later, the students repeated the task, and then compared their post-course map with their original map. Leinhardt and Gregg used a similar method with pre-service teachers visiting a museum. Other mapping techniques have been used in educational research, such as ‘flow diagrams’ (Davidowitz & Rollnick, 2005) and ‘vee diagrams’ (Trowbridge & Wandersee, 1998).

Critiques of concept mapping have been made by Kagan (1990) and Ruiz-Primo and Shavelson (1996). Kagan noted that they were used to assess short-term change rather than long-term gain and remarked that studies often compared subject maps with a target ‘master’ map. Many studies made claims that the map reflects an individual’s actual cognitive structure, while Kagan considered that the maps may reflect their ability to “reproduce the structure of the discipline” (p 451) rather than show real changes in students’ cognitive structures. Ruiz-Primo and Shavelson (1996) sounded warnings about using concept maps for assessment purposes, and stressed the need for further research on the relationship between the maps and students’ cognitive schema. Apart from the fact that I used PMMs to demonstrate short-term rather than long-term gain, these criticisms do not apply to my study, as I used the maps principally as a basis for further questioning rather than analysing their structure.

One key difference between many analyses of concept mapping and PMM is that there is no ‘correct’ map developed at any stage, against which the PMM is scored. In fact Falk (2003) maintains that such a form of analysis would be counter to the philosophy of PMM in the context of museum learning. For Falk, there is no ‘correct’ answer or series of answers that a museum visitor can be expected to come up with in relation to their visit. Unlike the school classroom, or the university lecture, where the students would be expected to learn particular scientific concepts or facts, the learning which takes place in museums is personal, context-bound and idiosyncratic. A PMM is therefore an individual’s personal construct of whatever learning took place as a result of their visit. As Personal Meaning Mapping is a relatively new technique, and has mainly been carried out by Falk and collaborators, no analysis or evaluation of the technique has yet been published. In making use of the technique, I comment on its usefulness in Chapter 9.

In my study, the environment for data collection was quite different to many studies using PMM. Like Luke (1998), my data was collected in the school classrooms of the

selected participants in the study. I initially gained permission of the school Principal and relevant class teachers, and obtained informed consent from the students and their parents (see section 3.5). I then addressed the students in class and explained that I am researching their forthcoming visit to one of the study sites. After handing out blue pens to each student, I explained that I wanted them to write whatever they think about when seeing the words in the centre of the sheet of paper. Before giving them the paper, I then showed an example on the chalkboard, using the word “Johannesburg”. I asked the class what things came into their heads when they saw that word on the middle of a piece of paper. Using examples from the class, I then wrote their suggestions on the chalkboard, linking the words they suggested to the central word “Johannesburg”, or to words they have already put forward).

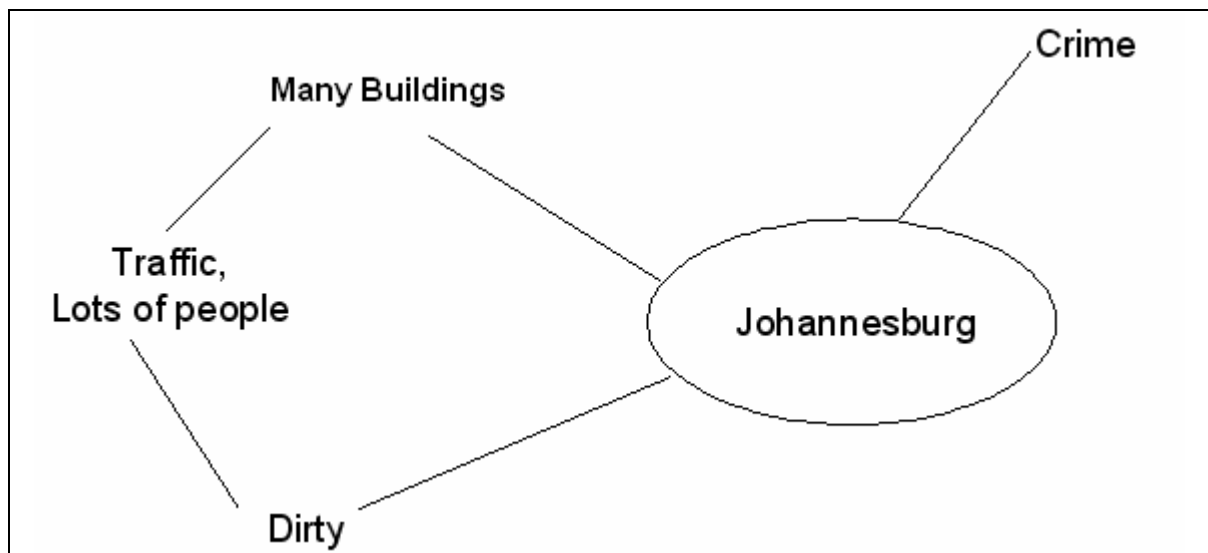


Figure 3.2 Example of initial PMM drawn on chalkboard

Once I had answered questions, and considered that students had got the idea of the technique, I would hand out the PMM sheet that I had prepared in advance for the study. The ‘prompt’ words in the middle of this sheet were “space, stars and planets”. Falk recommends that thorough piloting of the prompt is necessary (Falk 2003), and I did this in one of my pilot schools, using a combination of words including *space*, *Earth* and *stars* before deciding on the final wording, which elicited the most fruitful responses.

I then asked the students to write what they could tell me about these words. I stressed the following, that:

- Even if they were not sure about a particular issue, they should feel free to write about it.
- This was not a test.
- They could use words in their home language if they wanted.
- They could do drawings.
- They could write about their feeling and beliefs

I then gave the students time to complete the PMM. This varied from about 5 minutes, to a maximum of about 30 minutes. Most students would complete the map within 15 to 20 minutes. In order to ensure anonymity, I wrote a number on the PMM as each student completed it, and compiled a class list with the students' names and the PMM numbers. I could then cross reference each student against their own PMM, but anyone seeing a map would not be able to identify which student had completed it. As they completed their PMMs, students handed them to me. I then selected which students I wanted to interview, as described in Section 3.4.2.

3.3.2 Interview Schedules

Several researchers in the area of both astronomy education (e.g. Summers & Mant, 1995) and museum learning (Anderson et. al. 2000) have found that interviewing subjects can elicit more information from them, as well as allowing probing, through which the salience of the subjects' beliefs can be examined more carefully. In the light of this and my experience with piloting a questionnaire, I decided to design a structured interview schedule which would allow me to probe students' thinking more deeply, both prior to and after their visit to the study site. The resulting interview schedules were piloted with a small group of students in an independent school East of Johannesburg visiting the Planetarium during August 2003. Further development of the interview schedules resulted in four differing versions, two pre-visit and two post-visit, (Appendices B and C), each tailored to the study site the students were due to visit.

3.3.3 The pre-visit interview schedule

Each pre-visit interview schedule (Appendix B) is divided into four sections, A to D. Section A, identical in both study site versions, is introductory, dealing with informed consent and demographic information about the interviewee. Section B, also common to both versions, concerns the proposed visit, and what the students expect from the visit.

Research examining the effect of orienting students regarding ‘what to expect’ during their visit to a museum or science centre (Anderson & Lucas, 1997; Griffin & Symington, 1997; Kubota & Olstad, 1991) has shown that students benefit both cognitively and attitudinally from such orientation. The Section B questions were developed using methods described in such research.

The Section C questions differ according to which study site is due to be visited. During the early months of the study prior to formal data collection, I visited each study site several times, observing groups of students as they participated in the activities. I took field notes during these visits, and also audio- or video-recorded the proceedings. I then analysed the astronomy content that each of the study sites was aiming to impart to their visitors, and identified a number of key concepts that a visitor to the study site was exposed to. These concepts are shown in Table 3.1, and are developed into Big Ideas in astronomy in Chapter 5.

Table 3.1 Key concepts in astronomy identified at each study site

Planetarium	HartRAO
Stars and planets in night sky	Sun and stars: similarities and differences
Solar system: what it is, its shape	Sun temperature, other sun facts
Sun and its movement across sky	Sun and its movement across sky
Relative size of the sun and moon	Relative size of the sun and moon
Stars: what they are, how far away	Stars: what they are
Moon phases	Moon phases
	Satellite and satellite dish
	Gravity, with probes
Astronomy in the news	Astronomy in the news

Section C of each pre-visit interview asks questions related to the content shown in Table 3.1, according to whether students were visiting the Planetarium or HartRAO. For example, question C2 asked at the planetarium was “What is the solar system? What [things] does it consist of? What shape is it? How do you know?” Question C5 asked at HartRAO was “Stars at night look like pinpricks of light. Why? What are stars?”

Finally, Section D of each pre-visit interview (common to both study sites) asks questions related to students’ interests and attitudes towards school, recreation and astronomy, as well as students’ beliefs regarding extra-terrestrial life, astrology and

religion. Studies of peoples' attitudes towards phenomena have been carried out by psychologists for decades, and have tended to use quantitative measures (Crawley & Koballa, 1994; Osborne *et al.*, 2003). More recently, there has been interest in school students' attitudes towards various aspects of science, including astronomy (Jarman & McAleese, 1996; Jarvis & Pell, 2002, 2005). However, these studies have also been mainly quantitative in design, and their instruments were not helpful in my study. The questions in Section D were adapted slightly over the course of the study, as my interviewing technique improved. The intention of the Section D questions was to identify whether a student's attitudes or interests could be related to his or her learning at the study site. The pre-visit interview schedule was piloted in a private mission school on the East side of Johannesburg, and questions were revised on the basis of the responses by students.

3.3.4 The post-visit interview schedule

After the visit, students were asked questions (see Appendix C) related to their visit to the study site, as well as a repeat of the content questions asked in the pre-visit interview. Section A questions, common to both study sites, were again related to informed consent and identification of the student. According to Anderson *et. al.* (2000), very little research has been carried out on post-visit activities carried out by teachers who take groups of students on visits to science centres. The Section B questions made a brief follow-up on whether the students knew where they had visited, and why. The Section C questions were identical to those asked in the pre-visit interview, and were different for the two study sites. Finally, questions in Section D related to their attitudes towards the visit, and attempted to identify memories from the visit which could be construed as learning. In several articles and chapters, Falk and Dierking (1992, 1997, 2000) have indicated that it is better to try and identify learning *not* by asking "What did you learn in the Science Centre?" (e.g. Cox-Petersen, Marsh, Kisiel & Melber, 2003) but instead by asking for examples of aspects of the visit which interested students, or that they told to others. The questions on learning in Section D draw upon methods used by Falk and Dierking (1997).

3.3.5 Interviews

I conducted each interview at the schools visited. After obtaining permission from the Principal and relevant class teachers, and arranging for consent forms to be signed by the students and their parents/guardians (see section 3.5), I requested the teacher to arrange a room in which I could interview any selected student. The room varied according to the

school visited, but was usually an office or classroom not being used by others at the time. The interviewee and I were therefore accorded privacy, and I was able to ask questions and audio-record the interview. Interviews followed a standardised format, in which I would first confirm informed consent, and ask biographical questions to try and set the subject at ease. I would then go through the interview schedule from Section A to D, ending the interview with questions on the subjects PMM that they had previously written for me. At the end of the interview, I would thank the student, and request him or her to call the next selected student to come to the room. All interviews were audio-recorded on to cassette tape, and transcribed to a word-processor file, which could then be analysed.

3.4 Data Collection

3.4.1 Selection of the Study Sites

Despite South Africa's increasing prominence as a hub for astronomy and space science, there are relatively few sites promoting astronomy education in the country. The main ones include planetariums in Johannesburg and Cape Town, the South African Astronomical Observatory in Cape Town, the newly opened South African Large Telescope in Sutherland, the Boyden Observatory in Bloemfontein and astronomy-related sections of museums and science centres.

The logistics of my study meant that I preferred to work in the province based around Johannesburg and Pretoria. Within this region, the number of sites that combine both astronomy and informal learning was limited. I could have chosen sites of interest for amateur astronomers, such as the Observatory in Johannesburg, or other private observatories open to the public on a limited basis. However, my principal interest was combining informal learning with the school education system, hence I needed to locate sites which allowed or encouraged access for school groups. On this basis, one obvious choice was the Johannesburg Planetarium, located on the premises of the University of the Witwatersrand, and run by the university as part of its science awareness outreach programme. Large numbers of school groups visit the planetarium on a monthly basis, and it appeared to be an ideal site to base my study. When I approached the Director for permission to use the planetarium as one of my study sites, I was welcomed, and given permission, with the proviso that I feed back the results of my research to the staff. Originally conceived in 1956 as part of the celebrations for the 70th anniversary of the founding of Johannesburg, the planetarium was transferred by the City Council to the

University of the Witwatersrand and opened in 1960, housing a reconditioned star projector from Hamburg, Germany (Johannesburg Planetarium, 1999).

The disadvantage of the planetarium is that its educative experience is in the form of a presentation only which, even if made interactive by the presenter questioning the audience, is a mainly visual and auditory experience. In looking for an additional out-of-school astronomy experience, I met an astronomer from the Hartebeesthoek Radio Astronomy Observatory. He described their science awareness programme and explained that they encourage schools to visit the telescope and adjacent visitors' centre. Since it is located in Gauteng province less than 60 km from Johannesburg, HartRAO appeared to be an ideal additional site at which to base my study. HartRAO is an example of a 'large object with a small museum attached' (Gregory & Miller, 1998 p. 204) similar to the Jodrell Bank Visitor Centre attached to the radio telescope in the UK (Chaplin & Graham-Smith, 1992). Gregory and Miller consider such types of museum as typical of the later 20th century, as artefacts of science and technology which now concern themselves increasingly with both the 'cosmic and microscopic'. This contrasts with previous decades, in which the emphasis was on relatively *small* artefacts in *large* museums.

Situated in a hollow in the Magaliesberg hills West of Pretoria, HartRAO was built in the early 1960s as a tracking station for the United States' NASA Apollo and associated missions. Even in those early days, there was a form of 'science awareness' programme run by NASA, which included lectures to interested groups and visits by schools. The facility was handed over to the South African government in 1975, and was managed by the National Institute of Telecommunications Research, a part of the Council for Scientific and Industrial Research. For the next few years, HartRAO accepted one visit per month from schools and universities. In 1988, responsibility for the observatory was transferred to the Foundation for Research and Development (now the NRF), and in 1990 a member of staff was recruited to spend 50% of her time on a science awareness programme. The facility is currently managed by the National Research Foundation (NRF) as a radio telescope, and has expanded its science awareness programme considerably. The programme encourages visits by schools, clubs and the public to learn about astronomy, space and the research carried out using the radio telescope. In addition, the science awareness staff (two full-time educators, under the guidance of the programme manager) run teachers' workshops and participate in relevant science communication events in the region. (Gaylard, undated)

A visit to the planetarium typically involves a 50 to 80 minute ‘show’ in which an astronomy educator demonstrates the solar system, astronomical distances and an indication of the night sky constellations visible the same night. A visit to HartRAO typically lasts up to 4 hours, and entails interactive activities such as water rockets, whisper dishes and star spinning, and demonstrations of the solar system and the radio telescope. I describe the experiences of a student visiting each of the sites in detail in Chapter 4.

3.4.2 Selection of the Participants

In the original research design for my study, I planned to examine how both students *and their teachers* experienced astronomical phenomena at a science centre. I felt this important, as much of the literature related to astronomy education showed that teachers’ understanding of astronomical experiences is often as limited as that of their students (Summers & Mant, 1995; Trundle *et al.*, 2002) and it is unlikely that the situation in South Africa is different. As the research proposal progressed, and the focus moved towards the informal learning of astronomy and ‘museum learning’, the role of teachers was less of a priority, but I still considered it important, as many studies have shown (e.g. Anderson & Lucas, 1997; Griffin & Symington, 1997; Storksdieck, 2004). However, once I began to examine how school visits to my study sites were being arranged, it became apparent that only in a very limited number of cases would it be possible to collect data on teachers, as well as the students. This is because in most instances, the visit being arranged was unrelated to the actual teaching currently taking place in the school, and the accompanying teacher was often not teaching the subject of astronomy to the students participating in the visit. I therefore decided that it was more appropriate to assess the learning of the students, who were full participants in every visit to a study site, rather than include the teachers, who rarely participated in the study site activities.

The selection of schools and grade level of the students for the study was carefully considered. Reviews of museum and science centre learning (Falk & Dierking, 2000; Rennie & McClafferty, 1996) show that studies have been made with participants across a wide age range, from pre-school to adults. Reviews of astronomy learning (Table 2.1) show a similar wide range of participants, but include fewer adults, and larger numbers at the level of college and university students (Bailey & Slater, 2003; Dunlop, 2000). I chose grades 7 to 9 (mainly 13- to 15-year-olds) for my study because these grades form the Senior Phase of the General Education and Training (GET) Band of South Africa’s new

Curriculum 2005. This curriculum was phased in from 1996 to replace the ‘interim core syllabus’, in place since 1994. Grade 7 is the final year of primary school, while (in most schools) grades 8 and 9 form the first two years of high school, so my sample spanned the primary-secondary school border.

My original intention was to select schools principally from the public system of schooling in South Africa, as they form the bulk of the schools in South Africa, and any findings from the study would be most valuable if relevant to them. However, having chosen the two study sites as being ideal locations at which astronomy and informal learning are combined, and having a limited time for data collection, I was restricted to schools that had already planned to visit one of these two sites. In order to select schools, I contacted each study site and obtained lists of schools with classes in grades 7 to 9 visiting. I then approached the teachers and principals in these schools to enquire whether they would allow me to conduct my research with students in their schools. This usually entailed visiting the school, explaining my research project, and leaving them with a set of information sheets and informed consent forms. After a period of days, I would contact the school again, and, if permission was granted (it was in every case), I would make arrangements to visit the school to conduct the first phase of my study: the administration of Personal Meaning Maps.

As a result of this ‘convenience sampling’ (Cohen & Manion, 1994) of schools and classes, the schools shown in Table 3.2 formed the basis of my study, from which students were selected.

Table 3.2 Participant schools in the study

Name ⁷	Type of School	Location	Visit to	Classes
Lourdes Girls School	Independent Catholic Girls' School	Suburb, West Rand	Planetarium	1 Gr 8
Revelation School	Small independent Christian school	Suburb, East Rand	Planetarium	1 mixed Gr 7-9
Achievement School	Small independent school	Suburb, West Rand	HartRAO	Gr 7
St. Augustine's School	Independent Mission School	Town East of Pretoria	HartRAO	2 Gr 7
Balfour Forest School	Public school	Suburb, Johannesburg	HartRAO	2 Gr 7
Bokamoso School	Public school	Township West of Pretoria	HartRAO	Gr 7&8

The selection of students who completed the PMM was straightforward, and is described in section 3.3.1. In total I obtained 145 PMMs from students in seven schools. The actual number was closer to 170, but some of these students either did not return their informed consent forms, or did not actually go on the visit, and were therefore not used in the study. My study being principally qualitative, I needed to select a smaller number of students to interview, both with reference to their PMM and in relation to their astronomy knowledge (section 3.3.2). Selection of which students to interview needed a set of criteria which I set up based on my research questions and on similar studies in the literature (e.g. Anderson *et al.*, 2000).

My research question 5 asks 'How do students' interests and prior knowledge affect the learning experience of a school visit?' One of my criteria for selecting students for interview was therefore identifying students who had particularly strong interests or beliefs which may have affected their learning at the study site. Similarly, if a student either showed considerable prior knowledge or conversely lacked any prior knowledge in the area of astronomy, I could select them. Anderson *et al.* (2000), selected students who provided a range of scientific and alternative conceptions in their concept maps, as well as roughly equal representation of boys and girls; criteria that I also applied in my selection. In addition to this, where the classes I selected included both black and white students, I

⁷ In order to maintain anonymity, all school names are fictitious.

attempted to obtain representation from all population groups⁸. A further criterion used by Anderson *et al.* (2000) was the recommendation by the teacher that a student would be able and prepared to communicate effectively with the research team. I considered that this may introduce possible bias into the selection, and preferred to obtain a ‘veto recommendation’ from the teacher in cases where s/he considered the student unsuitable for interview. Selection of my final research sample of 34 students is described in section 3.4.2.

3.4.3 Triangulation

Triangulation refers to the process of obtaining two or more forms of evidence to improve the validity of the findings (Cohen & Manion, 1994). I collected evidence in the form of PMMs, interviews and field notes, as well as an audio or video record of the class visit. The process of data collection is summarised in Figure 3.3, and issues of validity are discussed in section 3.6.

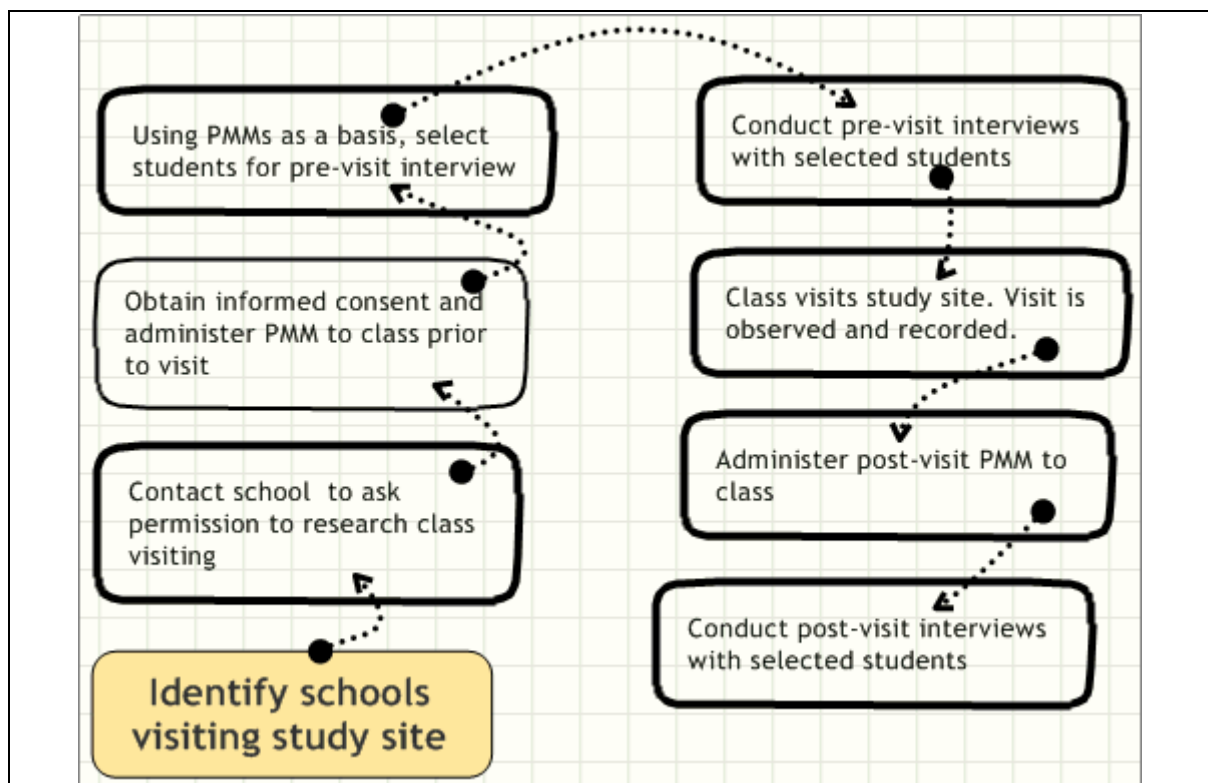


Figure 3.3 The sequence of events in data collection

⁸ In South Africa, reporting of statistics often includes reference to black, Indian, coloured and white individuals in order to demonstrate redress.

3.5 Ethical issues

Issues of ethics are prominent in all the research literature (e.g. Cohen and Manion 1994, Henning 2004). In my study, prior to starting my data collection, I had to satisfy the University's Human Ethics Research Committee (Non-Medical) that I had done everything possible to ensure proper informed consent, anonymity and confidentiality for the participants. To start with I obtained the permission of my two study sites to use them in the study, and also to use the real names of the sites in reporting on the research. Prior to starting data collection in a school I provided all the research participants (students) with information sheets on the proposed study, as well as consent forms (see Appendix D) for themselves and their parents to sign if they wished to participate in the study. I did not consider it necessary to obtain informed consent from the teachers, as they were not participants in the study.

Table 3.3 shows the return rate of informed consent for the 6 schools in which the study was conducted.

Table 3.3 Informed consent returns

Fictitious Name	Code	Classes	No. of students approached	No. of students who consented	% who consented
Lourdes Girls School	scf	1 Gr 8	21	16	76
Revelation School	sri	1 mixed Gr 7-9	8	8	100
Achievement School	vho	Gr 7	16	14	88
St. Augustine's School	sth	2 Gr 7	45	32	71
Balfour Forest School	swo	2 Gr 7	75	37	49
Bokamoso School	tsw	Gr 7&8	18	17	94

There was a relatively high level of return of informed consent from the majority of the schools. As could be expected, when the number of students approached was relatively small (25 or fewer), the rate of consent was highest. In all cases I explained the issue of informed consent to the students, but did obtain assistance from the teachers to collect in the forms. In two cases, I found that the teachers wanted to coerce the students to sign, for example by telling them that they would not be able to go on the trip unless the informed consent form was signed and returned. I explained to the teachers who did this that this

was neither necessary nor ethical, but they did not always appear convinced by my argument and I did not intervene further between the teacher and students in this matter.

The consent forms were provided only in English. I considered this appropriate as all the schools which participated in the study used English as their language of learning and teaching. Of the students interviewed, 38% (n=34) said they used English as their home language, and a further 38% used it as an additional language spoken at home. So from the point of view of the students and their parents' understanding and signing the forms, I considered that the use of English was appropriate. However, it could be argued that in the two public schools, while the students' level of English was sufficient to understand the forms for the purpose of being able to give their informed consent, this may not have been the case for their parents/guardians who were required to sign. Discussion with the students however, assured me that their parents/guardians level of English was sufficient to understand what they were signing.

Although students were told that, both orally and in writing, they were entitled to review the transcripts of their interviews, I did not actually offer this to them once the interviews were transcribed. This was partly due to the fact that the interviews were transcribed several months after the tapes were made, and also because the logistics of arranging a review of the transcription would have been difficult. Also, a number of qualitative methodology texts note that this 'respondent feedback' involves power relations which make it unlikely that the interviewee will make significant changes (University of Huddersfield, 2006). This is particularly relevant in the case of children who have been told that the transcript is a record of what they said recorded in the interview. However, I recognise that the fact that the students were not given the opportunity to review their own transcripts could be a limitation in my study.

One aspect of 'self' selection by students (or their parents) is particularly worth commenting on here, as it demonstrates how the context of a school visit in a developing country is very different from those in more developed contexts. In schools where the socio-economic level of the parents is relatively low, the issue of affordability of visits affects students' participation in school trips, and therefore in my study. In both the public schools, as well as in schools which were part of the pilot study, only students whose parents can afford to pay are able to participate in school visits. In effect, this selects *out* the students whose home circumstances precludes payment for visits to sites such as those used in my study, and therefore biases the results in favour of students from higher socio-

economic status homes. Since the entrance fees are subsidised, the biggest cost of visits to either of my study sites is the cost of transport. Unless the school is able to pay for such students, which Balfour Forest School did in the case of some students in my study, students whose parents who cannot or are not prepared to pay are excluded from my sample. This may well account for less than 50% of students/parents signing the informed consent forms in this school. If a student or parent knows they are unlikely to be able to attend the visit, there is little reason to agree to participate in the study. Students from Bokamoso were in a slightly different position, in that they were part of a science club for whom the visit was being organised. Being a relatively small self-selected group, there would have been more incentive to sign the consent forms. It is important to note that the two public schools are representative of the vast majority of schools in South Africa, and that, like the students in Jrene Rahm's study in the USA (Rahm, 2004), such students will normally have little access to science centres and museums.

Adler and Lerman (2003) stress that research, particularly in developing country contexts, has a multiplicity of responsibilities to and ownership by the participants, the researcher and his or her community, and the public. My study attempted to address these issues. Although my research did not directly benefit the students who participated, I consider that it does benefit future generations of students at the participating schools. I have kept in touch with the schools, and intend to make presentations on school visits to all staff once the study is complete. Other indirect beneficiaries are teachers and school children throughout South Africa and the region, as I have already presented interim findings to conferences, and intend to continue this. The principal beneficiaries of the research are the planetarium and HartRAO, who will receive copies of the thesis and I will make presentations to their educators and stress the implications for their own programmes. In addition, I will present my findings to the science centre community in Southern Africa at their annual conference. In these ways I believe I have addressed issues of responsibility to the participants, the research community, and to a lesser extent the public. However, aspects of ownership by these stakeholders are less clear, and I did not identify them as priorities when the study was formulated. While the research academy will have a degree of ownership as the topic of research is important in the informal learning community, I need to devise ways of greater ownership by the participants and the public in future research projects.

3.6 Issues of credibility and trustworthiness

Unlike quantitative research, a qualitative study cannot rely solely on the concepts of validity and reliability as criteria for assessing the quality of the research. Instead, qualitative research texts identify a variety of ‘quality checks’ to determine the extent to which the research can be regarded as credible and trustworthy. The following sections discuss how I attempted to build checks of quality into my research throughout the planning, data collection and analysis.

3.6.1 Validity

A great deal has been written about the concepts of validity and reliability with respect to qualitative research. Some case study research deals directly with issues of validity, for example Yin (1994) recommends using multiple case studies to improve external validity and matching predicted patterns with empirically based patterns in the data to improve internal validity. In my own case I asked content specialists to examine my interview schedules for face validity, and made changes accordingly. This was not however possible for the constructivist tool of Personal Meaning Mapping, where the concept of validity has little meaning. Many scholars who work qualitatively (e.g. Henning, 2004; Miles & Huberman, 1994) have questioned the use of validity in qualitative research as it is a construct of the positivist paradigm. An alternative is the concept of trustworthiness (Lincoln & Guba, 1985) which refers to the extent to which the reader can trust the findings, interpretations and claims as being “worth paying attention to, worth taking account of?” (p 290). Elliot Mishler goes even further, and asks whether subsequent researchers will value the findings and claims enough to use as a basis for their own research (Mishler, 1990). Instead of using “the static properties of instruments and scores” (p 419) investigators would examine the methods used in the research and base their judgement on this. Other researchers have described the need for an ‘audit trail’ in qualitative research which documents the steps taken and decisions made during the analysis to demonstrate how the researcher moved from data to the final findings and conclusions (Miles & Huberman, 1994).

I have attempted to lay out in this chapter the detailed procedures by which I collected my data, as well as the various assumptions I made. Chapters 5 and 6 explain the processes by which I analysed my data. More importantly, attached to this thesis is a CD containing the Hermeneutic Unit (HU) of the qualitative analysis software I used to

analyse all the data (ATLAS.ti version 5.2), which provides my audit trail. The HU includes all primary documents (PMMs and transcriptions of interviews), coding of these documents, code families, comments on codes and families, incidental memos I made while examining the data as well as a journal recording all my thoughts as the analysis progressed over the period 2004-2006. For example, a reader can decide to examine the data on which one of my portraits in Chapter 7 or 8 is based. If he or she chooses to look at Brenda's data they can open the HU, select the primary document family for Brenda, and examine all the data and how it was coded. Extracts from the HU are shown in Appendix E.

Together, these provide a satisfactorily detailed description of the basis for my claims in Chapters 9 and 10, and in this way satisfy the criteria for trustworthiness as detailed by researchers such as Henning (2004) and Opie (2004).

3.6.2 Reliability

Reliability refers to the ability to replicate the findings of the study if repeated by another researcher under similar conditions. As with validity, a qualitative research approach does not lend itself to replicability, given the fact that the data are collected under very specific conditions from a relatively small number of participants (Bassey, 1999). For this reason, it was not possible to use one of the normal criteria for reliability, which is to examine the consistency of results in a test over a period of time. Instead, I used the notion of inter-rater reliability to assess the degree to which other researchers would classify my data into categories, and compare those with my own (Ruiz-Primo & Shavelson, 1996). As I describe in Chapter 6, I asked two colleagues using my Big Ideas typology to group students into categories. The results of their classification were consistent with my own, and demonstrated that my results in this section of the thesis are as reliable as could be expected.

3.6.3 Reflexivity

Reflexivity or Reflexiveness is the extent to which a researcher is aware of his or her own assumptions and biases in constructing meaning from the data acquired during the research process (Ryan & Weisner, 1997). In Chapter 1 I described the position from which I approached my research, a point which I tried to be aware of during the data collection and analysis processes. As analysis proceeded I kept a journal (available within the Hermeneutic Unit of ATLAS.ti attached to this thesis) which shows my thoughts and

interpretations of the data. In these ways I attempted to ensure that bias was kept to a minimum in the analysis, and where present that I explained my thinking to the reader.

3.7 Reflection

My research methods were designed to capture students' prior knowledge of basic astronomy as well as their related interests and beliefs before they participated in the visit to the science centre. I need to accept that the process of the pre-visit PMM and interview, as well as my presence on their visit set up a pedagogical frame around the visit and probably heightened students' awareness of the trip and the topic of astronomy. In this sense my data collection could be regarded as a form of intervention which would be absent in most school visits. Although I tried to remain a non-participant in the visits made by the school classes to the study sites, at least some students would likely have viewed me as part of the educative team based at the science centre. Data provided in subsequent chapters needs to be viewed with this limitation in mind, and I will discuss it further in Chapter 9.

This chapter has described my research design and methods of data collection in some detail in an attempt to provide the reader with a full account of how the study was conducted. Chapter 4 provides a narrative of two students' visits to the study sites to show their experience as participants in the out-of-school trip.

Chapter 4

4 Setting the Scene – a narrative of the visits

This chapter shows the reader what it is like to visit the sites at which the study was based. I decided to present it as findings from the research, in the form of narratives of two students' visits. This serves two purposes: to enable the reader to experience a visit through the eyes of a child, and for me as researcher to share findings from interviews and observation and in doing so "open a window on the mind" (Cortazzi, 1993).

4.1 Introduction

Narrative is used in the qualitative research literature to refer to a variety of prose texts, but in this study I am using Polkinghorne's (1995) description of narrative as a text which is organised thematically by plot. In my case the plot refers to the experiences that the student has during the visit to the astronomy-based science centre. Polkinghorne identifies two types of narrative study, named rather confusingly as 'analysis of narratives' and 'narrative analysis'. In the former, a study examines people's stories and life histories and comes up with categories or groupings on the basis of such narratives. In narrative analysis a researcher uses data collected to produce a narrative or narratives as the result of the study. The findings presented in this chapter represent the latter.

Dollard (1935) developed a set of criteria which he "viewed as indispensable for judging a life history technique" (p 8). In his paper on narrative configuration, Polkinghorne (1995) adapted Dollard's seven criteria as guidelines for narrative analysis writing. I have followed Polkinghorne's advice and attempted to use these guidelines in the development of the narrative in Sections 4.2 and 4.3. The seven guidelines can be summarised as follows:

- Attention must be given to the *cultural context* in which the story is set. The characters in the narrative interact within a set of norms and values developed as the result of the culture in which they exist.

- The *protagonists* (main characters) in the story should be clearly described in terms of how they are *embodied*: age, physical features, mental capacities and emotional responses are some of the ways in which this can be expressed.
- *Relationships* between the people in the narrative need to be clearly explained in the development of the plot, so that the effect on the main characters can be brought out.
- A narrative that involves a main character (as both of mine do) “needs to concentrate on the choices and actions of this central person” (Polkinghorne 1995 p 17). Such a person does not only react to events but also shapes these events, and the researcher needs to describe how this *interaction* occurs.
- All characters have a *history*, and the describer of the narrative needs to be able to relate the protagonist’s actions in relation to his or her past experiences.
- The story that results from narrative analysis should be time bounded and presented in enough detail to demonstrate that it is a *unique description*, not merely an average account abstracted from a series of observations of different people.
- Finally, the *outcome* of the analysis needs to be plausible, understandable and believable, often with a clear conclusion which is a configuration of the various data elements into a well-rounded systematic whole.

In addition to Dollard’s criteria, Polkinghorne has developed a further guideline which he considers important. This is the need for the researcher to share with the reader the role the researcher played in the construction of the narrative, and how he or she has shaped the resulting story (Polkinghorne, 1995). I consider that this guideline is related to the analysis rather than the data, and have attempted to do so in this chapter. Wolcott (1988) makes recommendations for narrative accounts in his story of a ‘sneaky kid’. He suggests that “the story should make a point that transcends its modest origins”, and “the case must be particular, but the implications broad” (p. 246). In the narratives portrayed, what the students experience before, during and after the visits to Hartebeesthoek Radio Astronomy Observatory and the Johannesburg Planetarium are typical of the experiences of all the school visits observed in my study, including those observed during the pilot phase.

Zeller (1995a; 1995b) recommends a particular style for a narrative analysis, that of ‘new journalism’ as described by Tom Wolfe in 1973. The writing devices recommended for new journalism and espoused by Zeller are “the telling of a story in scenic episodes”, “character development through dialogue”, “experiencing an event through the perspective

of one of its participants”, and “the full detailing of the ‘*status life*’ – or rank – of scene participants” (Zeller, 1995b p. 79 after Wolfe 1973).

Each of these techniques has implications for a school visit narrative. Scene-by-scene construction consists of a series of events, each with its own ‘story’, and in a museum or science centre context can be equated to the main character visiting a series of exhibits with a narration of the experiences he or she has at each. According to Zeller the development of character through dialogue presents particular challenges for the qualitative researcher regarding the extent to which he or she should report actual dialogue or an impression (and therefore an interpretation) of the data. Similarly, the actual process of obtaining conversations in museum settings is difficult due to the nature of the interactive experience (Allen, 2002). Zeller’s recommendation of a subjective viewpoint by telling the story through the eyes of one of its participants is to show that no account can be truly objective. An attempt to present an objective description of a science centre visit could result in a mechanistic description of the exhibits and presentations which would not properly capture the nature of the experience for the majority of visitors. The final writing device (the provision of detail) is suggested to make the story and characters believable, and is found in many genres of writing.

In the case of a school visit, how the main character interacts with his or her surroundings, fellow students, teachers and science centre staff is important to provide the reader with evidence that the narrative presented is plausible, and relates to several of Dollard’s criteria described above. I demonstrate how each of the criteria relates to my data sources from the study in Table 4.1.

Table 4.1 Relationship of data sources to criteria for constructing narrative

Criterion (from Polkinghorne 1995)	Data Source
Cultural context	Interviews with students, field notes from school visits
Embodied protagonist	Interviews with students, field notes and video from study site visit
Relationships between people	Field notes from school visits, field notes and video from study site visit
Main characters interaction with events	Interviews with students, field notes and video from study site visit
Protagonist’s history	Interviews with students
Time bounded story	Field notes and video from study site visit

In the narratives I have attempted to follow the guidelines of Polkinghorne, Zeller and Wolcott in order to create a rich and textured narrative analysis of what it means for a student to visit either HartRAO or the planetarium. In doing so, I have drawn mainly on field notes and video- and audio-taped recordings of school visits to the sites, as well as field notes made during my visits to the schools and interviews with the students and teachers. However, what I'm presenting is not a life history, but a snapshot of an event in life, so some of the guidelines, such as 4 (the central character), 5 (the character's life experiences) and 6 (the unique description of the event) are more relevant than others such as 2 (the character embodied) and 3 (how the character relates to others).

In the following narratives, the fictional students Kaelo and Kitso are based on two individuals, but are a synthesis of several students who visited Hartebeesthoek Radio Astronomy Observatory and the Johannesburg Planetarium respectively.

4.2 A visit to Hartebeesthoek Radio Astronomy Observatory

4.2.1 Before the visit

Kaelo was very excited to be visiting Hartebeesthoek Radio Astronomy Observatory. His science teacher, Mr. Maoto, had told him that all three classes in the 7th grade would be able to go, but that they had to pay R90 for the trip. His excitement was tinged with a concern that his parents would not be able to pay, and that he would be left behind. He felt it was a bit unfair that if this was a school trip related to the topic they were doing in Natural Science ('NS' as they all called it at school), they should *all* get to go. When he told his parents and gave them the information sheet and indemnity form for their signature he feared the worst, but when he reminded his Mom the following week, he was delighted that she signed and gave him the money to take to school the next day.

Kaelo had celebrated his 13th birthday in June at his home in Alexandra ("Alex"), a township in northern Johannesburg. It wasn't a big party, just a few friends round. His parents had long ago explained to him that they were prepared to have small celebrations for Kaelo's and his siblings' birthdays, although in their own SeTswana culture birthdays weren't really observed. Kaelo was the third of four children: two boys and two girls, which his mother always said made a nice even number. Until recently, he had been going to school in Alex, but his mother was concerned that the high school he was likely to go to after completing his grade 7 was 'not doing well'. Kaelo didn't understand what his mother was referring to, but he didn't complain when she moved him to Balfour Forest School, as

he knew he could make new friends quite quickly. For Kaelo, that was the main reason for tolerating school: his friends.

In NS, all the grade 7 classes were doing the same topic in term three: stuff to do with energy. Kaelo accepted that they were going on a trip to an observatory, which *wasn't* to do with energy. He didn't think much about it; he knew that an observatory was something to do with the stars and astrology (or was it astronomy?), and the idea of going on a trip was cool. In primary school they had once been on a trip to Johannesburg Zoo, which he still thought about. A few days before this observatory trip a tall white man ("Mr. Lelliott") had come to the school and explained that he wanted them to draw and write for him. Before they did so, he drew a sort of spider diagram on the board and asked them questions about Johannesburg. He then said he'd like the class to draw their own diagram, but based on 'space, stars and planets'. Kaelo didn't mind doing this – at least it was different from his normal class – but he found he couldn't write much on the diagram. He mainly put down words he was familiar with – the names of the planets he knew, galaxy, comet, asteroids and suchlike. He didn't really know much about the words, but he did know that they were in space, and that's what the man seemed to want.

After the class Kaelo and his friends didn't discuss the man's visit. Kaelo heard some of the girls saying they should go and look up about space and planets in books so that they could show the white man that they knew a lot. Kaelo thought, as he had many times, that he would never understand girls! A few days later Kaelo saw the man again, and some of the class were called, one-by-one, to see him. Kaelo wasn't one of them, and he was a bit relieved.

When the day finally came, a Friday, Kaelo was almost bursting with excitement about the trip. But it was unfair for his seven or so classmates who wouldn't be going. His best friend Karabo was amongst them, and he avoided talking about the trip when Karabo was around. Still, nothing in class had been done in preparation for the visit anyway. All Mr. Maoto had done was to collect the money and indemnity forms, and tell the class what they should wear for the trip. In fact Mr. Maoto told them that he wouldn't be going himself, but he didn't say why. Kaelo was pleased, as he didn't like his teacher's sharp tongue, especially when they were out of class, playing football for example.

At seven o'clock Kaelo arrived at school by minibus taxi as usual, met up with his friends, and they climbed on the bus together. His mother had given him a packed lunch, and he decided to eat the chips straight away. The bus left at seven-thirty and Kaelo and his

friends recited some hip-hop songs on the journey. There were three teachers on the bus, and as Kaelo had joined the school in January he only knew one of them. He was pleased that the teachers kept mostly to themselves, and that he and his friends could enjoy themselves. After about 80 minutes Kaelo saw that they were among hills, and there were some ‘satellites’ in the distance, like the ones people had on their houses to watch DSTV⁹, only much bigger. Then the bus turned on to a narrow road and began to descend steeply. They suddenly saw a really big ‘satellite’, as well as a number of buildings, and Kaelo realised that they had arrived.

4.2.2 “Planets and stars and like, well, space”

The students all got off the bus chattering loudly. Kate and Daisy met them, introduced themselves as ‘educators’, and said that they would be showing the students around the observatory for the next few hours. The students were split into two groups, and Kaelo started off with Kate, who acted just like a teacher: “What is astronomy? Can anyone tell me what it is?”

It’s space ma’am
The study of the stars
It’s like when people tell your future
...Planets and stars and like, well, space

After a few answers from the class and an explanation from Kate, Kaelo heard that astronomy and astrology were two different things, although he still wasn’t quite sure of the difference between them. He wasn’t surprised to hear that HartRAO (as Kate called the observatory) was built as long ago as the 1960s; Kaelo thought that they looked pretty old. His mind began to wander a bit when Kate went on to describe why the observatory was built for several of the space missions to the Moon, Venus and Mars, and how the South African government now owned it. He did notice that Kate mentioned something called “Nasser”, which he knew was involved with space travel.

They went inside a large hall which had some pieces of weird apparatus, some exhibits and posters on the walls, as well as a very large model of what Kaelo thought must be the Moon. The students sat on the floor, and Kate began by asking them questions about the solar system and planets. Most of the students called out planet names, as well as other words like comets, asteroids and galaxies. Kate stressed that the visit today was about

⁹ The main satellite pay television channel in South Africa

having fun and learning at the same time, and that they should try to think as well as play with the exhibits. Kate then talked to them about the sun and stars. Kaelo knew some of what she was saying, about how the sun is a star, but he had thought that the sun is the biggest star. He heard that the stars are mostly the same size as or bigger than the sun and that it is only because they are far away that they seem so small. Kaelo understood when Kate said that the tree in the car park looks big compared to the trees on the hill, but they are actually the same size. His mind wandered a bit when Kate started talking about light travelling from the stars to Earth, and he started whispering to Siphiso about the big satellite when Kate talked about light years. He listened again when Kate started to talk about the death of the Sun when it runs out of fuel to burn. Kaelo thought the idea of the Sun dying was cool. She said that stars spin, and asked if it will spin faster when ‘living’ or when it is ‘dead and collapsed’. Kaelo then jumped up when Kate called out for volunteers to sit on a sort of turntable. He shot up his hand and laughed when he was called first, wondering what he was going to have to do on this rotating disc. To him it looked a bit like a giant version of a turntable that DJs use to play vinyls at the community hall back home – he’d been to a very loud party there once.



Copyright © Hartebeesthoek Radio Astronomy Observatory

Figure 4.1 The Turntable

Kaelo knelt on the turntable, and Kate gave him weights to hold in his hands. He held them out while Kate spun the turntable slowly, making him rotate. Then on Kate’s instruction he pulled his arms into his sides and found that he immediately spun much

faster and nearly fell off; everybody laughed. He got off the turntable and other students tried, with similar results. Feeling dizzy but excited, Kaelo didn't really listen to Kate explaining why he spun faster with his arms pulled in, but heard her saying something about the energy needed to spin a large star (arms out) was converted to speed in a small star (arms in). He just liked spinning and feeling the difference in speed, and wasn't too disturbed by the shouting of the other students outside. He couldn't see what they were doing, but it sounded fun as they were making a lot of noise and he could hear water splattering around. Kate then pointed to the enormous model of the Moon in the hall, and asked Kaelo's group what you see when you look at the Moon over a few nights.

It changes shape ma'am, sometimes it's round like a plate, and
sometimes looks like a banana.
It's a crescent or a half moon.

Kate said "Yes, that's right, does anyone know why it does that?" No one was sure, so Kate took the group to a dark room at the back of the hall to demonstrate¹⁰. One lamp was set up in the room to represent the sun; each student was provided with a ping pong ball ("the Moon") on a stick, and Kate showed how to turn round and round on your feet ("rotate 360 degrees" Kate called it) and observe what was happening to the lit and unlit sides of the ball. Kaelo tried it out, and saw that the light from the lamp lit different amounts of the ball, depending on its position in relation to the lamp. For example, when he was standing with his back to the lamp, the ball was fully lit, and Kate said that this represented the full moon, and when he was side-on to the lamp only half the ball was lit, representing a half moon. Kaelo realised that the ball was meant to be the Moon going round the Earth and how the sun's light fell on the Moon caused the different Moon shapes. So it wasn't the Earth's shadow falling on the Moon making it look sometimes half and sometimes full! He wanted to ask Kate why sometimes there is no Moon in the sky at night, but Kate said it was time to move on, so he didn't get the chance.

¹⁰ Not all groups who visited HartRAO during my study looked at Moon phases



Copyright © Hartebeesthoek Radio Astronomy Observatory

Figure 4.2 Moon Phases

4.2.3 The Sun, Whispers and Rockets

Kaelo and his group then moved outside, and Daisy called them over to a small telescope pointing up to the sky, with a round white ‘shade’ attached to it. Daisy said that she was going to show them the sun. First, she told them something Kaelo already knew: never to look at the sun directly, especially with a telescope or binoculars. Then she told them how hot the sun is: 5000 degrees at its surface and 15 million degrees at its centre. Kaelo tried to think about this, but couldn’t really imagine that sort of heat; he knew that water boiled at just under 100 degrees at school as they had measured it once, so the idea of thousands or millions of degrees didn’t really make sense. Before Kaelo could puzzle this out, Daisy arranged the telescope so that a round white patch was projected on to a small card under the telescope. Kaelo saw that the white patch was actually the sun (Daisy said the “sun’s image”) and noticed that it moved slowly across the card even though the telescope wasn’t moving. Daisy said that this was due to the “rotation of the Earth”, and the “sun’s apparent movement across the sky” was because the Earth spins on its axis. Kaelo had heard about this in primary school and seen a video of it on television, so he knew what Daisy was talking about: day and night caused by the Earth spinning with different sides facing the sun and getting daylight. Then Daisy pointed out some tiny black patches on the sun “Does anyone know what these are?”

“Some dirt on the microscope glass” said Tebogo and several boys laughed. Daisy said that these were sunspots. Kaelo had never heard of these, and heard Daisy saying they are cooler areas of the surface due to magnetic storms on the sun blocking out the light. Kaelo wasn’t really sure what a magnetic storm was, but he thought they looked pretty cool anyway. He also heard Daisy say that 100 Earths could fit across the image of the sun they were seeing, and he thought how enormous the sun must be. Daisy asked the group “Would you like to live on the Sun?”

No!
Why not?
It’s too hot!



Figure 4.3 Projection of the Sun

After a few more questions from the group which Kaelo didn’t really listen to, they went to the car park, where there was a sort of figure-of-eight and a curved line painted on the ground. Daisy explained that this is a sundial, used for telling the time, and that the time is painted in white on the curved section and the date is the yellow writing on the figure-of-eight. She then asked the students the date (24 October), and got one of the girls (Nnaniki) to stand on the yellow line at the right position. Nnaniki then put her hand up and Daisy explained that where the shadow of her hand crossed the white circle was the time of day. It wasn’t very clear to Kaelo, but when Daisy used a long pole instead of Nnaniki, Kaelo could see that the pole’s shadow crossed the white line at just after the

“10” mark. Looking at his watch, he could see that the real time was ten past ten; this sundial was quite accurate! Daisy explained that before the invention of watches this method was an important way of telling the time. She went on to say that as the position of the sun changes in the sky, the shadow it casts moves, and can be used to tell the time. She then asked:

What direction are you guys facing towards now?

East! North! South!

Daisy laughed.

OK, which one **is** it? Look we are facing towards the sun now. Where does it rise?

East!

OK, which direction is that? Point to it.

Several of the class pointed East, others pointed in other directions.

Right.

Daisy confirmed those who were correct.

So if that direction is East, where is North?

Finally, the class was oriented and Kaelo saw that he was facing roughly North while the sun’s shadow was pointing roughly South. He got a bit lost when Daisy began to talk about the yellow figure-of-eight being called an analemma, and its shape being due to the Earth’s tilt and orbit. Again, his mind began to wander a bit ...



Figure 4.4 Sundial

Kaelo's attention was jerked back to the present when Daisy then said that "girls like to talk on the telephone". This was something that Kaelo knew, as his older sister often chatted for ages on the phone to her boyfriend. Kaelo thought they were now going to do something with cell phones, but they walked over to what Kaelo thought of as a satellite, pointing sideways. Daisy called them dishes, and split the group into two; one group standing next to one dish and the other group at a dish about 20 metres away. The two dishes were facing each other and one person could then whisper into the dish in turns. Kaelo's classmates showed some surprise when whispering and listening at the dishes, and when it came to his turn he found he could hear the person whispering from the other dish perfectly. Kaelo heard Siphon saying something rude about Bontle into the dish, and the boys near them laughed, a little cruelly Kaelo thought. The group each had two turns at this 'telephone' as Daisy jokingly called it, and then she asked them if they knew how it worked.



Figure 4.5 Whisper Dish and Telescope

There are wires running under the ground ma'am
It's like a cellphone ma'am
No miss, it's the shape of the satellites

Daisy picked up on this last suggestion and ignored the others. She compared the dish shape to a reflector on car headlights or a torch. She said that the shape concentrated

the sound, and the fact that the dishes were lined up very carefully with each other meant that the sound carried perfectly between the two. She said something about a parabolic shape of the dishes, but Kaelo didn't quite get that part of it. But he did see the similarity between these dishes and the enormous dish pointing at the sky. Daisy said that it is a radio telescope, and that its shape concentrated waves coming from stars so that they could be detected by the astronomers studying them. Daisy also said that DSTV dishes did the same thing, and that they are pointing to a satellite in the sky sending television signals. Kaelo wished that he had DSTV; he had watched the cartoon channel at his friend's house a few times. At this point the group stood under a tree, and Daisy answered lots of their questions on all sorts of aspects of astronomy. Kaelo asked "If the DSTV satellite in the sky is going round the Earth, how come there is no break in signal when it goes the other side?"

"That's a very good question. In fact the DSTV satellite orbits the Earth at exactly the same speed as the Earth spins. So it is always in our sky, and there's no break in signal". Kaelo heard Daisy, but he wasn't sure he really got it. He wondered if satellites ever smashed into each other. But he didn't ask Daisy.

Daisy then walked the group to the other side of the car park where Kaelo had earlier noticed the shouting and sloshing-of-water sounds coming from the other group. Daisy told them that they were going to be launching rockets into space! In fact they were using Coke bottles and bicycle pumps, but it still looked fun. Kaelo paired up with Ross and they filled their bottle half full of water from the tap, fitted it to the 'rocket launcher', and pumped it with the bicycle pump. Ross started pumping it, but got tired when nothing happened, so Kaelo took over the pumping and noticed air bubbling through the water inside the bottle. Suddenly the bottle shot high into the air, showering them with water.



Copyright © Hartebeesthoek Radio Astronomy Observatory

Figure 4.6 Launching Rockets

Kaelo thought this was cool, the best thing they had done here so far, and ran to the water tap to refill the bottle. Daisy came over and suggested that they experiment with different amounts of water in the bottle. They tried with a full bottle, but it didn't rise very high into the air, as it seemed to be too heavy. They found that a quarter bottle flew highest in the air. Kaelo found that if he held the bottle on the launcher with a finger while it was being pumped it flew higher. They then tried it with no water at all, but it hardly rose off the launcher. After more fun Daisy called the group together and asked if they could explain what had been happening. Kaelo wasn't really interested in this bit, he would have preferred to carry on launching rockets, and he didn't really listen to what Daisy said. If he had been asked he would probably have said that rockets should only carry a small amount of fuel (water) in order for them to rise highest in the sky. "Why ask us about this?" thought Kaelo, feeling frustrated.

4.2.4 Break with Gravity

At about 10.40 Daisy said it was time for break. Kaelo and his friends sat outside to eat their food. Kaelo now wished he hadn't eaten his chips on the bus, as he only had a sandwich and drink now. He did have some money, and he went to the tuck shop to buy some *Astros*. The shop had posters of the planets and some booklets, but he didn't have enough money to buy these. On his way back outside, Kaelo saw some other 'exhibits' in

the hall he hadn't noticed before. He called Ross over and they picked up Coke cans from a table. Each one was a different weight, and they were labelled with the names of planets and the Moon. The 'Jupiter' can was very heavy, while 'Pluto' was very light. Was this to do with the size of the planet or was it that Pluto was very far from the Earth?

Why's Pluto so light? Kaelo asked Ross.

I dunno. Proibly an alien drank all the coke!

They both laughed. There wasn't anything explaining what the Coke cans were for, and if there had been Kaelo probably wouldn't have read it anyway.



Figure 4.7 Coke cans and gravity

Kaelo then saw four bathroom scales on the floor, marked Earth, the Moon, the Sun and Jupiter. On the Moon scale he only weighed about 8.5 kilograms, while on the Earth scale he weighed 52 kg, which he thought was about right. He weighed 132 kg on Jupiter and 1400 kg on the Sun, which was weird! Kaelo remembered that the Jupiter Coke can had been heavy.

Hey, you're lighter on the Moon because it's closer to the Earth said Ross.

No, it's not that. It's because the Moon has no gravity, that's why.

Kaelo chatted about it with Ross, and they decided that it **was** something to do with gravity. They knew gravity on the Moon was low, in fact if asked, they would probably both have said that people float on the Moon. Now it looked like gravity on Jupiter was high and it was humungous on the Sun. Ross couldn't really understand this as he thought

both Jupiter and the Sun were made out of gas, so how could they have a lot of gravity? They both went away a bit puzzled from the scales, but with the impression that gravity was different on different planets and the Sun.

Kaelo also saw a game-type exhibit called “Cosmic Pinball - Can you make a comet crash into Jupiter?” Kaelo slid a ball bearing (representing the comet) around a funnel (representing the solar system) that gets increasingly steep towards the centre (representing the Sun). The trick is to ‘orbit’ the comet around the bowl so that it is captured by a depression (signifying Jupiter). If you get it wrong the comet will be drawn by (actual) gravity towards the hole in the centre and fall through it. Kaelo tried this a few times and managed to hit Jupiter twice, but he didn’t try and reflect on what the exhibit represented, he just treated it as a game.



Figure 4.8 Cosmic Pinball

4.2.5 Taking the Solar System for a Walk

The whole class joined together after break, and sat down in the hall together for a talk by another educator called Musi. He started by showing the students photographs and models of all the planets in the solar system, each of which was mounted on a stand. Musi explained that these were scale models of the real planets, and that they had been reduced four billion times. Kaelo didn’t really know what that meant, but it sounded quite impressive. Musi then talked briefly about the Sun and gave a few facts about each of the

planets in turn, from Mercury to Pluto. Kaelo knew some of what Musi was saying, as they had covered each of the planets in class, such as the largest, smallest, closest to and furthest from the Sun. For Kaelo, the most interesting part of the talk was the bit about the asteroids, and how one day an asteroid might collide with Earth. He was fascinated to hear that one had crashed near Pretoria hundreds of thousands of years ago, as well as another to the South of Gauteng, and that it may have caused all the minerals that were being mined now. Kaelo's mind wandered a bit, and he thought of that film where there was a rock smashing into the Earth, causing floods and all the people running to the mountains. He quite liked the idea of terrible devastation – he wondered what he'd have done if it happened to him...



Figure 4.9 Taking the Solar System for a walk: the Sun

His mind jerked back to hearing Musi speaking again. Another fact that struck Kaelo was that Jupiter had about sixty moons; he couldn't really believe that was possible. One of his classmates asked whether it could ever be day on Jupiter with so many moons orbiting the planet. Kaelo thought this was an odd question, but Musi explained patiently to the student that it wasn't the Moon that caused night, but the sunlight falling on the planet as it rotated. The class asked Musi lots of other questions during the talk, especially about the asteroids, Jupiter and Pluto.

Musi then handed each planet to a student, and took the whole class outside, saying that the solar system could do with some exercise, so they should take it for a walk. Just outside the hall Musi got a student to place the Sun on its stand. He told the class that the model was reduced four billion times from reality, and said that they would need to pace the distance from the sun to each of the closer planets. They set up the Mercury stand 20 paces from the Sun, while Venus and Earth were placed 36 and 50 paces respectively. Kaelo didn't pay much attention to these distances, but he was carrying Mars, and he knew that he had to pace 27 steps from Earth. He set up the Mars stand and looked back towards the Sun. Although he hadn't fully understood what Musi had said about the four billion, Kaelo thought there must be an awful lot of space in space. The planets (big though they appear up close) were tiny in relation to the Sun and sitting at enormous distances from each other. He would have thought about it for a bit longer, but the class was now chanting "15-16-17" as they paced the asteroid belt beyond Mars. When they reached Jupiter, 190 paces from Mars, Musi said that they needed to stop, as the planets beyond were too far to pace. Kaelo couldn't believe that Pluto would be about 1.5 km from the Sun. He looked towards the horizon and tried to imagine that this distance represented the size of the solar system, with these tiny models representing the planets. When Musi said that the nearest star (Alpha Sen, or something like that) would be 10,000 km away on this scale it almost hurt his brain just to think about it, so Kaelo ran into the building when Musi said they'd now be having a slide show. On the way, Kaelo punched Ross on the arm.

4.2.6 Landing on the Moon

The room for the slide show was cool and dark, and Kaelo got a seat at the back with a group of his friends. Daisy began by asking questions: "Who was the first man in space?" "Who was the first man on the Moon?"

Kaelo didn't know the answer to the first one, but shouted out "Mark Shuttwerth" to the second, as did many of his classmates. Daisy said that while Mark Shuttleworth was the first South African into space, it was an American called Neil Armstrong who was the first man on the Moon.

When Daisy asked who wants to be the second South African into space, the class called out "Me! Me!" Daisy quickly chose a small boy called Titus, and said "Today I'll take Titus, and I'll take another tomorrow". She went on to say "OK, he's been trained, can he go dressed in uniform?" The classed chorused "No!"

Why not?
He'll bounce
There's a special suit
For protection

Titus then dressed in a white overall, with a NASA logo, and Daisy sometimes referred to him as Titus Shuttleworth or Tito Armstrong. She then suggested he would need boots, "Why?"



Figure 4.10 The Second South African in Space

"So that he doesn't float". Daisy said that the gravity on the Moon is one sixth that of the Earth, and that he needs something heavy to keep him on the ground. This fitted with Kaelo's own idea that people float on the Moon, and that they need to be held down with something heavy. Titus then donned rubber boots as well as a pair of gloves. Again, Daisy asked the class why he would need gloves, and settled on the idea of protection against extremes of hot and cold. She then handed Titus a helmet to wear, and asked the class why he would need one.

No atmosphere.
Dangerous gases.

...were ideas offered, and Kaelo heard Daisy saying that the helmet was needed to protect his head from the Sun's rays and extremes of temperature. Finally, Titus was given

an “oxygen tank” (which Kaelo could see was just a plastic 2 litre Coke bottle) and was told he had a microphone inside the helmet as there is no air in space, and that sound cannot travel.

Daisy then introduced a slide show, saying that Titus had taken the photographs during his trip to the Moon. Kaelo saw a series of photographs projected on to the screen, and Daisy questioned the class as each one was shown. Some of them, such as the photographs of the Saturn 5 rocket, the Earth from space and the Moon from space didn't make much impression on Kaelo, but when it came to the first steps taken on the Moon he paid more attention. He remembered he had heard the phrase “One small step for Man, one giant leap for mankind” before and could now understand what it was talking about when he saw the black and white photos of the astronauts walking on the Moon's surface. Daisy said that the Moon was like a desert: it has no water, also no air, and although there is soil it is not fertile, and temperatures are so extreme that you can't grow anything. Kaelo was surprised to see what Daisy called a ‘lunar buggy vehicle’ which the astronauts used to explore the surface. Daniel suggested “Their vehicle help them to not float. Maybe their vehicle have gravity” and everybody laughed, though Kaelo wasn't sure why. Daisy ended by showing a footprint in the dust of the Moon, and asked if it is going to stay there forever. “Yes” they chorused, and Daisy emphasised that there is no wind to blow it away, no water to wash it away and no weather. It would stay there unless a meteorite hits it. Kaelo wasn't so interested in the last few photos, which showed the space ship returning to Earth and landing in the sea. The lights were then switched on and class then asked a few questions before they went outside. Kaelo was getting a bit restless by this time, and was pleased to be back in the open air.

4.2.7 The Telescope and Control Room

Outside, Musi stood the class in front of the telescope. Kaelo was amazed how big it was. From where they had been at the Visitors' Centre it hadn't looked so large. To start with, Kaelo listened to Musi, and heard that the telescope once monitored Apollo missions to the Moon, and that it was the only one of its size in Africa. As he was talking, the dish began to move, and Musi explained that it is because they are studying stars. Now Kaelo wasn't quite sure about this, as it was daytime, and he knew that we see stars at night. He was pleased that one of the class asked the question in his mind: “How can it see stars in the daytime?” Musi explained that the dish was listening to the sound that stars make, and that

the sound will bounce on the dish into a receiver. They stayed outside for another 10 minutes or so, and Musi answered lots of other questions from the class while Kaelo drifted to the edge of the group with Ross and they chatted about other things.



Figure 4.11 The radio telescope at HartRAO

The class was then ushered into the building next to the dish and Kaelo was excited to see lots of electronic equipment with lights flashing, rather like in a science fiction movie. In fact he was so overwhelmed that he didn't really listen much to what he was told in the short time they spent there. Then Musi played a tape which sounded like someone beating a drum, and said that this is what some stars sound like. Kaelo then realised that the big dish was somehow hearing stars rather than seeing them, so he now understood how the dish could be used in the daytime.

It wasn't long before they were back in the sunshine and walking back to the visitors' centre. As they walked with Daisy and Musi, some of the very keen students carried on asking questions. Kaelo had one or two he would have liked to ask, but he got talking with Ross, and didn't really get the chance to do so. In the visitors' centre they sat around for a short time, then the class monitor gave a vote of thanks to Kate, Musi and Daisy for showing them round the site. Kaelo joined in the clapping enthusiastically, as he had really enjoyed being there.

4.2.8 After the visit

The trip back to school passed quite quickly for Kaelo, and although they sang songs and messed around on the bus he felt quite tired. He caught the minibus taxi from school and rushed home to tell his mother what they had done at HartRAO. His mother listened patiently as the words tumbled from his mouth: pumping the rockets, spinning on the turntable, picking up Coke cans, talking through the whisper dishes, hearing stars drumming and seeing the big dish moving. After the evening meal he watched some television and went to bed enervated, but still quite excited.

Over the weekend, Kaelo thought about the trip from time to time, and wondered whether he might ask his father to take him back to HartRAO sometime. But his father always seemed to be so busy, even at weekends, that he wasn't sure whether to or not. On Monday, back at school, Mrs. Kathrada talked to the class about the trip, and said that they ought to carry on studying about space, and she gave them a piece to read about Neil Armstrong's first footprint on the Moon. Kaelo liked this, as he could relate the article to what he had seen on the slide show at HartRAO. However, Kaelo had to be a bit careful around Karabo, who hadn't been able to go on the trip. Kaelo held back talking about the trip too much, so that Karabo wouldn't feel bad about it. During the week, Mr. Lelliott came back and all the students who had been on the visit went to an empty classroom with him. Mr. Lelliott gave the students the spider diagram each one had completed before the trip, and Kaelo was pleased to be able to add to his, as well as cross out 1 or 2 things that he now decided were not right. In fact Kaelo had so much to add that he wrote some things on the back of the sheet. Later on Mr. Lelliott asked the same students he had seen before the trip to speak with him again, but as before, Kaelo wasn't one of them.

Over the next few weeks they didn't do anything related to the trip in class either with Mr. Maoto or any of the other teachers, and the visit slowly faded from Kaelo's mind. One day, when he happened to see the television news his father was watching, there was a report of a Chinese astronaut going into space and orbiting the Earth. Kaelo started chattering to his father about how they had seen pictures like this at HartRAO and his father appeared quite interested. But then there was a programme that his father wanted to watch in peace, and Kaelo left the room to do some homework. Over the next months the visit faded further in Kaelo's memory, and in January he started grade 8 at the high school near to Balfour Forest. However, he did find that even over the next year, he was reminded from time to time about the visit, by schoolwork topics (in Geography) by occasional items

on the television and in talking with his friends. For Kaelo, the relatively brief visit had made a lasting impression.

4.3 Discussion

Like Falk and Dierking's (2000) descriptions of museum visits, this narrative shows what school children experience at the Hartebeesthoek Radio Astronomy Observatory. While Kaelo's experiences were a composite of what the whole group experienced, each event described was based on data from my study that involved individual students. It is worth noting here some of the experiences, how they relate to themes in the literature review, and how they are drawn from the data gathered in the study, many of which will be described in subsequent chapters. Five issues are described here: student misconceptions; socio-economic constraints on museum visits; inadequate preparation; inappropriate follow-up; and enjoyment.

First, Kaelo was presented with quite a lot of information about astronomy, and the narrative shows that he entered the centre with several misconceptions. I will illustrate this with three vignettes from Kaelo's story, and show also how the centre either changed or reinforced his ideas.

- Kaelo originally thought that the Sun is the biggest star, but the explanation he was given together with the analogy of the distance of trees demonstrated to him that the Sun only appears big because it is close. In this case the explanation by the educator appeared to change Kaelo's understanding of the Sun in relation to stars. Data for this observation was gathered from students who changed their opinion that 'the Sun is the biggest star' to 'the Sun is the closest star' in their pre- and post-visit interviews. Although it is likely that in some cases they just remembered this as a fact, in other cases the student explained that their understanding of star distance in relation to the Sun had changed.
- Kaelo and Ross had several misconceptions about gravity demonstrating a limited understanding of it: they thought there was no gravity on the Moon and that the Sun or Jupiter would not have gravity as they are made of gas. By interacting with the Coke can exhibit and the gravity scales Kaelo and Ross came away with slightly changed knowledge of gravity: that gravity is different on different planets. However, the gravity exhibits at HartRAO were not themselves sufficient to result in a major shift in their understanding of gravity. Some intervention by an educator

was necessary to explain what the displays represented. Although there were several explanations of other exhibits as described in the narrative the centre did not address gravity as a central issue. In fact during the Moon landings slide show some students' conceptions of gravity were reinforced, by the presenter suggesting that heavy boots need to be worn, and not dispelling the suggestion that they are needed to prevent the wearer from floating.

- The narrative does not show us what Kaelo's perception of space was, although many students in their Personal Meaning Maps described it as empty, lacking air and water. The description of Kaelo's experience of 'taking the solar system for a walk' tries to demonstrate that this activity did indeed have at least some effect on his understanding of the emptiness of space. The data for this claim was gathered by watching and listening to students as they paced out the distance between the planets. There was genuine amazement that the Sun could be so small and far away by the time students reached Mars, in contrast to Musi's statement that the models are reduced four billion times from their actual size. This figure appeared to be incomprehensible to most students, who never referred to it in their subsequent interview.

The misconceptions demonstrated by Kaelo were similar to those recorded in the literature regarding the Sun, stars, gravity and space (Bailey & Slater, 2003). Although museum researchers are usually careful not to make claims about substantial change in visitors' knowledge as a result of a visit to a museum, the evidence from Kaelo's narrative suggests that there were some shifts in his knowledge of astronomy and conception of gravity and space.

Secondly, the narrative brings out a contextual issue regarding the visit. As discussed in section 3.5, only students whose parents could afford to pay for the trip actually took part in it. Out of a total of 75 students in the two grade 7 classes at Balfour Forest School, only 37 (49%) completed consent forms and 30 (40%) went on the trip. The percentages of students who participated in the trip were much larger in the other schools as they were mostly private schools where the socio-economic status of the parents was likely to be much higher. However, Balfour Forest School is more representative of the majority of schools in South Africa, although it too is privileged, being located in a former 'white' suburb of Johannesburg. Kaelo's mother's remark, that the local township school was 'not doing well', is a reminder to the reader of this fact.

Thirdly, the narrative demonstrates the limited extent to which Kaelo and his classmates were prepared for the visit. In his school they did no classroom preparation for the visit, and in most schools the students were currently studying another topic in science (or geography in the case of Lourdes Girls School). No preparation for the visit was the case in all schools except Bokamoso, whose science club visited HartRAO. Six individuals across the whole study did some personal preparation, and gave specific examples of what they did. There was some evidence that individuals did the preparation because they wanted to ‘impress’ me with their knowledge, and my visit did have some effect in raising students’ awareness and the profile of the topic. These issues are discussed under the limitations of the research in section 9.8. The narrative also notes that the student’s science teacher, Mr. Maoto, does not attend the visit with his students, and instead other teachers accompany the class. This too was a common occurrence in my study, and is one of the reasons I did not include teachers in the study.

Fourthly, the issue of follow-up after the visit. Kaelo’s narrative shows that a teacher did get the students to think about the trip by giving them a reading about the Moon landings. However, although this is what was stated by the teacher, Kaelo did not relate what Mrs. Kathrada did with students in her English class when I asked him in the interview, possibly because nothing was done in his science class. No students worked on astronomy between the time of the trip and when I visited to interview them, and this varied from 1 to 35 days. What *did* happen after the visit was that Kaelo told his mother a lot about what he had experienced at HartRAO. Except for Nonkululeko, all students told someone, usually a member of their family of the experiences they had during their visit. This question was a useful method of eliciting what students found exciting or important for them at the visit. There is substantial evidence in the literature that teachers fail to use school visits to museums as effectively as they might (e.g. Griffin, 2004; Storksdieck, 2004), and exhortations from researchers to correct this situation (e.g. Falk and Dierking 2000). The narrative shows that there is considerable potential for teachers to work with their classes after a visit, both from the viewpoint of learning about subject matter as well as using the visit as a focus for other work, in language classes for example.

Lastly, it is clear from the narrative that Kaelo regarded the trip as an enjoyable event. I showed in Chapter 2 that the research literature on museums and science centres has tended to dichotomise fun and learning, with several opinion pieces decrying the hands-on experience as being ‘minds-off’ (Parkyn, 1993; Sanders, 1998). Kaelo however,

appeared to learn something about astronomy as well as have fun at HartRAO. As Falk and colleagues have demonstrated (Falk *et al.*, 1998; Griffin, 2004) and I show in subsequent chapters, education and entertainment are not likely to be on a continuum, but complement each other in a science centre environment.

Kaelo's narrative describes experiences that are common to many South African learners on school visits to museums. These include difficulties with funding and lack of preparation for the visit, disengagement of teachers and the didactic nature of the experience during the visit, and a lack of follow-up after the visit when back at school. The narrative also demonstrates that in a few cases a student's idea about a scientific concept might be completely changed as a result of the visit. For example Kaelo's realisation that the Moon's phases are caused by sunlight falling on different amounts of the Moon's surface, rather than his previous idea that the phases are caused by the Earth's shadow. However, they also demonstrate that previously held misconceptions can remain unaltered or be further reinforced during the visit. For example Kaelo's idea that in order not to float on the Moon one needs to wear heavy boots. It also demonstrates that the majority of learning is likely to be small and incremental, a notion that is explored more fully in Chapters 6 and 7.

4.4 A visit to the Johannesburg Planetarium

Welcome to the Johannesburg Planetarium, to the Wits University. I'm Caroline. I'm doing a show for you today. What are we going to look at today?

Space!
Stars!
The Moon!
Planets!

Okay I've got bad news for you guys. Your teachers booked you into the solar system show. Okay so what is in the solar system? Planets, the sun. How many stars in the solar system?

Student 1: Millions.

Caroline No sorry

Student 2: One.

Caroline: One. Okay. So tough luck. We can do 8 000 stars with our projector here, but we're booked into the solar system show.

Kitso was finally sitting in the rather uncomfortable seats of the Johannesburg Planetarium, looking up at the dome which was covered with stars. She had been looking forward to this

visit for some time, so now what was the planetarium lady talking about? Had there been some sort of mistake in their booking?

That's one way we can get around that. If we're going to look at the solar system we might as well look at where the solar system fits in, in space and we are doing solar system here but we'll start by looking at the stars.



Figure 4.12 Zeiss star projector in the planetarium

OK, that sounded better, and Kitso realised that maybe Caroline had been joking. Kitso had always been interested in the stars and planets, though she wasn't that keen on geography (which is where the topic fitted in at her school). Kitso attended Lourdes Girls School in the western suburbs of Johannesburg, and was unaware that the astronomy topic had now been changed in the curriculum to fall within the new Natural Sciences learning area. She just knew it as part of geography. She had heard from friends that the planetarium was really cool, that she would actually see the planets and stars and stuff.

Caroline: I just want to start about, with those particular stars. Does anyone know the names of any of those stars up there that you can see now?

Student: I can see Orion

Caroline: Okay, right. Southern Cross. Can you see the Southern Cross there?

Students: [Some say yes, others say no].

Caroline: No? Some of you can. Yeah. Here it is.

Kitso had no idea of the names of any stars. She just knew them as stars, that they consisted of burning gases, were small objects (say the size of the Earth) and far away.

People looked at the sky thousands of years ago, it's only in the last couple hundred years that we have the tools for understanding the universe. But we know that people have always been interested in it, mainly because they gave names to things. That one there Betelgeux, which is an Arabic word that means the armpit of the giant. (Laughter) Look here is the giant, his belt – these three stars in a row - What are they called? Three sisters some people called them. Some people called them Orion's Belt and some people used to call them dikolobe. What does that mean? Pigs. Ja. So that's Tswana for pigs.

Kitso could see what Caroline meant, as she was pointing out the stars with a sort of light-pointer torch. Kitso had some vague memory of being at her grandmother's house sitting round a fire at night, and one of her cousins mentioning *dikolobe* in the sky. She wondered if any of the really bright stars had names, but Caroline was moving on.....

Nowadays we can do more than just naming stars and looking at them. We actually know what they are about and the reason we could do that is we've got better equipment. What's that? That's a telescope.

Now Kitso saw a picture projected on to the planetarium dome. Wow, this show wasn't just going to be about stars and space. They'd be seeing "real things" too, like on TV.

Ja. That is quite a small telescope. It's the kind of thing that people who's really into astronomy will go out and they'll buy. Now the size of that we know will be about 10, 15 centimetres which means already that is about 400 times better than your eye.

Anyone know the name of South Africa's big new telescope?

Students: SALT

Caroline: Yes, it is called SALT - South African Large Telescope. It is going into that building there, the building is finished, the telescope should be finished some time next year. There is one obvious thing you can do with the telescope, you can see more. That makes people realise that the universe is much bigger than we thought.

Caroline went on to explain how astronomers look at the colour of stars, which helps them work out the hotter ones (blue) and the cooler ones (red), and how you can use a sort of spectrum of the stars to work out their composition. Kitso found this all a bit confusing. As far as she was concerned stars were these little dots in the sky, and just as she was wondering what they'd be like if you got close to one, Caroline did just that.....

So that particular star, bright stars in fact, are mainly hydrogen and a bit of helium then a couple of other gases as well. A star is a ball of burning gas. Right, so if you went up close to a star, about 150 million kilometres away

..... *What's that?*

Students: The sun.

Caroline: The sun. Yah, what is the sun? A star?

Students: Yes.

Caroline: It is the which star?

Students: The biggest!

Caroline: It is not the biggest star. The?

Students: Closest.

Caroline: Closest Thank you. It is the one that we live close to, it is not bigger at least not of all the stars, it is a very ordinary type of star.

Kitso heard Caroline talking, but she didn't really take it in, as Caroline seemed to be saying so many things: the Sun is 6000 degrees, UV-rays, X-rays, the ozone layer. Anyway Kitso *knew* the sun is the biggest star. It's obvious anyway, as it's much bigger than the other stars in the sky. Then a video film started playing on the planetarium dome, which Caroline said was the Sun, taken with a special camera.....

Now one thing to notice is that the sun is turning. Everything in the Universe is spinning. If you look at the top where you can see it against the black of space, you can see jets of gas being thrown off. If you ... just watch and tell me if it goes away from the sun or back to the sun? It's going back. Right. So how does it pull it back? Gravity. Ja. The sun has about 28 times as much gravity as the Earth which it's useful. If it didn't had enough gravity it would just sort of blow itself apart from heat. Heat makes things expand. Gravity holds things like the sun together. We wouldn't have a star if it wasn't for gravity.

Kitso thought the video was really cool. She knew a bit about gravity: she knew that in space there was a lot of gravity, and that with a lot of gravity you could float around. She tried to reconcile what she knew with lots of gravity on the sun, and thought maybeugh, she couldn't really think about it, as a very big number then flashed on to the planetarium dome:

40,000,000,000,000 km

Caroline said that was the distance from the Sun to the nearest star: Alpha Centauri: 40 million million kilometres. Kitso wasn't great at Maths and the number on the dome was mind-boggling.

How far is it? How would you describe that?

Student: Far.

Far. Very, very far. Light years away. Right the problem with a number like that is no human being has ever experienced that number, not physically, not themselves. You never had to walk that distance or travel that distance. Our brains can't really understand stuff that we haven't actually had to deal with physically.

Caroline then tried to make the distance to Alpha Centauri more understandable by comparing it with the distance across the solar system, which is 10 thousand million kilometres. She then suggested that if we could travel across the solar system in a very fast rocket in one year (20 times faster than we can), then we can do a sum to show how long it would take to reach the nearest star:

$$\frac{40,000,000,000,000}{10,000,000,000}$$

$$\frac{40,000,000,000,000}{10,000,000,000}$$

Which gives us 4000 years.

Okay, so if you could travel twenty times faster than what we can now then you will be able to get from the Earth to the edge of the solar system in half a year, then you travel for 3 999 years and you get to the first star. What would you pass on the way? Nothing. It would be the most boring journey imaginable.

Kitso found this a bit confusing. Even with Caroline's attempt to try and make the distance understandable, Kitso didn't really identify with the 'years' explanation. She did though remember the 'sound' of the distance: forty million million was quite easy to remember, even if she was not sure what it referred to. When she was asked later, she said it's the distance from the Earth to the Sun.

The next part of the planetarium show was about stars being born. Caroline pointed out Orion's cellphone (Kitso liked that idea - a cellphone in the stars) which was really a nebula, or cloud of gas and dust. She then showed how the cloud is 'lumpy' and that gravity pulls the gas and dust together until it becomes hotter and begins to burn, forming a star. She then demonstrated this with a video animation of the formation of the solar system, and stressed that our solar system is plate-shaped, with the sun in the middle, surrounded by the planets. This didn't really mean much to Kitso. She thought of the solar system as some sort of belt of planets surrounding the Earth, and so couldn't relate what Caroline was showing to her own concept of a solar system. Kitso confused this further in her mind with a system of heating water by using a solar panel on the roof of her neighbour's house. Wasn't that a solar system?

Right, let me get closer to Mars. You can see Mars in the evening sky now.

Have you all seen Mars? Those who have seen it was it easy to find?

Students: Yes.

It looks like a star, million kilometres away into space and it looks tiny but it

is very bright. Okay have a look at that sky there. Okay. Right, have a look especially at these two here. Jupiter and Mercury.

Kitso was amazed. She didn't realise that planets were visible in the night sky. OK they weren't very impressive in size, as they looked like bright stars, but the fact that they were other worlds far out in space, and we could see them was really cool.

Right let's go look for the stars, but to see stars we are going to have to speed up time now. then the sun will move across the sky. Okay, we will go from there all the way across to that side and it will go underneath the horizon there and the elephant will come and collect it and carry it all the way around there and put it right there for tomorrow morning. (Laughter).

What's really happening?

Students: The Earth is moving.

Caroline: The Earth is?

Students: Rotating.

Caroline: Rotating or spinning. The stars looking like they are moving over in fact it's just the Earth spinning.

Kitso didn't understand what Caroline was doing. As far as Kitso was concerned the sun **did** move across the sky, as did the Moon at night. She had never really noticed the stars much. Caroline then got the class to use star charts to try and identify the planets and some specific stars. The idea of this was so that the students could use the chart at home and look at the night sky, but Kitso got confused by the chart, and how to hold it. She was also confused that East and West seemed to be mixed up, but she got a bit more interested when Caroline pointed out some of the horoscope constellations...

Let's go now back to the Southern Cross and Antares, the heart of an animal. It's very well known. Right can you see a scorpion there? I mean look at the shape and the size of this scorpion if I take it away you can then see the sting at the end of the tail. This is Libra. Used to be part of the Scorpion. There's Virgo and you've got Leo down at that part of the sky over there? Capricorn is just down here. You've got Capricorn but the rest of them you'll have to wait ... okay you have to come back to the planetarium in the summer for Taurus and in spring for Pisces.

Wow, this was really interesting! Kitso always looked at her horoscope in her mother's magazine. She was a Leo, and now she could actually see the Leo stars in the sky. She might try and use that star chart after all and see if she could make it out in the real sky, though she knew that the street lights around her home were really bright. What Kitso didn't notice was how Caroline was trying to point out that the star signs were the constellations through which the planets and the moon passed over the course of the year.

How many planets?

Students: Nine

Nine okay that is not very helpful, then move on from that if you actually want to know what is going on in the solar system. Could anything be living on other planets? It's unlikely on Mercury and Venus. Why? Too hot.

Caroline then went through the planets of the solar system, describing and showing slides of each briefly in turn. The one that caught Kitso's imagination was Mars. She saw that it had ice caps, that it had been visited by many space craft, that it had mountains, and erosion channels which looked like they had been carved by water. She had never thought about it before, but Kitso realised that the planets out there in the solar system were actually a bit like Earth, with ground and soil and stuff. She was disappointed to hear that the temperature on Mars never really went above zero, as well as the fact that it took so long to get there.

Jupiter, Saturn, Uranus and Neptune. They're huge. They've made of gas.

You cannot live in a gas cloud. They are very far from the sun. They should be really, really cold. Does anyone know how many moons Jupiter has? Twenty something. Twelve. Sixteen.

Okay none of those are the correct answer. Let me just tell something if you go and look in the books you will see that Jupiter has 16 Moons.

We put together a show about planets and about Jupiter and I think when we started we were saying it had 51 moons. By the time the show finish about 2 months later ... we were up to 61 moons. So when anyone asks you how many moons Jupiter has? So at least 61 is about the best answer.

There's another of Jupiter's moons. This one is called Europa because that white stuff is ice.

There's our Pluto. Right you were supposed to say "what about Pluto?"

We left out Pluto because no space craft has been there. So we don't have a decent picture. There's the best picture of Pluto. They're talking about sending a space craft there next year.

Kitso was really enjoying the pictures of the planets, and then suddenly Caroline said they had run out of time.

Okay now, we'll get it really dark because actually the other thing I want to show you is the Milky Way. The Milky Way right now is going right over your head more or less over there but we need a nice dark sky to see that and then the other thing we have to do in a planetarium like this is play music which has to be educational music. So this one is for the teachers. This one is called the astronomy song.

And that was the best bit. Caroline speeded up the stars spinning overhead, she made it as dark as the darkest night and played the music loudly. Kitso thought she could watch this

for hours, and then suddenly the lights came up and the class all started talking animatedly as they walked out of the planetarium.

A few days later Kitso found her star chart crumpled up in her pocket. She did go outside with it one evening, but it was cloudy and she didn't try again. She did tell her cousin about the trip, especially the bit about the photos of Mars' surface, and how it looks as though there is another Earth up there somewhere. During break the following week some girls from Grade 7 asked Kitso and her friends how the trip had gone, and Kitso explained how everything looked so real. She also saw a brief clip from the News on television which showed a planet in the solar system, but when the next item referred to Mount Ararat and that the ark in the Bible might not have existed in reality, Kitso mixed the two items in her mind, and didn't see how one related to the other.

Over the subsequent months, much of what Kitso had seen blurred together in her mind, but she still remembered the photographs of Mars and how cold it was in the planetarium!

4.5 Discussion

This narrative shows some of Kitso's thoughts as she watched the planetarium presentation, and is a composite picture, based principally on interviews with students. Although Kaelo had a number of scientific ideas before he visited HartRAO, Kitso's scientific knowledge is considerably less, which results in less learning and understanding of what is being presented at the planetarium. Her ideas about the stars as relatively small (the size of the Earth), and the Sun being the biggest star did not change during the presentation, even though the educator specifically referred to it. Similarly, her naïve ideas about gravity, the solar system and day and night remained unchanged. Like Kaelo, Kitso had no preparation for the visit and no follow-up afterwards (although her interview only 2 days after the visit did not allow much time for this). Also, she talked to her cousin about the trip, and discussed it with some other school students the following week, indicating that aspects of it had made an impression on her. In fact, the effect of the visit on Kitso was more to do with emotions, the affective aspect of learning, than on cognitive change. This is examined in more detail in Chapters 7 to 9.

The aim of this chapter was to show the reader what it is like to visit the two sites through the eyes of the participants in the study. Although based on data collected during observations of the school visits, and interviews with the students, it is necessarily

subjective, in that I have chosen which scenes to highlight and which to omit. However, it is precisely the subjective nature of the narrative that allows me to illustrate, in an ethnographic style, important points which appear to be common to many school visits, not only in Johannesburg but elsewhere. Several of these were identified in Chapter 2, such as the disengagement of teachers and the types of learning that occur in science centres. The following chapters take a more objective stance. Chapter 5 shows the collective trends in learning across the entire data set from the study, while Chapters 6 to 8 examine what and how individual students learnt during their visit.

Chapter 5

5 An Analysis of Collective Learning

While Chapter 4 provided a narrative of what some students learnt in the process of a visit to a science centre, this chapter examines what the complete sample of students in my study learnt about astronomy during their visit to either the Johannesburg Planetarium or Hartebeesthoek Radio Astronomy Observatory visitors' centre. It attempts to answer research question one using the concept of Big Ideas in science as a framework for learning.

5.1 Introduction

One of the aims of my study was to examine what the students learnt from the visit to either the Johannesburg Planetarium or Hartebeesthoek Radio Astronomy Observatory. This chapter describes and analyses what the entire group of 34 students collectively learnt from their visit. It demonstrates that cognitive learning of astronomy topics occurred at different levels across a range of students.

The chapter is divided into the following sections:

- A description of the research sample and how the final 34 students were selected from the original 57 from whom data were collected.
- A reiteration of what I consider as learning in the context of the study
- The use of Big Ideas in astronomy as an organising framework for the analysis of students' learning
- What students collectively learnt from their visit to a study site, and how this relates to the literature on basic astronomy and learning in science centres.
- How Big Ideas are used with respect to individual learning in subsequent chapters.

5.2 The Research Sample

Chapter 3 describes how I obtained the study sample of 145 Personal Meaning Maps from students in seven schools (including a pilot school). However, only 57 students were interviewed both prior to and after their visit to one of the study sites, and interviews from

one of these schools were used as pilot data. During transcription of the data, and some initial analysis, I decided to exclude two of the schools from the full analysis. The first of these, Revelation School, was excluded because their visit to the planetarium on 4 September was followed almost immediately by their school vacation which lasted over two weeks. Due to my absence from Johannesburg later in September, I was unable to complete their follow-up PMMs and interviews until 9 October, 35 days after their visit. The mean number of days after the visit when data was collected in the other four schools used was five (SD: 5). The principal aim of my study is to ascertain the learning that happens during and as a result of students' visit to the planetarium, and I considered that my follow-up data would likely have been influenced by intervening experiences, which may not have necessarily happened at school.

The other school excluded was St Augustine's School. In this case their visit to HartRAO took place on day one of a school 'tour' lasting five days and organised by a commercial 'school tours' company. I would not have had a problem with this, as it would have been interesting to determine what had been learnt from the HartRAO visit as part of a longer tour involving a considerable number of new experiences. However, three incidents resulted in my decision not to analyse the data from this school in detail. The first was that the school arrived over two hours late at HartRAO, potentially reducing the time they would have for the visit. The second incident was that the 'tour guide' accompanying the classes decided that they needed to leave at midday, thus cutting their visit even shorter, with the result that they spent only seventy minutes at HartRAO, compared with the 3 to 4 hours that other schools spent. The teachers accompanying the students later explained to me that this was out of their hands, that they reached their destination for the day unnecessarily early, and should have spent at least a further two hours at HartRAO. The third incident was at St Augustine's School on 17 October, 11 days after their visit, when I had arranged for the students to repeat their PMM and be interviewed by me. Unfortunately this day was 'Civvies Day'¹¹, and the students were in a generally playful mood. In order for them to complete their PMM, they were asked by their teacher to stop what they were doing (and apparently enjoying; it was not normal school work) and complete their PMM. I noted at the time that most of the students tended to rush through the PMM to get back to the task they were doing before being interrupted. Further, during

¹¹ A Civvies Day in South African schools is a day on which the uniform code is relaxed, and students can wear whatever clothing they like. It is often associated with an event or festival.

the interviews with each student, several of them appeared distracted, and wanted to get away to join the other students as part of the day's festivities. For these reasons I decided not to use the data from this school, as I considered it would be collected under very different circumstances compared with data from the other schools.

In excluding these two schools, the final number of students interviewed was 34, from four schools, and I have summarised demographic and other relevant information about them (Table 5.1).

Table 5.1 Demographic information on sample of students

Fictitious Name	Student code	School	Age	Gender	Grade	Home Language	Population Group
Sibongile	scf06	Lourdes	14	F	8	isiZulu	Black
Susan	scf08	Lourdes	13	F	8	English	White
Lara	scf10	Lourdes	14	F	8	English	White
Helen	scf11	Lourdes	14	F	8	English	White
Sarah	scf12	Lourdes	14	F	8	English	White
Fatima	scf15	Lourdes	14	F	8	English	Coloured
Kitso	scf17	Lourdes	15	F	8	seTswana	Black
Antonia	scf19	Lourdes	13	F	8	English	White
Sipho	sw05	Balfour Forest	13	M	7	isiZulu	Black
Zanele	sw06	Balfour Forest	12	F	7	isiZulu	Black
Bhekiwe	sw07	Balfour Forest	13	F	7	isiZulu	Black
Mpho	sw014	Balfour Forest	13	F	7	seSotho	Black
Banyana	sw020	Balfour Forest	12	F	7	seTswana	Black
Ntobeko	sw022	Balfour Forest	13	F	7	isiZulu	Black
Nonkululeko	sw026	Balfour Forest	12	F	7	isiZulu	Black
Douglas	sw029	Balfour Forest	14	M	7	tshiVenda	Black
Julius	sw036	Balfour Forest	13	M	7	sePedi	Black
Neo	sw042	Balfour Forest	13	F	7	sePedi	Black
Batsile	sw053	Balfour Forest	14	M	7	seTswana	Black
Thapiso	sw059	Balfour Forest	13	F	7	isiZulu	Black
Phillip	sw069	Balfour Forest	12	F	7	sePedi	Black
Brenda	sw070	Balfour Forest	13	F	7	sePedi	Black
Tlotlo	tsw02	Bokamoso	13	F	8	seTswana	Black
Botho	tsw04	Bokamoso	13	F	8	seTswana	Black
Fane	tsw08	Bokamoso	13	M	8	seTswana	Black
Nnaniki	tsw15	Bokamoso	12	F	8	seTswana	Black
Paul	vho02	Achievement	13	M	7	English	White
Vicky	vho06	Achievement	13	F	7	English	White
Theresa	vho09	Achievement	13	F	7	English	White
Judy	vho10	Achievement	12	F	7	English	Coloured
Caroline	vho11	Achievement	13	F	7	English	White
Richard	vho12	Achievement	13	M	7	English	White
Ross	vho13	Achievement	12	M	7	seSotho	Black
John	vho16	Achievement	15	M	7	English	White

Lourdes Girls School visited the planetarium, while the other three schools visited HartRAO. Of the 34 students, 74% (25) were girls, 62% (21) were black and 6% (2) were

coloured. The white and coloured students all spoke English at home, while the black students spoke either isiZulu (7), seTswana (7), sePedi (4), seSotho (3) or tshiVenda (1 student) at home. 13 students (38%) of the total sample stated that they spoke a second language at home, the commonest ones being English (7 students) and Afrikaans (4). 22 of the students (64%) were in grade 7, while the remaining 12 were in grade 8.

5.3 Learning in Science Centres

In Chapter 2 I described how learning can be understood in the context of a school visit to a museum or science centre. I stipulated a definition which I repeat here to set the scene for the breadth of learning the students show.

Learning is a process of active engagement with experience. It is what people do when they want to make sense of the world. It may involve the development or deepening of skills, knowledge, understanding, awareness, values, ideas and feelings or an increase in the capacity to reflect. Effective learning leads to change, development and the desire to learn more (Braund & Reiss, 2004 p. 5)

While few people would disagree with this, the idea of learning as conceptual understanding or conceptual change is held in high regard by many South African teachers (e.g. Hlatshwayo & Stanton, 2005; Potgieter, Engelbrecht & Harding, 2006). From the point of view of many interested parties, from teachers to funding sources aiming to increase the quality of science and mathematics programmes, learning involves an increase in knowledge and understanding on the part of the learner. If students go on a visit to a science centre, it might be expected that they should improve their knowledge in the area in which the science centre specialises. In order to compare this 'expected learning' with a wider view of learning such as that expressed by Braund and Reiss, I developed a set of categories of learning using the notion of *Big Ideas* to define key concepts in basic astronomy for my study.

The notion of Big Ideas comes from the American Association for the Advancement of Science's (AAAS) Project 2061 which developed what it regards as topics of importance for literacy in science, mathematics and technology. These themes (important concepts) have been assigned benchmarks (ideas and skills) which the AAAS considers all students should be exposed to during their schooling as far as grade 12 (American Association for the Advancement of Science, 1993). Project 2061 is a reform initiative started in 1985 to improve science literacy among United States citizens, and takes its name from the year in which Halley's Comet will next be visible from Earth. In

their *Atlas of Science Literacy* (American Association for the Advancement of Science, 2001) the Project 2061 developers map out different aspects of science, such as the Nature of Science, the Physical Setting and the Human Organism, and identify clusters and strands of science within these categories. Their intention is to provide a series of strand maps which educators such as teachers and curriculum developers can use to locate the benchmarks for science literacy within the bigger picture. However, I was recently made aware by a planetarium director that when the national standards were drafted, astronomers were only involved at a late stage, and that “the astronomy portions were added as a kind of afterthought” (Jim Beaber pers. comm.).

Instead of the term ‘theme’ or ‘topic’ the AAAS has started informally using the term *Big Idea* (American Association for the Advancement of Science, 2005), a notion which I find useful to identify key concepts for my study. The notion of Big Ideas has also been used by Loughran and colleagues in their development of teachers’ Pedagogical Content Knowledge (PCK), but they use the term to refer to science ideas that teachers regard as being important in the topic being studied (Loughran, Mulhall & Berry, 2004). Also, Big Ideas should not be confused with Big Science, a term coined by Alvin Weinberg in 1961 to refer to science activities (such as space research or nuclear physics) which involve expensive and elaborate equipment and large teams of scientists (Goldberg, 1995).

As my analysis proceeded I independently identified three Big Ideas which coincided with the strand maps of the AAAS under their cluster ‘The Universe’. The three Big Ideas are gravity, stars and the solar system, and I also identified a fourth idea (size and scale) which the AAAS includes in a separate theme common to other aspects of science, mathematics and technology. I chose the Big Ideas for my study using three main criteria: (i) the extent to which a concept is fundamental to the science of astronomy; (ii) the extent to which a concept is reflected in the research literature on astronomy education; and (iii) the extent to which either the planetarium or HartRAO addressed the concept in their exhibits and presentations. I chose two further *Significant Ideas*: the day/night cycle and the phases of the Moon. While these cannot be regarded as ideas fundamental to astronomy, they have been extensively researched and I regard them nevertheless as key concepts that were addressed, at least obliquely, at my study sites. The Big and Significant Ideas I chose for my study are shown in Table 5.2, together with a summary of how they are presented at the study sites and their frequency in the research literature.

Table 5.2 Big Ideas used in my study

Big Ideas	Peer-reviewed studies since 1975	Presentation at planetarium	Presentation at HartRAO
Gravity	9	2 video clips, 1 reference	4 demonstrations, 1 reference.
Stars (and Sun)	4	6 demonstrations and explanations	4 demonstrations and explanations
Solar System	3	2 demonstrations	1 extensive demonstration
Size and scale	1	1 explanation and 1 extensive demonstration	1 explanation and 1 extensive demonstration
Day and night	16	2 explanations for observations made	Demonstrations of the ‘sky moving’
Phases of the Moon	13	Moon landing slide show; phases not discussed	Photos of Moon; phases not discussed

I also chose one item which I refer to as a *Dominant Artefact*: the satellite dish. At HartRAO the 26m-diameter radio telescope dominates the whole site, and dishes are visible in a number of places, even on the road leading to the observatory. Let me say a little more about the rationale for choosing each of these concepts.

5.4 Big Ideas

5.4.1 Gravity

I chose the concept of gravity (as one of the four fundamental forces in the universe) as it is crucial in the understanding of astronomy and cosmology. It is often covered at school as a rather dry topic within the theme ‘mechanics’, and as a result, students’ understanding of gravity in relation to the Earth and the solar system is usually limited to solving calculations and exam-style problems. In the *Atlas of Science Literacy* (American Association for the Advancement of Science, 2001) gravity is regarded as being of sufficient importance to be allocated its own strand map. In the South African school system, gravity has traditionally been covered at senior primary and junior secondary level (grades 7 to 8) as part of acceleration and forces. At higher grades, gravity has been covered as part of Physical Science within the grade 12 syllabus under Newton’s Law of Gravitation. Since the implementation of Curriculum 2005 and the Revised National Curriculum Statement (RNCS) gravity is now covered in the Senior Phase of the General Education and Training band as “The force that keeps planets in orbit ... and governs ...

motion in the solar system” (Department of Education, 2002 p. 71). Within the newly implemented Further Education and Training curriculum (Department of Education 2003) gravity is covered under mechanics in grades 10 and 11.

The concept of gravity was covered quite differently at the two sites in my study. At the planetarium, where students are taken on a visual tour of the solar system, the presenter used the word ‘gravity’ 17 times during the visit by St Theresa’s school (during the pilot study). This compares quite favourably with other astronomy-related words, for example she used the word ‘moon’ 52 times, ‘planets’ 33 times, ‘Pluto’ 22 times and ‘gas’ 17 times. The concept of gravity was used in a variety of ways during the show, as follows.

First the students were shown a video clip of a corona mass ejection from the sun, and this was described as being rare, as the sun’s mass is held together due to gravity. The presenter stated “The sun has about 28 times as much gravity as the Earth which is useful.....If it didn’t had enough gravity it would just sort of blow itself apart from heat. Heat makes things expand. Gravity holds things like the sun together.” (Theresa pltm 038).

Secondly, students were shown a video clip of how the solar system formed, whereby dust and gas accumulate together, and are pulled by gravity to form a star and planets. The presenter stated “So you can programme a computer using maths to say what would gravity do to all those billions of little bits of dust and gas in that ball over there” and “So what you end up with is huge lumps in the middle with a lot of gravity and a lot of pressure.” (Theresa pltm 070).

Thirdly, with respect to an artificial satellite, the presenter described how it orbits the Earth at speed, so that it can remain in orbit: “On this picture here the international space station would be about that distance above the Earth which is why it has to keep moving. If it stops moving what would happen to it? Gravity will pull it down to the Earth. It will fall out of the sky.” (Theresa pltm 122).

During the visit by Lourdes Girls School, similar explanations were used by the planetarium presenter. She also made a statement that stressed the importance of gravity throughout the solar system: “Gravity, okay so the sun has gravity the Earth has gravity all of these others have gravity as well so Mercury pulls the sun, Mars pulls the sun, Jupiter pulls the sun hugely the sun isn’t standing still the sun goes entirely in circles so we can look at other stars to see if they are moving entirely in circles and about hundreds of them

look like they are we assume because they are pulled by the gravity of planets” (Lourdes pltm 353)

These excerpts show that students are exposed to the concept of gravity in the following four ways throughout the show:

- Gravity is very high in a massive object such as the sun, and it pulls not only material ejected from it, but also the other bodies in the solar system.
- Gravity is responsible for ‘pulling together’ a proto solar system.
- Gravity pulling an orbiting body is counteracted by the body orbiting at high speed,
- All the solar system bodies are pulling on each other due to the gravity of their masses.

At HartRAO gravity was also referred to, but in a less didactic and more ‘hands-on’ manner. Students experience gravity principally through an activity using ‘Coke bottle rockets’. During this activity they attach two-litre plastic bottles to a one-way valve within a metal frame, which acts as a launcher, positioned vertically. The valve is attached to a hand-operated air pump, which is used to pump air into the bottle. When the pressure inside the bottle reaches a critical level, the bottle shoots out from the launcher into the air. Students then experiment with different levels of water in the bottle to see which will allow the ‘rocket’ to fly to the highest altitude. After the activity is completed the HartRAO educator would normally discuss the students’ findings, referring to gravity, the relative amounts of water in the bottle, and the altitude reached.

A second way in which students may experience gravity at HartRAO is by handling Coke cans. Situated on a table in the Visitors Centre, there are ten 340ml Coca-Cola cans, each labelled with the name of one of the planets in the solar system, as well as the Moon. The ‘Pluto’ can is empty, and all the others are filled with an amount of sand such that the relative weights are in proportion to the weight they would be on the different planets. The idea is that by picking each one up and feeling its weight, visitors can understand the relative effect of gravity on each planet. Unlike the rocket activity however, students are not directed by the HartRAO educator to carry out any activity with these cans. There is a label in the centre reading “What would a Coke can weigh on each planet?” Like many exhibits in a science centre, visitors can choose to interact with the display or not. All the groups in my study who visited HartRAO were given time to wander around the visitors’ centre and handle exhibits. On each occasion, a number of students chose to pick up the Coke cans. However, as there is no written explanation of the science involved students

have to use their prior knowledge about weight, gravity and the planets to understand their significance, or they need to ask their peers, the HartRAO educator or their own teacher.

A third approach to students' experiencing the effects of gravity is by the use of calibrated 'bathroom scales'. HartRAO has four scales at the visitors' centre, in the same area as the Coca-Cola cans. As in the Coke can activity, students are not directed to use the scales, so a visiting student may or may not get to interact with the exhibit. All scales are measured in kilograms and are calibrated according to four bodies in the solar system: Earth, the Moon, the Sun and Jupiter. A student standing on the 'Jupiter' scale would see what his or her weight would be like on the planet, which is intended to assist in a greater understanding of the concept of weight in relation to gravity. Again, like the Coke cans, there is no written explanation of the relationship of weight to gravity or size of the solar system body. The activity therefore intends to stimulate the student to find out more about the relationship for themselves.

A fourth way of experiencing the effects of gravity is by visitors 'trying to hit Jupiter with a comet'. In this exhibit, visitors slide a ball bearing (representing the comet) around a flattened bowl-shaped structure (representing the solar system) with a hole in the centre (representing the Sun) as explained in Kaelo's narrative in Chapter 4.

The fifth, and probably lesser, way in which gravity may be directly referred to at HartRAO is during the slide show, which in the case of the Balfour Forest and Achievement School visits was about the moon landings. During the slide show the topic of gravity was mentioned in passing, for example when asked about the lunar rover, one of the students suggested "Their vehicle help them to not float. Maybe their vehicle have gravity [laughter from peers] or weight". However, the HartRAO educator did not follow up on this observation.

In contrast to the planetarium, students at HartRAO had opportunities to experience the effects themselves. The two main experiences being experimenting with water-filled 'rocket' bottles and feeling the simulated effect of gravity on planets in the solar system. The extensive literature on learning about gravity is highlighted in section 5.8.1.

5.4.2 Stars and the Sun

I chose stars and the Sun because students have direct experience of them as objects in the sky and because having knowledge of their size, composition and position in space gives students an understanding of the scale of the solar system and universe. Like the concept of

gravity, this is crucial to students' overall understanding of astronomy, and the topic 'stars' is allocated its own strand map in the Atlas of Science Literacy (American Association for the Advancement of Science, 2001). In the analysis of students' knowledge it was not always possible to separate what they knew about the Sun from their knowledge of stars, so they are treated together much of the time in this chapter and elsewhere in the thesis.

The RNCS refers to the following as core knowledge and concepts for the Intermediate Phase. "The stars' apparent positions in relation to each other do not change, but the nightly position of the star pattern as a whole changes slowly over the course of a year. Many cultures recognise and name star patterns..." For the Senior Phase it states: "The sun, an average star, is the central and largest body in the solar system" and "The sun is the major source of energy for phenomena on the Earth's surface..." (Department of Education, 2002 p. 70-71)

At the planetarium stars are a key part of the presentation: they are present as a backdrop for almost the entire duration of the show. At the presentation given to Lourdes Girls School the planetarium presenter used the word star or stars 116 times compared with the words Mars (80 times), Earth (57 times) and Sun (51 times). In addition, the following aspects of stars were given special emphasis:

- The names of stars and constellations e.g. Sirius and Orion; how to use a star chart to identify them.
- An explanation of the star signs (zodiac)
- Working out star composition using a spectrometer.
- The Sun as the closest (not the biggest) star.
- The distance to the next closest star: Alpha Centauri
- Nebulae and star formation

At HartRAO stars are also given considerable prominence by the educators in the following main ways:

- An explanation of why stars appear small and the Sun appears larger.
- A demonstration of the difference between 'living' and 'dead' stars using a turntable.
- A demonstration of the Sun's image, showing sunspots.
- A demonstration of a large sundial in the car park.

Stars and the Sun feature little in the research literature, and this was a further reason for including them in my study. Comins (2001) lists numerous misconceptions that undergraduate students hold about the Sun and stars, such as the Sun is not a star, and there are many stars in the solar system. Sharp (1996) included children's views on the nature of

the Sun and stars in his study of a variety of astronomical concepts. Roald and Mikalsen (2000) asked deaf and hearing children in Norway about the Earth and heavenly bodies, including stars, but found that interpretation of the data on stars was difficult, due to the children's confusion between astronomical stars and other bodies which appear like stars. Other than occasional questions in multiple choice tests given as part of larger studies, the only substantial reported research on stars is by Agan (2004). Comparing high school and undergraduate students, Agan used semi-structured interviews to find out students' ideas about what stars are, how far they are apart and whether the Sun is a star. Her results claim that high school instruction can improve students' knowledge about stars, particularly when related to nuclear fusion and energy production in stars.

5.4.3 Solar System

I chose the solar system as a Big Idea as it is fundamental to students' scientific understanding of the Earth in relation to the Sun, the Moon and other planets. Like the first two Big Ideas described, the solar system is allocated its own strand map in the Atlas of Science Literacy (American Association for the Advancement of Science, 2001).

The RNCS Senior Phase Core Knowledge and Concepts refers to the following: "The earth is the third planet from the sun in a system that includes the moon, the sun, eight other planets and their moons, and smaller objects such as asteroids and comets". It also contains further references to the solar system when describing motion and gravity (Department of Education, 2002 p. 70-71).

The planetarium provides an animated video of the formation of a solar system with gravity pulling together matter to form a star, surrounded by orbiting matter which develops into planets. The plate-shaped structure of the system is demonstrated. The bulk of the rest of the show is then a 'tour' of all the planets of the solar system, as well as some suggestions that other stars might have their own solar systems. At HartRAO the educator questions students about the planets in the solar system, describes their characteristics, and goes on to demonstrate, using a scale model, how far each planet is from the Sun. This latter demonstration overlaps with the fourth Big Idea: size and scale.

Like 'Stars and the Sun', research studies on people's knowledge of the solar system are few, and this was one of the reasons for including the topic as a Big Idea on my study. Treagust and Smith (1989) interviewed grade 10 students about their understanding of the motion of the planets and gravity in the solar system. Their study uncovered many

misconceptions students possessed in relation to gravity and the motion of the planets. Summers and Mant (1995) in their study of primary teachers used a true/false questionnaire to determine knowledge about a variety of astronomical concepts including the solar system. They found that the teachers did not have a clear picture of what constitutes the solar system, and the majority included stars near to and among the planets. Sharp's (1996) study in which he interviewed 42 10- to 11-year-old children found that they held a variety of ideas about the solar system, but that over half could describe a 'scientific' model of its structure.

5.4.4 Size and Scale

Like the concept of gravity and the nature of stars, most astronomers regard size (e.g. of heavenly bodies, the solar system and the universe) and scale (e.g. distances across the solar system and between stars) as being crucial to an understanding of astronomy. In the school classroom they are some of the most difficult concepts to get across to learners due to the enormous distances and scale of the universe (Sadler, 1998) and visiting a planetarium or telescope might be expected to provide opportunities for demonstration of scale not available to the classroom teacher. The Atlas of Science Literacy incorporates aspects of size and scale into the 'Stars' and 'Galaxies and Universe' strand maps.

The RNCS does not make specific reference to size and scale, but they appear in its 'unifying statement' for the knowledge strand Planet Earth and Beyond which states "Our planet is a small part of a vast solar system in an immense galaxy" (Department of Education, 2002 p. 69). Sharp (1996) is relatively optimistic that children of primary school age are capable of grasping "complex and abstract information" about basic astronomy, and that "comparisons involving relative size, distance, age and time were ... useful and familiar to children" (p. 707 and 709). Conversely, Sadler (1998) suggests that "comprehension of vast astronomical scales appears to remain beyond the reach of students even after taking an Earth science course [or] astronomy course in high school" (p. 283). A similar concept to size and scale that I investigate is student understanding of geologic time, where the scale involved is massive and difficult to comprehend. Dodick and Orion (2003) in their study of grade 7-12 students and geologic time suggest that around Grades 7 and 8 students can begin to appreciate it. This grade range is similar to that of my own study (age 12 to 14), and I suggest in section 5.8.4 that students are capable of a greater

understanding of size and scale within the solar system and universe as a result of interactions during their science centre visit.

At the planetarium, the presenter explains why the Sun appears so much bigger than other stars even though it is an ordinary star, as a result of the immense distance the stars are away. She then demonstrates just how far it is from the Sun to the next nearest star (Alpha Centauri) by comparing the distance across the solar system with the distance between the 2 stars. By calculating a relatively simple division sum (as described in Kaelo's narrative in Chapter 4) she shows that it would take about 4000 years to reach Alpha Centauri, travelling at speeds twenty-times faster than our current spacecraft. At HartRAO, the educator uses an analogy of close and distant trees to explain why the Sun looks so much larger than the stars. The extensive activity of 'taking the solar system for a walk' uses a scale model of the solar system reduced 4 billion times, to pace out distances between the Sun and planets. In addition to these more substantial presentations, both sites referred to size and scale in other discussions, such as the size of the Earth in relation to the Sun and Moon at the planetarium and when viewing sunspots at HartRAO.

Relatively few studies have incorporated size and scale into their investigation. In their 1992 study of British primary school teachers' knowledge of astronomical phenomena, Summers and Mant (1995) concluded that few had an accurate knowledge of scale of the Earth-Sun system, whereas 85% knew that the Moon is smaller than the Earth. Sadler's quantitative study of 1250 grade 8-12 students in the USA (Sadler 1998) had one question on the distance between the Sun and the closest star, which the majority of students were not able to answer accurately. Trumper used Sadler's question and 2 others of the scale of the Earth and the Sun in his studies (Trumper, 2001a; 2001b). Trumper concluded that this topic was one of the weakest areas of high school students' knowledge, with only 20-25% answering these questions correctly. More recently Agan (2004) has shown that high school students were able to speak of 'great distances between stars', but only the undergraduate students could relate the distances to a scale model.

5.5 Significant Ideas

5.5.1 Day and Night

In contrast to 'stars', an understanding of the day/night cycle has been investigated extensively in the research literature, and I considered that it would be a useful idea to examine. The Atlas of Science Literacy incorporates the day/night cycle into the 'Gravity'

and 'Solar System' strand maps. In the RNCS there is specific reference to the day/night cycle in the Intermediate Phase: "Day and night may be explained by the rotation of the earth on its own axis as it circles the sun". Similarly, at the Senior Phase there is reference to the motion of the Earth explaining the day (Department of Education, 2002 p. 69).

The concept of the Earth spinning, however, is referred to only briefly at both the study sites. At the planetarium there are several demonstrations of the stars, Moon and Sun moving fast across the dome, and the presenter makes reference to the fact that this is the Earth spinning or rotating rather than a real movement of the stars. At HartRAO there are two opportunities for the educators to refer to the Earth spinning. First, during the demonstration of the Sun's image projected on to a card, where the image moves over the course of a few minutes, and secondly when the sundial is demonstrated to show how the Sun can be used to tell the time. In both these cases, the educators explained that the movement was due to the Earth rotating.

There are more than 16 peer-reviewed articles examining students' and teachers' ideas about day and night. A study by Baxter (1989) showed that from age 9 to 16 a larger proportion of the older children in the sample used a scientific explanation for day and night, but that misconceptions persisted throughout the sample. A very influential paper by Vosniadou and Brewer (1994) explained 6- to 11-year-old children's understanding of day and night in terms of mental models: from initial (naïve) through synthetic to scientific, and again found a progression towards the scientific notion in the oldest children. These results have been confirmed by subsequent researchers such as Sharp (1996), Sadler (1998), Roald and Mikalsen (2001) and Trumper (2001a, 2001b) in children, and Summers and Mant (1995) and Atwood and Atwood (1995) in primary teachers. Kikas (1998) conducted a longitudinal study in which she found that a group of 20 students were able to remember the (textbook) scientific explanation for day and night 2 months after teaching. However she found 4 years later their scientific knowledge was not remembered and they relied heavily on everyday experience to explain the phenomenon. Albanese *et al.* (1997) strongly criticise the work of Baxter (1989) and Vosniadou and Brewer (1994), and by implication the subsequent papers based on their mental model theories, and suggest that further research on this topic is needed.

5.5.2 Phases of the Moon

Like the day/night cycle, the phases of the Moon are a concept which has been studied extensively. The Atlas of Science Literacy incorporates the lunar cycle into the Solar System strand map. At the Intermediate Phase of the RNCS core knowledge about the Moon includes “The moon’s apparent shape changes in a predictable way and these changes may be explained by its motion relative to the earth and sun” (Department of Education, 2002 p. 69). There is further reference to an explanation of the Moon phases at the Senior Phase.

At the study sites the Moon is discussed in several contexts, for example at the planetarium the path of the Moon through the sky is demonstrated, and photographs of its surface are shown. At HartRAO there is a giant (3m diameter) model of the Moon donated by NASA (and therefore ‘upside down’ from our point of view in the southern hemisphere!) which students are referred to and the Moon is discussed in relation to the Earth when the scale of the solar system is explained. However, at neither site are the phases of the Moon specifically discussed, modelled or explained in terms of the Moon orbiting the Earth with sunlight falling on different amounts of the Moon’s surface as viewed from Earth over 28 days. It would therefore not be expected that students in the study improve their understanding of the Moon phases after the visit.

I identified more than 10 peer-reviewed articles discussing people’s understanding of the Moon phases. In contrast to the majority of older children being able to explain day and night, knowledge of the cause of the Moon phases is generally poor in school-age children, tertiary students and teachers (e.g. Barnett & Morran, 2002; Baxter, 1989; Summers & Mant, 1995). However, a number of researchers have been able to show substantial increase in student understanding as a direct result of instructional activity (e.g. Stahly, Krockover & Shepardson, 1999).

5.5.3 Dominant Artefact: Parabolic/Satellite Dish

I chose this as the dominant artefact of the study because of the radio telescope at HartRAO which dominates the entire visit to the site. Just as the backdrop of stars strongly influences a visit to the planetarium, the parabolic dish of the telescope is the main centre of attraction at HartRAO. Since the advent and increasing popularity of satellite television in the 1990s, dishes are common sights on buildings in most urban settings, and students could be expected to be familiar with their shape.

Not surprisingly, the RNCS does not make specific reference to satellite dishes, but does refer to satellites as object which may be observed in the sky (Foundation Phase), and both Earth-based and orbiting telescopes (Senior Phase).

The planetarium presentations made no reference to satellites or dishes, although they did show dishes fixed to spacecraft as part of the slide show. At HartRAO the 2 main ways in which parabolic dishes were demonstrated were the ‘whisper dish’ activity and the explanation of how the main telescope functions. During the activity, pairs of students whispered into parabolic dishes placed 20m apart, and the educator explained how sound waves are focused in the dish and reflected from one to the other. She further compared the parabolic shape with torch reflectors, satellite dishes and the radio telescope. One of the highlights of the visit for the students was standing close to the radio telescope dish (Figure 4.11) and seeing it move to point to a particular part of the sky. The explanation of the telescope’s shape and function, together with the playing of sounds recorded from stars, allowed students to question the educators about various aspects of the site.

The only study involving whisper dishes reported in the literature is one by McClafferty (1995) in which he found that some visitors were able to learn from the exhibit. Others however, were unable to transfer their prior knowledge of reflection and focussing to the new context of the whisper dish, suggesting the situated nature of knowledge that others have described (Lave & Wenger, 1991).

5.6 Coding for Big Ideas

Throughout the rest of this thesis, the eight concepts in astronomy I have identified as Big and Significant Ideas as well as the Dominant Artefact will be referred to collectively as Big Ideas. For each Big Idea, I developed hierarchical categories of student knowledge (1 highest and 3 lowest) based on how the students responded to the interview questions during their pre and post-interviews. The Big Idea categories and criteria for assigning students’ views to a category are self-explanatory and are shown in Table 5.3. Each student was placed into a category for each of the Big Ideas they demonstrated during their structured interview, both prior to and after the visit to the study site. As exemplars, I examine each Big Idea and show how students were categorised in section 5.6.1.

Table 5.3 Criteria for assigning students to knowledge categories for Big and Significant Ideas and the Dominant Artefact

Big or Significant Idea	Knowledge Level 1*	Knowledge Level 2	Knowledge Level 3
Gravity concept – the extent of knowledge and understanding of gravity	Gravity as a pulling (or pushing) force only. No additional knowledge or understanding 1.5 Very limited understanding of gravity, one correct idea, but no conceptual understanding.	Limited understanding of how gravity pulls towards a body. Misconceptions apparent (e.g. no gravity in space, on Moon etc.) 2.5: Basic scientific understanding, but still with at least 1 misconception.	Substantial scientific understanding regarding mass and gravity. No major misconceptions apparent.
Star concept – the extent of knowledge and understanding of stars.	Minimal idea: stars as lights at night, no correct reference to composition, no scientifically correct idea of size, little or no idea of position in space	2: Stars as suns. Burning ball of gas. Misconceptions in terms of e.g. size, composition, and position in space.	Fully scientific explanation. Including: Ball of burning gas, reference to H/He. Correct idea of size & position in space. May include misconception(s) or an omission regarding composition, distance or size
Sun concept – the extent of knowledge or understanding of the Sun	The most naive level of conceptions: e.g. sun bigger & brighter than stars, sun-by-day & stars-by-night, ball of fire, sun hot, sun light, sun huge, uses for drying, for plants	Sun as star, sun as biggest star. Some indication of more developed than lower concept. No reference to difference as being related to distance or wrong idea of distance. Other sun facts may include: energy, gas, sunspots etc.	Sun as closest, not biggest star, i.e. idea of scale. Indication of more developed knowledge than lower concepts. Properties may name gases, refer to nuclear energy, UV light, age, future
Solar System – the extent of knowledge about the composition and shape of the solar system.	No scientific knowledge of what solar system is.	Knowledge of what constitutes solar system, but misconceptions prevalent (e.g. shape, stars in solar system)	Substantial scientific knowledge of solar system, including shape. No major misconceptions.
Size and scale – the extent of knowledge and understanding of size, mass and distance (excluding gravity)	Confused and conflicting knowledge regarding size, mass and distances.	2: Some correct ideas regarding size, mass and distance. Some incorrect ideas and misconceptions. 2.5: Basic scientific understanding, but with at least 1 misconception.	Scientific understanding of size, mass and distance in the solar system and beyond.

Big or Significant Idea	Knowledge Level 1*	Knowledge Level 2	Knowledge Level 3
Day and night – an explanation for why the Sun appears to move across the sky	Student shows confusion regarding the concept or student may show misconceptions such as day and night reversed, revolution around sun as reason for sun movement.	Scientific conception develops as a result of using model. May have referred to Earth revolving/orbiting around sun as initial explanation of day and night, but by manipulating model, develops correct conception.	Full scientific conception from start of explanation: Earth spinning on axis.
Phases of the Moon	Little, confused or no idea of cause of Moon phases.	2: Explanation involves a misconception e.g. Earth's shadow. Or limited explanation but not wrong. 2.5: Partial scientific: explanation has some reference to sun shining or 'reflecting' on moon, but no ref to Moon orbiting Earth. No obvious misconception.	Full scientific explanation referring to the Moon orbiting the Earth and sunlight shining on part of the Moon.
Dominant Artefact: Parabolic/satellite dish	Little or no idea of idea of 'collection of signals' or similar, but not able to express properly. Direction not correct.	2: either correct explanation of waves bouncing or correct pointing direction (but not both) 2.5: correct explanation of waves bouncing and correct pointing direction but needed considerable probing.	Correct explanation of waves bouncing and correct pointing direction with no probing.

* one student (Nonkululeko) had no idea what gravity was, and was classified as knowledge level 0. For all other Big Ideas, students had at least a minimum level of knowledge, and so the lowest knowledge level was 1.

5.6.1 Helen and gravity

The students in Lourdes Girls School, who visited the Johannesburg Planetarium, were not asked about gravity in their structured interview, but Helen referred to it in her PMM, and I questioned her on the basis of what she had written. In her PMM Helen had written that there is “No gravity in space so you float around” (scf11pre 22). The transcript of the interview is as follows:

- Interviewer: What is gravity?
Helen: It's a grav... It's a pull that hold us on Earth.
Interviewer: Uh-hmm.
Helen: Umm. There is no gravity in space so we just float around if we went there.
Interviewer: Uh-hmm.
Helen: Like the astronauts and the spaceships.
Interviewer: Uh-hmm. Okay. What about if you would go to the moon? Is there gravity on the moon?
Helen: No. You would just float around.
Interviewer: Uh-hmm. Is there gravity on the sun?
Helen: Umm. Nnnn....No.
(scf11prepmm 45-65)

In this exchange, Helen gives a brief definition of gravity as a pull that holds us on the Earth, and indicates that there is no gravity in space. When probed, she also suggests that there is no gravity on the Moon or on the Sun. According to my gravity criteria Helen has basic knowledge of gravity as a “pull” and has misconceptions that there is no gravity in space, on the Moon or the Sun. She is therefore placed in category 2 for gravity prior to her visit.

After the visit she added to her PMM, writing under her previous statement that there is no gravity in space the additional note “But the planets do have gravity” (scf11pos 13). She further wrote that “Each planet ...holds the sun in place by means of their gravity” (scf11pos 15). When questioned on these new statements she had written, the interview went as follows:

- Interviewer: Tell me about this, you say planets in our solar system hold the sun in place by means of their gravity. Tell me a little bit about that.
Helen: Okay. The sun doesn't stand still. It moves around. If you look through a telescope you can actually see it wobble a bit from time to time.

Interviewer: Okay.

Helen: And because of our gravity. The sun ... Hold. The sun's gravitation holds us in place, but we also hold the sun in place by our, by the means of our gravitational pull. And the planets.

Interviewer: Uh-hmm. Okay. Umm. Okay. You're saying that there's no gravity in space. You've said before ... And the planets do have gravity. What ...? Umm, what is gravity related to? Do you know? Why do planets have gravity?

Helen: To keep things onto them, like their ... Like ... We wouldn't float away.

Interviewer: Yeah.

Helen: So, we could be ... Stuck to the ground.

Interviewer: And ... Umm, so, which ones ...? Do they have the same amount of gravity or is it different on different planets?

Helen: They're different.

Interviewer: Okay. Why is that? What's it related to?

Helen: I'm not sure.

Interviewer: Okay. Like the moon or ... you don't know?

Helen: The moon is ... If we went like, right here ... Here ... Umm, we ... If, let's say, I weigh 40kg here [on Earth], on the moon I'll weigh about 10.

Helen: Because the gravitational pull is less.

Helen: And it pulls you more, yeah, it pulls you in.

Interviewer: Okay. And supposing you are on Jupiter? Would it be greater or lesser?

Helen: Greater, I think. The bigger the planet is I think, the more gravity you've got.

Interviewer: Okay. (Pause) Where did you learn that?

Helen: I don't remember.

Interviewer: You just knew it?

Helen: Yes, I think.

(scf11pospmm 01-07 & 37-75)

Helen's knowledge was quite different from that prior to the visit. Not only does she have a sophisticated understanding of how the Sun holds the planets in space (and vice versa) by means of gravity, but also that the Moon and planets have gravity and the cause of gravity is related to mass of the body. In Braund and Reiss's terms (2004), she has deepened her knowledge and understanding of gravity. While it is not certain whether she still holds a misconception that there is 'no gravity in space' or on the Sun, her understanding of the concept of gravity appears to be moderately well developed. I therefore placed her in gravity category 3 as a result of this post-visit interview.

5.6.2 Helen and stars

All the students who visited the planetarium were asked about stars in the following way “Stars at night look like pinpricks of light. Why? What are stars?” Helen’s response before the visit was as follows:

- Helen: Umm. They’re masses that give off their own light and heat and that’s how and that’s why they twinkle and the light takes a long time to travel to us.
- Interviewer: So why are they so tiny?
- Helen: Because they are far away from us.
- Interviewer: Uh-hmm. What size are they approximately? I mean, in terms of a moon, Earth, sun, what sort of size are the stars?
- Helen: Oh, they can be different sizes.
- Interviewer: Uh-hmm. Give me some range.
- Helen: They can go ... well, there is another ... Umm, well, a star that is as big as our sun...some kilometers or light-years away from us and then there are stars as big as the moon and the Earth.
- Interviewer: Okay. What are they made of?
- Helen: Umm. Mass.
- Interviewer: Mass being what?
- Helen: Rock? More or less ...
- (scf11preint 146-170)

Helen clearly has some scientific knowledge of stars: she knows that they emit their own light and heat as well as having some idea of their size, although her knowledge here appeared insecure. She also knows that they are “far away” which results in their appearance being so tiny. One misconception she has regards their composition: she thinks that they are made of rock, but again appears to be uncertain. I classified her at level 2 in my criteria because although she didn’t know the composition of stars, she had some idea of their position in space and size, as well as their production of heat and light.

After the visit, Helen’s response was similar, but showed that she now remembered that stars are made of gas, but did not elaborate enough about their composition size or position to be classified as level 3:

- Helen: Stars are masses, no, they’re balls of burning gasses that umm, produce light and heat, which is their own light and heat.
- Interviewer: Uh-hmm. Okay. What sort of size are they?
- Helen: Umm, they’re big. They can actually ... I think they can vary but normally they’re as big as our sun.
- (scf11posint 82-86)

Helen was therefore classified as having a similar conception of stars from pre- to post-visit. While she had not acquired additional misconceptions or erroneous knowledge, she had also not substantially changed her knowledge about stars.

5.6.3 Helen's conception of the Sun

In her pre- and post-visit interviews I asked Helen "Tell me anything you know about the Sun". Her answers were relatively brief, and I did not probe her very much. Before her visit she stated:

Helen: Umm. It consists of lots of gases, then it gives light to all the planets around it and then it's the centre of our solar system.
(Laughs)

Interviewer: Okay. Umm. What are the gases doing?

Helen: They form heat.

Interviewer: Okay. Do you know the names of any of them?

Helen: Umm. No. I dunno.

(scf11preint 87-95)

She also knew that the Sun is regarded as a star, as when she was asked for the names of any stars she knew, she referred to the Sun. On these bases, I classified Helen as having knowledge about the Sun in category 2. Her post visit responses to the same questions were very similar, and she added nothing to her ideas about the Sun.

5.6.4 Helen's conception of the solar system

Like other students visiting the planetarium, I asked Helen what the solar system is, and probed by asking what it consists of and what shape it is. Prior to the visit, Helen already had a scientific conception of the solar system, but I classified her as knowledge level 2 on the basis that she thought the solar system contained stars (in addition to the Sun) and was oval shaped, like a plum:

Helen: It consists of planets, the stars, umm, the sun, our ... The centre of our u ... eer....solar system, yes. And then nine planets and then they all have moons, (pause) yeah.

(Interruption on school P.A. system)

Interviewer: Umm. What shape is ... the solar system?

Helen: Umm. Umm. An oval shape?

Interviewer: Uh-hmm. Oval ... Oval like a plum or oval like on a flat surface?

Helen: Oval like a plum.

Interviewer: Okay. Umm. How'd you know?

Helen: Cause we've done projects on this.
(scf11preint 65-79)

After the visit her knowledge was very similar, except that she also included the Milky Way in her conception of the solar system, and I again classified her as being at knowledge level 2.

5.6.5 Helen's conception of size and scale

Helen showed a relatively sophisticated conception of distances, sizes and the scale of the solar system and universe prior to the visit. She was one of only 6 students who referred to the concept of the light year as a measure of distance, and her knowledge of the relative sizes of the Earth, Moon and Sun was scientifically accurate. Her knowledge of star size as being roughly the same as the Sun was clearer after the visit, and she remembered the length of time it would take to reach the nearest star to our solar system (4000 years) whereas she had guessed at 100 years in her pre-visit interview. On the basis of her relatively advanced conceptions of scale, I classified her as being at knowledge level 3 both pre- and post-visit.

5.6.6 Helen's understanding of day and night

The extensively-researched Big Idea of the day/night cycle has been discussed in Chapter 2 and section 5.5.1. Prior to her visit Helen appeared to be confused about day and night. Like several other students she used the term revolve without clarifying whether she really meant revolve or rotate, and when supplied with a model of the Earth and Sun was unable to explain the Sun's apparent movement across the sky. For these reasons, Helen was classified at knowledge level 1 for the day/night cycle:

Helen: Because the Earth revolves.
Interviewer: Okay. Can you, if I give you a little model like that and can you and let me get my sun out, if you got the sun and you turn it on, have the sun on one side, show me what's going on.
Helen: Okay. Here you have the sun.
Interviewer: Yeah.
Helen: Then the Earth moves, umm, this way...
Interviewer: Uh-hmm.
Helen: Wait, wait, this way.
Interviewer: Okay.
Helen: And then keeps like that.

Interviewer: So, ... What's that side at the moment? What's...? When you have the sun moving across the sky everyday. What's on this side?

Helen: Nothing.

Interviewer: Okay. And the other side? Okay. So, so on this side...

Helen: Yes?

(Blank on tape. About 10 seconds.)

Interviewer: What's going on with the sun moving over the sky there?

Helen: It moves from West to East.

Interviewer: Okay. Right. Okay, thanks.

(scf11preint 99-132)

However, in her post-visit interview Helen was able to articulate the reason for the Sun's apparent movement fluently. Unfortunately I didn't probe her about her change in idea, but clearly some clarification had taken place in her mind over the week between the first and second interview. Something may have increased her reflective capacity (Braund & Reiss, 2004). On the basis of the following transcript, I classified her knowledge level as 3:

Helen: It's because we rotate.

Interviewer: Uh-hmm. Okay. So, with the model we got here. If the sun is there, what's the Earth doing?

Helen: The Earth is going this way like a...

[Demonstrates the Earth spinning on its axis and orbiting the Sun with the latter stationary].

Interviewer: Okay. So what's actually causing the sun to move? Apparently ... Is it the moving round of the sun or is it the rotating?

Helen: Rotating.

(scf11posint 57-65)

5.6.7 Helen and the phases of the Moon

Helen was one of only five students in the study who, prior to her visit, was able to explain why the Moon's shape appeared different over the course of a month. Most students had some difficulty with expressing themselves when asked about the cause of the Moon's phases, and Helen was no exception. However, she was able to explain the lunar cycle in terms of the Moon orbiting the Earth (although she initially said the Sun, she corrected herself) and the Sun's light falling on different amounts of the Moon's surface, thus:

Helen: Because, umm, it reflects like the sun's light and its shadow, some, some parts are different, like it revolves around the sun, the Earth...the Earth and then the sun's light covers some parts of the moon and sometimes other parts like you can see only one part of the sun.

(scf11preint 182-186)

After the visit she gave a similar explanation:

Helen: Because ... Umm, the moon revolves around us, the Earth. And the sun's light ... Umm how can I say, the sun's light ...OK You can only see the parts of the moon that ... Umm, the sun, that receives the sunlight. The sun's light. The shadow part you can't see.

(scf11posint 094)

On this basis I classified Helen at knowledge level 3 both prior to and after her visit to the planetarium.

5.6.8 Siphon and satellite dishes

Students were questioned about satellite dishes only if they visited Hartebeesthoek Radio Astronomy Observatory, so I here use Siphon from Balfour Forest School to show how I classified a student into categories of knowledge for this dominant artefact. Although he was familiar with dishes, prior to his visit to HartRAO Siphon had only a limited idea about their shape or where they point to, as the following transcript shows:

Interviewer: Like a satellite dish. Okay. What is the shape of that dish?

Siphon: The shape ... It is circle and it's a little bit like a circle and oval.

Interviewer: Okay. And it's... Like a dish at the same time?

Siphon: Yes.

Interviewer: Okay. Umm ... Why is it that shape do you think?

Siphon: I think it could be, it's easy for it to pull ... Some message from ... the planets or something what ever it's (//) it to do.

Interviewer: Where is it pointing to? You know the satellite dish on the house, where is it pointing to?

Siphon: The ... at the sky ... and the moon.

(swo05preint 154-170)

On this basis, I classified him at knowledge level 1.5, where he could not explain the reason for the satellite dish shape, and was not clear about the direction in which the dish might point. However, he was able to expand considerably on his explanation in the post-visit interview, and although he was not scientifically correct in all details, he showed an improved knowledge level, which I classified as 2.

Interviewer: Okay. And a satellite dish, why is it that shape?

Siphon: In order for let's say that we used in Hartebees when we talk about our voice it bounce back and then it bounce to the other dish then it comes out with the wires.

Interviewer: Okay. And a satellite dish that is maybe used for something like DSTV where is it pointing to?

Sipho: To the moon.

Interviewer: Uh hmmm. Why is it pointing to the moon?

Sipho: Because there are some other satellite dishes that are also pointing to us so because when it's there on the moon the satellites that are on the moon they can see everything around the world. Now when this one points it just get the information.

Interviewer: Okay. So it comes from the moon?

Sipho: Yes.

Interviewer: Okay.

Sipho: No, with the Americans build it there on the moon.

Interviewer: Okay. How do you know that? How do you know it's on the moon?

Sipho: Because of when I watch television I can see that like even there at Hartebees when we asked some questions they also even told us that every country can build it's own satellite dishes or whatever it wants to do there on the moon it does.

(swo05posint 085-111)

In Braund and Reiss's terms, Sipho actively engaged with his experience at HartRAO, and learned as a result of that experience (Braund & Reiss, 2004).

5.7 The Extent of Learning

The categorisation of students using their knowledge level of Big Ideas was then used as an organising scheme to determine the extent of their learning, specifically how they developed their knowledge, understanding and ideas (Braund & Reiss, 2004). The remainder of this chapter examines the students as a group and demonstrates the extent to which they acquired knowledge during the visit to the study site. Miles and Huberman (1994) recommend three 'flows' of analysis activity, namely data reduction, data display and the drawing and verification of conclusions. I have reduced the data from the interviews conducted with students by categorising their knowledge of Big Ideas as shown in Table 5.3. The results from the responses to the pre- and post-visit interviews were coded and converted into tabular form using the software program ATLAS.ti. The following section displays the reduced data in the form of tables and bar charts, which are subsequently discussed and conclusions drawn from them. For each section I provide a short comment to clarify the data presented. In all of the responses listed, the numbers of students sometimes vary from the total number interviewed and analysed (34: 26 who visited HartRAO and 8 who visited the planetarium). Where variance occurs, I provide an explanation in the relevant section.

5.7.1 Preparation for, anticipation of and knowledge regarding the visit

The students were going to visit either the planetarium or HartRAO, and the visit was related either to the learning area of natural science (NS) or human and social science (HSS) depending on how the school had implemented the new curriculum. It was pleasing to see that, prior to their visit over 80% of students knew both where they were going and that it related to their school curriculum. After the visit, this figure increased to over 90%.

Nearly 90% of students' views regarding the purpose of the visit related to education or learning. Prior to the visit, without being prompted, only one student referred to 'having fun' as being part of the visit's purpose. After the visit, the number of students who considered the visit was related to learning dropped slightly, while the number who related it to 'having fun' increased markedly. This is likely to have been due to the fact that I asked whether students thought 'having fun' was part of the visit's purpose after they had returned, but was not asked prior to the visit (Table 5.4 and Table 5.5).

Table 5.4 Responses to Question B1 and B2: Where are you going/did you go on the forthcoming visit? What subject and topic area is/was the visit related to?

Visit location and subject/topic	Pre-visit		Post-visit	
	Number of students (n=34)	Percent age	Number of students (n=34)	Percent age
Students who knew where they were going/had gone and what the subject and topic was	27	79	31	91
Students who knew where they were going/had gone and had an approximate idea* of the topic	4	12	0	0
Students who didn't know where they were going/had gone, but knew what the subject and topic was	3	9	3	9
Total	34	100	34	100

* Answers included astrology, experiments and Mars

Table 5.5 Purpose of visit: Responses to Question B3: What do you think is/was the purpose of the visit?

Purpose of visit	Pre-visit		Post-visit	
	Number of students (n=34)	Percent age	Number of students (n=34)	Percent age
Related to education or learning	30	88	31	91
Related to interest in or visualisation of space	4	12	3	9
Related to having fun	1	3	16	47
Not related to having fun	0	0	1	3
Related to Mars	1	3	1	3
Purpose unknown or not answered	1	3	1	3

Several students gave more than one purpose, so the totals do not add to 34 or 100%

Only a fifth of the students reported having done any preparation in class, most of who referred to covering the topics of space, stars and planets earlier in the year (Figure 5.1). However, other than covering the topic in class, no students described any specific activities relating to the visit. There were however six students who did some preparation for the visit *outside* class. Three of these were members of a science club at Bokamoso School who prepared together with a teacher and made a sundial. Two other students did some private reading, and at least one student (Banyana) appeared to have made the effort to prepare for the visit as a direct result of my initial visit to the school, as can be seen from the following exchange:

Interviewer: Okay. Have you been doing any preparation for the visit at school, recently?

Banyana: Of course. I did a little bit of research.

Interviewer: You have. Okay. Did you do that yourself? Or was it done with everybody in the class?

Banyana: I did it myself.

Interviewer: Okay. What did you do?

Banyana: No, umm... We have books at home.

Interviewer: Uh-hmm.

Banyana: About stars, the universe and everything. Because we have sort of like a library so, I just wanted to use it...

Interviewer: Okay. Right. When did you do that?

Banyana: Umm ... I did that after you came to visit.

(swo20preint 17-35)

This is an example of how the research process, although not planned as an intervention, had direct bearing on the pre-knowledge of a student. According to her pre-visit interview Banyana had a strong interest in space, which would also likely have influenced her decision to prepare on her own.

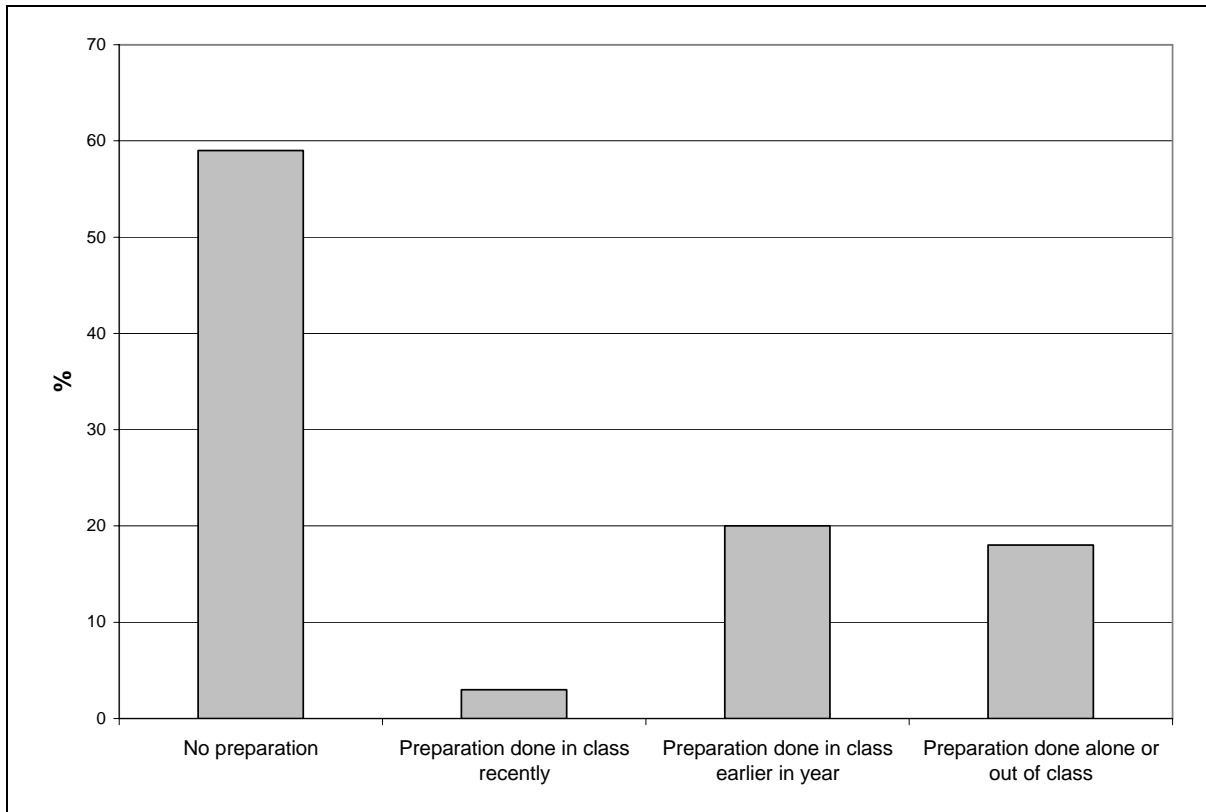


Figure 5.1 Student preparation for the visit (n=34)

All students expressed that they were looking forward to the visit, six of them emphatically so. 16 students (47%) indicated that learning or education was their main reason for looking forward to the visit. By expressing this, they may have been linking the visit to the academic goals of schooling. A similar number (41%) expressed their anticipation in terms of interest, experience or excitement, but did not directly relate it to learning. Only 5 students (15%) referred to the fun or enjoyment of such a visit, and three of these had heard about this aspect from others (Figure 5.2). However, it is likely that the students perceived me as being ‘educational’, and answered me in a way that they thought I expected.

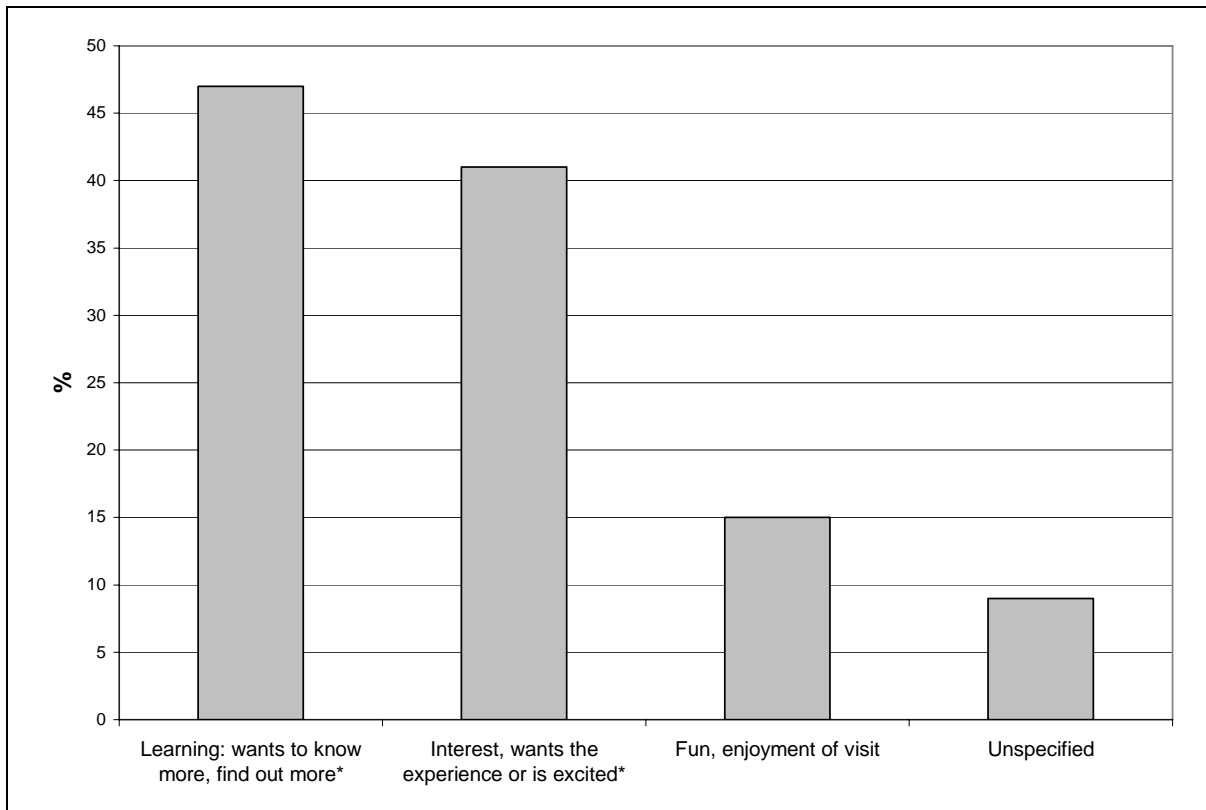


Figure 5.2 Student anticipation of visit.

Some students gave more than one purpose, so the totals do not add to 100%

I asked these initial questions to determine if students knew where they were going on their visit, what subject(s) in their curriculum it was related to, their understanding of the purpose of the visit, the extent to which they had prepared for the visit, and what they were expecting from the visit. The majority of students in my study knew where they were going and how it was related to their school curriculum, indicating that their teachers had given them this basic information. Nearly 90% of students were aware that the purpose of the visit was related to education or learning, which is not really surprising given that the visit is organised by their teachers and is related to their curriculum. It is also possible that students related to me, their interviewer, as a teacher, and gave me that answer they thought I wanted to hear. Very few students (23%, n=34) reported having done any preparation for the visit in class, and none provided any details of what they had been doing. The museum research literature on school visits suggests that very little is done to prepare students for trips to museums and science centres. Griffin and Symington (1997) reported from Australia that out of 12 schools going on excursions to museums, the students involved from 7 schools reported no preparation had taken place (beyond logistical arrangements), while the students from a further 4 schools reported some task-

specific preparation such as handing out of worksheets. Similarly, Storksdieck (2004) in Germany found that in self-report interviews over half the teachers taking students on a visit to a planetarium admitted they did not prepare students for the visit. Yet there is considerable research evidence which shows that preparation for a visit can have a highly positive effect on the students' learning experiences. Kubota and Olstad (1991) showed that preparation by the teacher in reducing the novelty of the visit was effective in improving cognitive learning for the boys (but not the girls) in their 6th grade sample, while Anderson and Lucas (1997) confirmed this for both genders in year 8. Lucas (1999) demonstrated that Mr. Jones' exemplary preparation for his class of 10-year-olds' visit to a science centre was highly beneficial to his students' visit. Although a limited sample, my study supports the research elsewhere that pre-visit preparation for school visits is not regarded as important by most teachers.

5.8 Knowledge about Big Ideas in astronomy prior to the visit

The following questions (from Section C of the Interview Schedule, Appendix B) were intended to ascertain students' prior knowledge about Big Ideas in astronomy as described earlier in this chapter, and to determine whether that knowledge changed as a result of the visit to either HartRAO or the planetarium. The knowledge levels referred to in the discussion are those defined in Table 5.3. Where I have appropriate data I use percentages, while if numbers are low I give the actual numbers.

5.8.1 Gravity

Studies of students' understanding of gravity are prominent in the research literature. Much of this research has been within the subject of physics, and related to students' understanding of gravitational acceleration, often with respect to applied problems (e.g. Bar, Zinn, Goldmuntz & Sneider, 1994; Gunstone & White, 1981; Palmer, 2001). Another strand of research has been with respect to how gravity is understood in relation to the Earth (Nussbaum & Novak, 1976; Schoultz *et al.*, 2001; Vosniadou & Brewer, 1992). A few studies have examined gravity with respect to space and spaceships (e.g. Bar *et al.*, 1997; Treagust & Smith, 1989). There is a degree of overlap in many of these studies, and they identify a number of misconceptions that students and others have about gravity. One prominent misconception is that the cause of gravity is not related to the mass of an object but is due to something else, such as air or the Earth's rotation (Borun *et al.*, 1993; Palmer, 2001). A related misconception that there is no gravity in space has been reported as being

very prevalent among both students and adults. This misconception seems to be associated with the idea that gravity requires a medium in which to operate (usually air), and that since there is no air in space, there will also be no gravity. Several researchers (e.g. Bar *et al.*, 1997; Borun *et al.*, 1993; Moolla, 2003; Watts, 1982) have conducted studies which demonstrate the predominance of the idea. Although the misconception may well be linked to the absence of air, it is likely to be reinforced by images of weightless astronauts in space and spaceships.

In my study, how the students understood gravity was investigated in two main ways. First, students might refer to the word ‘gravity’ in their PMMs, which would normally result in some discussion of it during the interview, by probing their knowledge. Secondly, students visiting HartRAO were specifically questioned on their knowledge of gravity during the structured part of the interview. The initial question they were asked was “What is gravity?” or “Do you know what gravity is?” This was sometimes rephrased, if students initially did not answer, to “What does [gravity] do?” Further questions asked were “Do you know what causes gravity?” “What would gravity be like on the moon?” “What about on somewhere like Jupiter?” “Does the Earth’s gravity have any effect on the moon?” and “Do you think the moon’s gravity has any effect on the Earth?” For each of these questions, depending on the student’s response, further probing of their answer ensued. Students visiting the planetarium were not specifically questioned on gravity during the structured part of the interview because when the interview questions were planned, I did not anticipate that the planetarium show was going to cover gravity in the detail that it actually did. In retrospect, these students should have been asked the same questions as those visiting HartRAO. However, two students visiting the planetarium who referred to gravity in their PMM or the interview based on their PMM are included in the results which follow.

Students showed a substantial change in their overall knowledge of gravity after their visit. Whereas initially over half the students were classified at knowledge level 1, whereby they knew that it is some sort of pulling (or in some cases pushing) force but knew very little else, after the visit this number had dropped to 3. The number of students at knowledge level 2 showed a slight increase (by 2 students) after the visit. However, the number of students at level 2.5 and 3 increased from 2 to 9 students, indicating a considerable shift in knowledge across the group. Only one student did not know what gravity was either before

or after the visit. Figure 5.3 shows students' overall conception of gravity both prior to and after their visit.

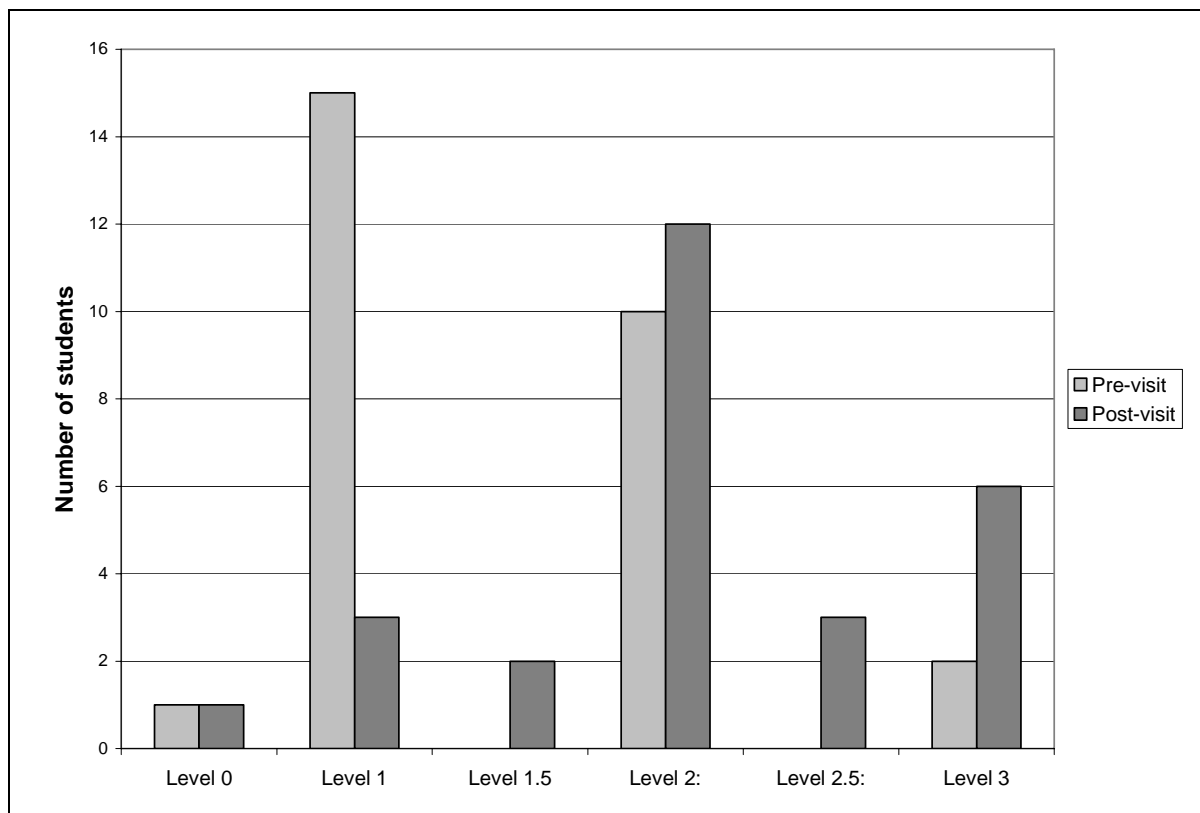


Figure 5.3 Students' conceptions of gravity (Pre-visit: n=28; post-visit: n=27)

Prior to the visit, 23 out of 28 students who were asked specifically gave some sort of definition of gravity during their interview. Of these, 20 gave an acceptable, partial scientific answer (relative to school grade 7-8) to the question “What is gravity?” by stating that it is some type of pulling force. The majority of these students referred to a pull towards the Earth. These ideas held by students are consistent with much of the literature (from Bar *et al.*, 1997; to Nussbaum & Novak, 1976) whereby students identify objects as falling *down* towards the Earth. The 3 students who didn't identify gravity as a pulling force downwards referred to it “pulling you up” to “holding us up”. These notions are not consistent with most descriptions in the literature but may refer to gravity stopping us ‘falling off the Earth’, a common idea in the research literature (e.g. Vosniadou & Brewer, 1992). After the visit the definitions of gravity elicited from the students were not substantially different from those expressed before the visit. I consider it unsurprising that there was little change in students' definitions of gravity, as neither of the study sites discussed the *meaning* of the word gravity, or defined it as a concept.

However, a fuller understanding of the concept of gravity is likely to involve not just the idea that it involves a pulling force, but that a student can expand their definition to involve what causes gravitational force, or how it occurs within the solar system. Students in the study were asked about the cause of gravity during their pre-visit interview only if they had already expressed some ideas about gravity. Despite the prevalence in the literature of the idea that gravity is related to the presence of air (Berg & Brewer, 1991; Palmer, 2001)), only 2 students during their interview specifically spoke about gravity being related to an atmosphere. However, other students stated in their PMMs that in space there is no air and no gravity, indicating a possible relationship between the two. One student stated that gravity is somehow related to rocky planets, and this idea was alluded to by a number of other students who suggested that a gas planet is unlikely to have gravity. Four students stated that they did not know what caused gravity and only three students were able to explain that gravity is related to mass or size. After the visit, only one student thought that gravity might be caused by the atmosphere, while 10 students now were able to explain that gravity is related to the mass (or size) of an object.

Most students who visited HartRAO were asked about their knowledge of gravity on Jupiter and the Moon as shown in Figure 5.4 and Figure 5.5. The number of students in these charts is lower than the total who visited HartRAO as some students did not discuss these issues if they lacked knowledge about gravity generally. Figure 5.4 shows that prior to their visit, the majority of students (12) believed there would be no gravity on Jupiter. Most students did not give reasons for their belief, but those that did ascribed it to the lack of an atmosphere, it 'being in space', or being gaseous. After the visit, there was a substantial increase in the number of students (from 4 to 12) who understood that the gravity on Jupiter is high. The number who said there is no or low gravity on Jupiter decreased from 12 to 8, and the number of 'don't knows' decreased to 3. These figures suggest that the students' visit changed their knowledge about Jupiter's gravity towards a more accepted scientific view.

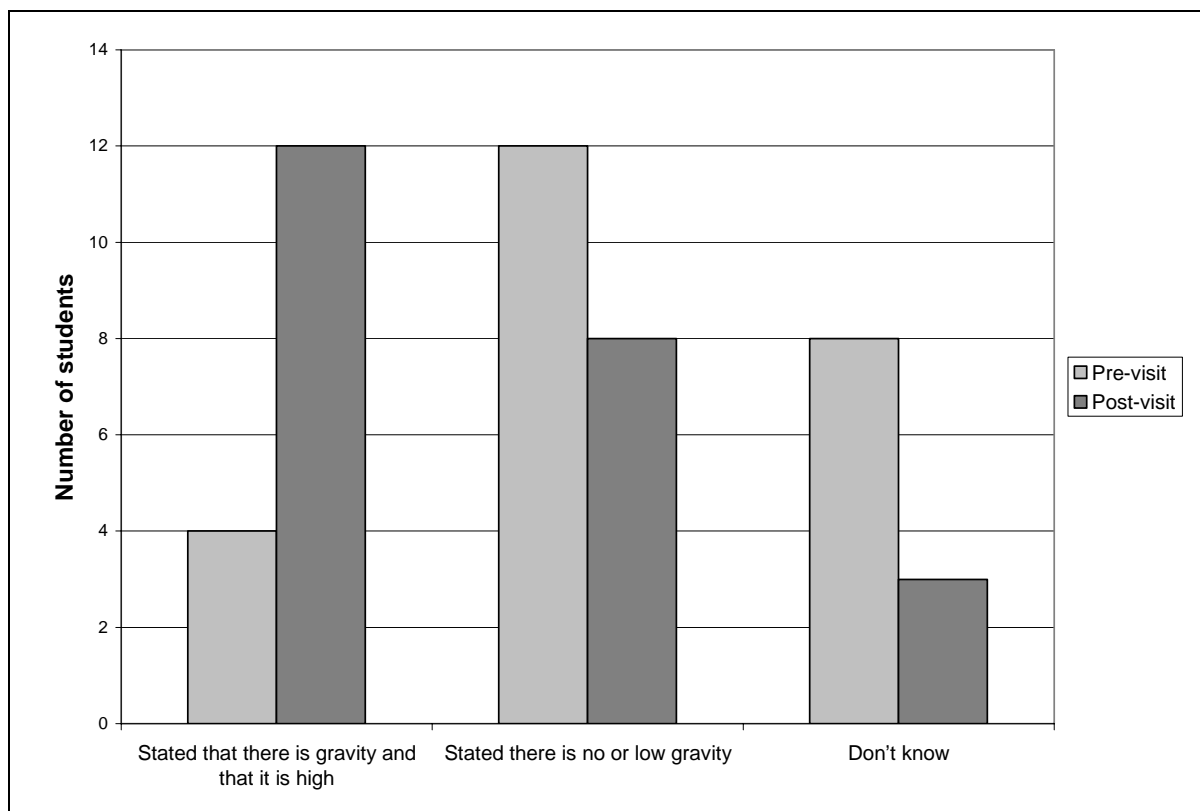


Figure 5.4 Students' ideas of gravity on Jupiter (n=24)

Before the visit, 9 students knew that gravity on the Moon is less than that of Earth, while 12 believed that there is no gravity on the moon, and several of these students referred to being able to 'float' or 'fly' above the Moon's surface. There appears to be confusion in some students' minds between being 'in space' (where many students believe there is no gravity) and being 'on the Moon'. As the Moon is 'in space', there is a conflation between the two, and students may believe that being distant from the Earth, in an environment where there is no air ('space') results in there being no gravity. This misconception is consistent with the literature (e.g. Palmer 2001) and was not necessarily corrected during the visit. After the visit, the number of students who knew that there is gravity on the Moon increased to 19. Similarly, the number of students who believed there is no gravity on the Moon dropped to 5, and the number of students who were uncertain dropped to one (Figure 5.5). These figures indicate that the visit assisted students to change their mind about the absence or presence of gravity on the Moon, and to adopt a more scientific conception. The majority of students who were questioned about the Moon and gravity visited HartRAO. The features of the visit may have accounted for their change in view were likely to have been the Coke can exhibit, the 'gravity scales' and a slide show about

the Moon landings. Six students changed their ideas regarding gravity on both Jupiter *and* the Moon to a scientifically accepted conception.

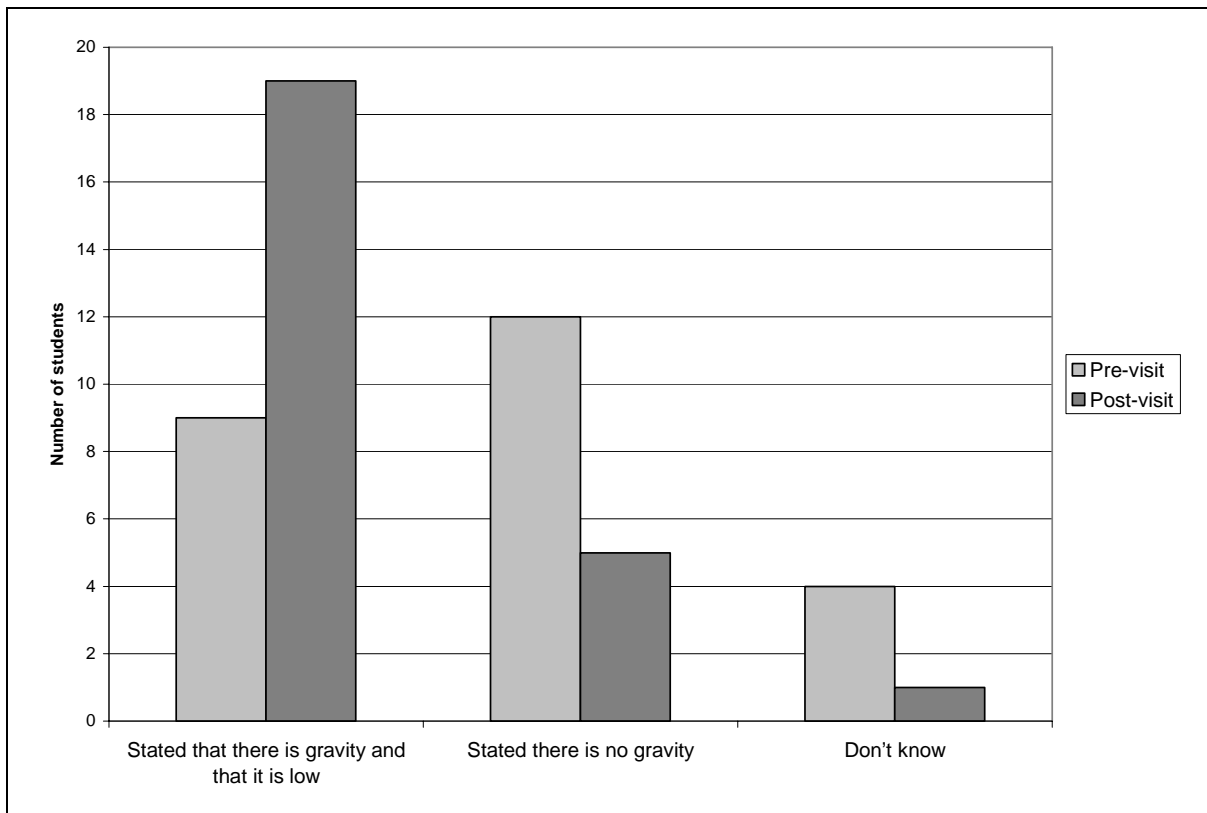


Figure 5.5 Students' ideas of gravity on the Moon (n=25)

5.8.2 Stars and the Sun

The word 'stars' was provided to students on their blank Personal Meaning Map, while 25 students (74%) referred to the Sun of their own volition in their PMM. Prior to the visit, nearly half of the students (44%) had a very minimal knowledge of what a star is (level 1): they typically referred to stars as lights in the night sky, and they had no idea of stars' size, composition or position in space. These students gave no indication that stars are actually suns or that our Sun is a star. Slightly more students did understand that stars are suns (level 2), and they typically gave the definition of a star as a 'burning ball of gas'. However, this category of students possessed various misconceptions about stars in terms of their size, composition or position in space, and examples of these misconceptions can be found in the student portraits in Chapters 7 and 8. Two students (6%) from the same school could give a fully scientific explanation of stars (level 3) with no misconceptions and further elaborated on aspects of star composition. After the visit there was a 20% shift from a minimal knowledge of a star (level 1) towards level 2, while only 1 student

increased their knowledge of stars to category 3. While I cannot determine whether this shift is significant, there is a trend towards an improved scientific understanding of stars, shown in Figure 5.6.

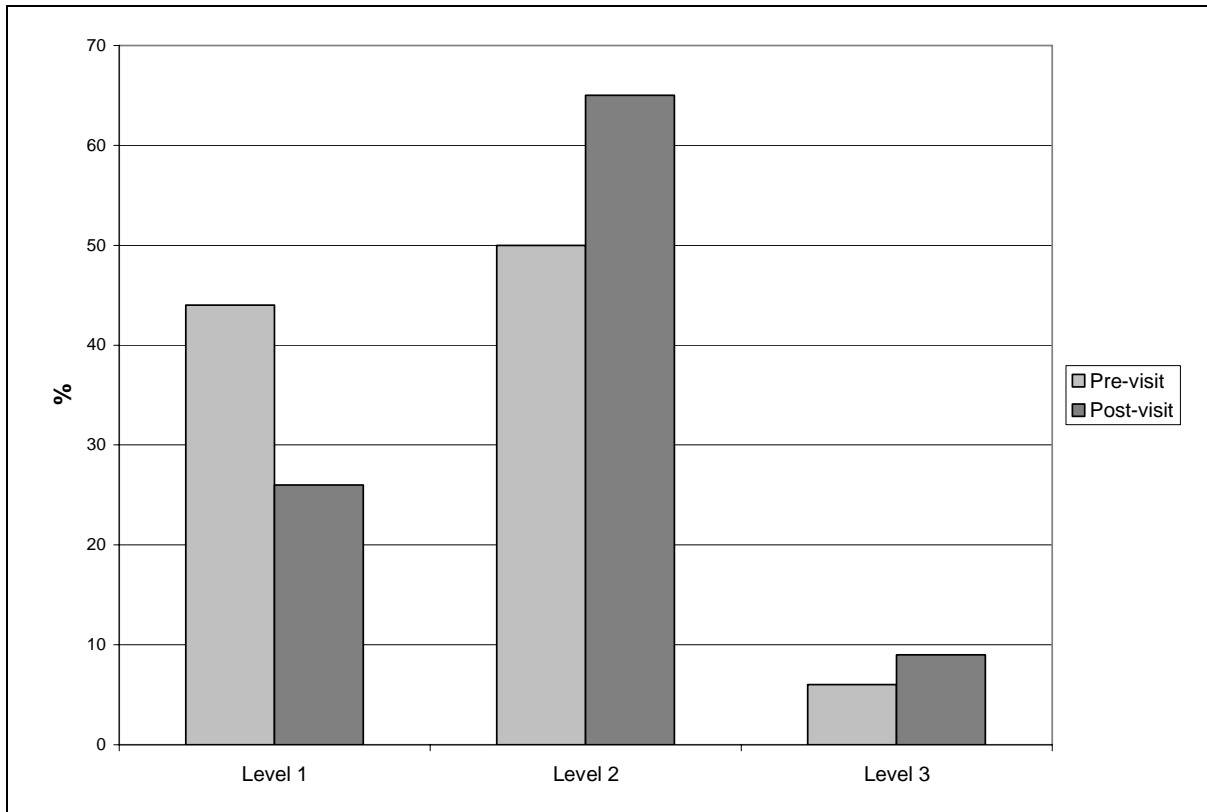


Figure 5.6 Students' conceptions of stars (n=34)

Analysis of students' conceptions of the Sun are based on their answers to questions HartRAO C1 ("how is the sun similar or different to stars?") and C2 (students were asked about the day's temperature, boiling water temperature and the Sun's temperature, before being further asked "What else can you tell me about the Sun?"). Students visiting the planetarium were asked C3 ("Tell me anything you know about the Sun").

Prior to the visit, one quarter of the students had a relatively naïve concept of the Sun (level 1) as bigger and brighter than stars, as occurring during the day and with properties such as being fiery and hot. None of these students referred to the Sun being a star. Half of the students had a more sophisticated scientific idea of the Sun (level 2): as a star, often the biggest star, but no explanation of size as being apparent and related to distance. These students referred to similar properties as the first group, but tended to also include additional scientific facts such as gas, and energy. The remaining quarter of students had substantial knowledge of the Sun (level 3) in relation to scale, as the closest but not the

biggest star. Some of this group also referred to facts about the Sun indicating a more advanced understanding, such as ultra-violet light, nuclear reactions and the Sun's age and future.

After the visit considerably fewer students (9%) held the most naïve conception of the Sun. Compared with the pre-visit results, fewer students (41% instead of 50%) held level 2, while half the students now had the most substantial knowledge of the Sun (level 3). These findings (Figure 5.7) indicate that students showed a more developed understanding of the Sun during the post-visit interviews than they did prior to their visit.

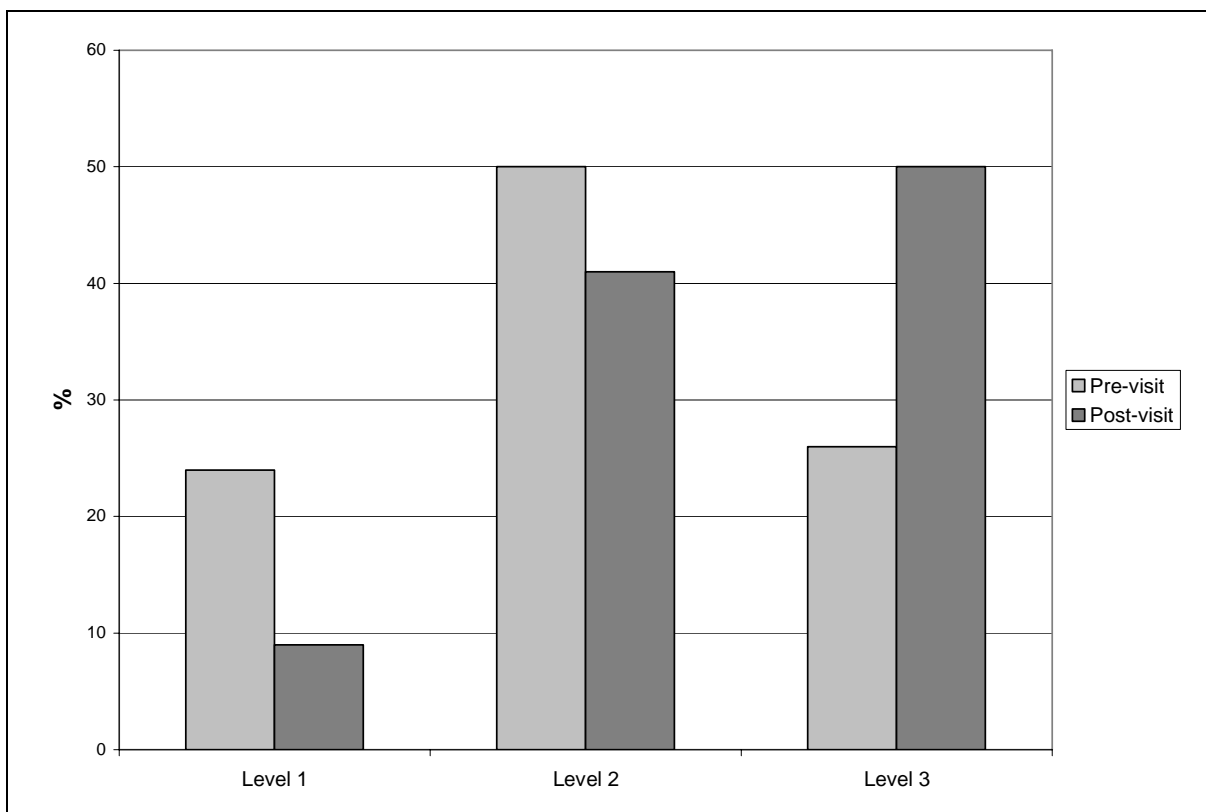


Figure 5.7 Students' conceptions of the Sun (n=34)

Few studies have been reported in the literature about students' conceptions of stars or the Sun (Bailey & Slater, 2003). Sharp (1996) explored the ideas of 42 10- and 11-year-olds in England and showed that most had a basic knowledge of the Sun's shape, composition and position. However, only 57% were sure that it was a star. The same students' knowledge of stars was much less clear, and consisted mainly of observational and stylised descriptions. Comins (2001) indicated that undergraduate students do not understand that the Sun and stars are essentially the same, as well as holding several other misconceptions.

Agan (2004) worked with small numbers of high school and university students in a study of their understanding of stars, and one of her interview questions was almost identical to my C1. My findings for comparable age ranges (12 to 14 years in my study and 14 to 15 years in Agan's research) are similar. Prior to their visit, over three quarters of the students in my study had knowledge of the Sun as a star. Agan's 8 students did recognise the Sun as a star, but believed that it is the biggest star, as did 6 of the students in my study. My students' knowledge of the Sun appeared to be more sophisticated after the visit, showing a greater ability to name sun composition, properties and evolution. More importantly, several students seemed to have gained a greater understanding of scale, as they now related the Sun as being closer than the other stars as the reason that it appears bigger. Agan's senior high school and university undergraduates were able to explain this, but not the students close to the age range of those in my study.

5.8.3 The Solar system

Although both study sites provided students with information about the solar system, only the 8 students visiting the planetarium were specifically questioned about it, but the results from this question are inconclusive probably due to the small numbers involved. All I can deduce from Figure 5.8 is that after the visit there were no students who had *no* scientific conception of what the solar system is, whereas prior to the visit there was one student in this category.

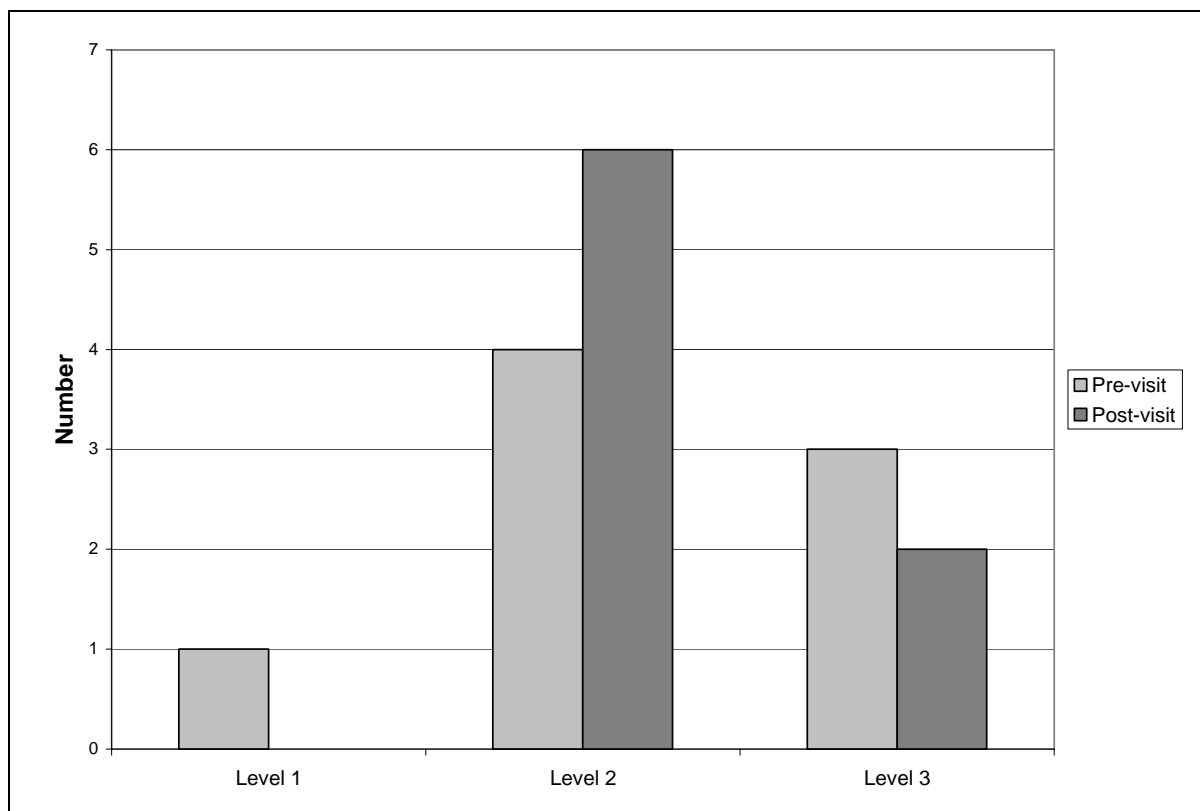


Figure 5.8 Students' conceptions of the Solar System (n=8)

A clearer assessment of what students learnt from the visit is gained from an examination of their PMMs which demonstrate additional facts about the planets, particularly ones such as Mercury (closest to the Sun and hottest), Pluto (furthest from the Sun and coldest), Jupiter (the biggest), Mars (various facts as it had been in the news recently) and the Earth (as the most familiar planet). Both study sites provided this sort of information about the Solar System, so an increase in factual knowledge about individual planets is the most likely outcome. Only 4 students (and one student from pilot interviews) referred to there being other solar systems around other stars after the visit.

5.8.4 Size and scale

Size and scale as a Big Idea is a composite estimation of a student's knowledge of the size of the Sun, stars, the Moon and other heavenly bodies as well as his or her understanding of distance within the solar system and beyond. Students' knowledge and appreciation of size and scale in the solar system (and for some students the universe as well) improved considerably over the period between the pre-visit and post-visit interviews. Students at the lowest level, with confused and conflicting ideas about size and scale decreased from 15% to 6%; only 2 students remained at knowledge level 1, and they both showed the least

change in all the Big Idea categories across the study (see Chapter 7). Students with an apparent scientific knowledge (levels 2 and 2.5) decreased while level 3 students increased from 20% to 48% (Figure 5.9). Since both study sites dealt with various aspects of both size and scale, it is likely that the visit itself was mainly responsible for the change in knowledge, and was successful in doing so. Given that Trumper's work (Trumper, 2001a, 2001b) suggests that this is one of the weakest areas of high school knowledge in Israel, my study suggests that astronomy-related science centres are effective sites to get this type of knowledge and understanding across to students.

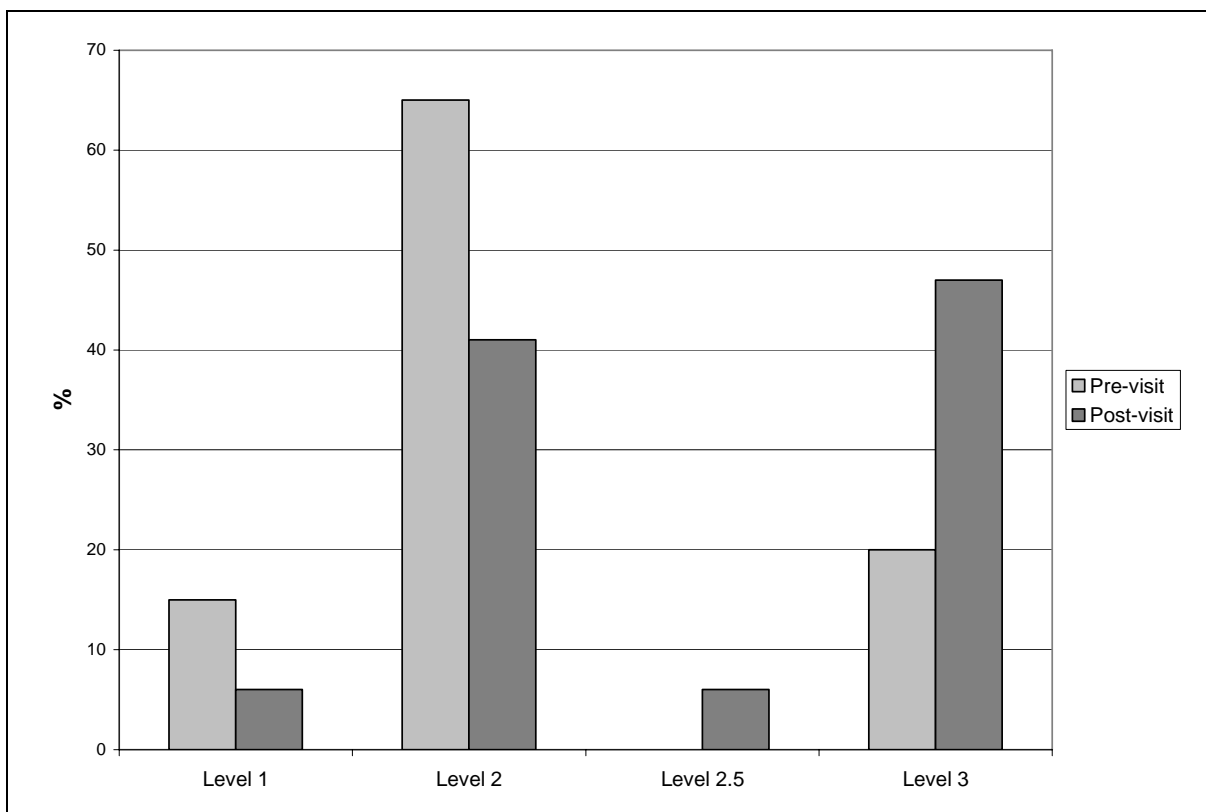


Figure 5.9 Students' conceptions of size and scale

In relation to size and scale, a specific question relating to the relative size of the Sun and Moon and the explanation for this was asked.

Knowledge levels for this question were defined as follows:

<p>Level 1: Does not know relative sizes of sun & moon, thinks moon is larger than sun, or thinks they are the same size. Distance may not have been asked.</p>	<p>Level 2: Relative size of sun and moon is correct, but student does not understand relative distance of sun and moon correctly, or cannot explain the difference in size.</p>	<p>Level 3: Student has correct conceptions of the relative size and distance of the sun and moon</p>
--	---	--

Like a number of other questions (e.g. questions on stars and gravity) I asked this question to determine whether students could not only relate scale and size in the sky, but give reasons for why objects look similar or different in size. Many students do know the difference in size of the moon and the sun, but can they explain why they *look* the same size in the sky? If they can, then they understand more about scale in the solar system. The question only determined the **relative size** of the Sun and the Moon, not the **extent** of the Sun's magnitude in relation to the Moon.

Prior to the visit, just over half the students (19 students, 56%) had a scientifically correct concept of the relative size of the Sun in relation to the Moon (level 3), and could also explain that their apparent similarity in size is due to the fact that the Moon is closer to the Earth than the Sun. Before going on the visit, 12 students (35%) did know that the Sun is larger than the Moon, but could not explain why they looked the same size in the sky in terms of their relative distances from the Earth (level 2). Taking these two categories together, the vast majority of students (91%) did know that the Sun is larger than the Moon, and only 3 students thought that the Moon is larger than the Sun or that the 2 objects are the same size. After the visit the percentage of students in category 3 (scientific conception) increased to 69%, and **all** students could describe the Sun as being larger than the Moon. The percentage of students in category 2 decreased slightly after the visit, and no students remained at knowledge level 1 (Figure 5.10). These results are in line with Summers and Mant's study of British primary school teachers, most of whom knew the relative sizes of the Moon and the Earth (Summers & Mant, 1995).

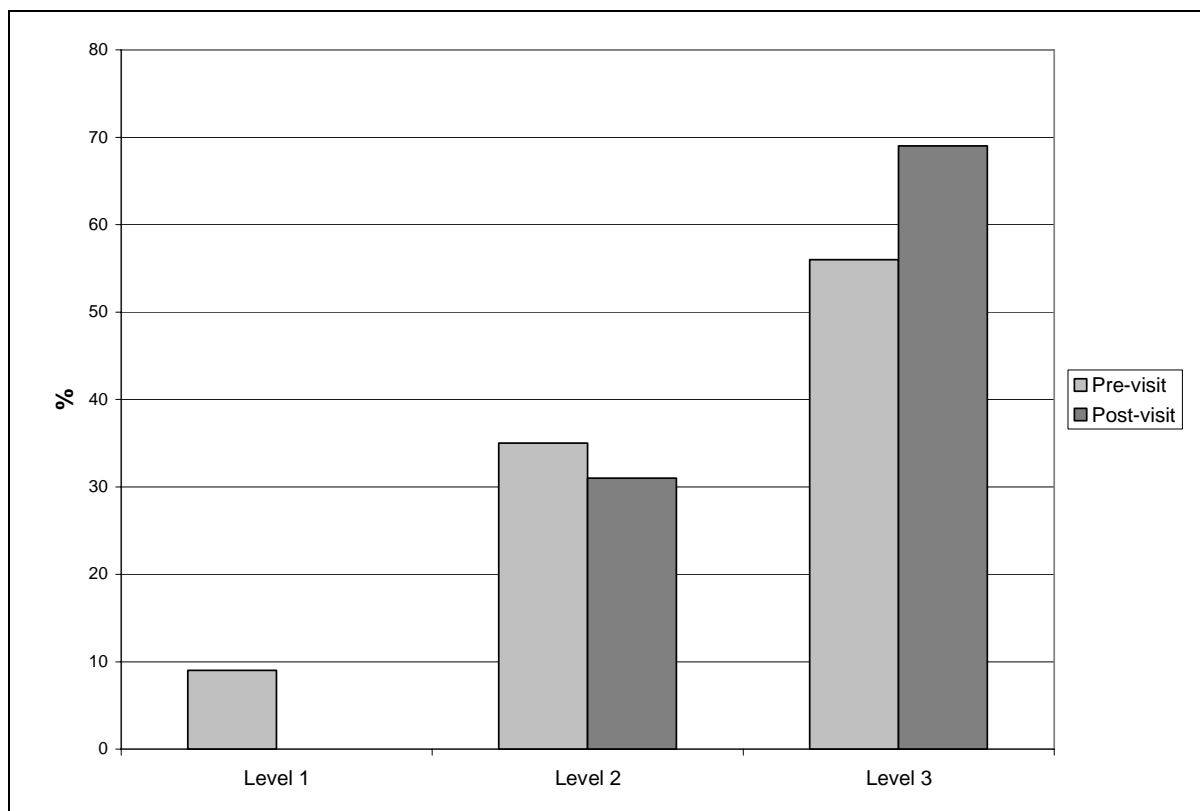


Figure 5.10 Students’ knowledge of the size of the Sun and Moon (n=34 pre-visit, n=29 post-visit)

5.8.5 Day and Night

Understanding the cause of day and night is an important step in understanding how the Earth-Sun-Moon system works. Instead of asking why day and night occur I asked “Why does the Sun move across the sky each day?” to determine whether students could explain the apparent motion of the Sun across the sky as being due to the Earth spinning. However, in discussion with colleagues while analysing my data, I have considered that the question’s phrasing might have prompted a particular type of answer, which I initially classified as teleological¹², and the implications of this are discussed below. After the initial question was asked, I handed each student a model Earth globe and a torch to represent the Sun, and asked them to use these to elaborate on their explanation (“show me what’s happening”) with relevant prompting.

Prior to the visit, 25 of the students (74%) could explain the cause of the Sun’s motion (levels 2 and 3), but of these, 10 (30%) needed the ‘prompt’ of the model in order to explain the concept in an acceptable scientific manner. In knowledge categories 2 and 3

¹² Teleology is a branch of philosophy which ascribes design or purpose to natural phenomena.

four students also used a ‘teleological’ answer as their first explanation of why the Sun moves. Nine students (26%) showed confusion in the explanation of day and night (level 1) even when they had the assistance of the model. This category included students who confused day and night on the model (or maintained misconceptions such as revolution of the Earth around the sun as the cause of day and night) and ‘teleological’ explanations (Figure 5.11).

After the visit, there was little change overall in students’ conceptions of why the sun moves across the sky. While there was a slight increase of students who could explain the Sun’s motion (now 79%), a similar number (32%) still relied on the model to assist their explanation. There was a slight decrease in the number of students who showed confusion in their explanation of day and night, but it is unlikely that this number is significant. As the samples were not randomly selected, it would not be valid to carry out significance tests. The importance of my findings in this knowledge area is that the use of a model as a prompt in the interview process changes student responses, as discussed later in this section.

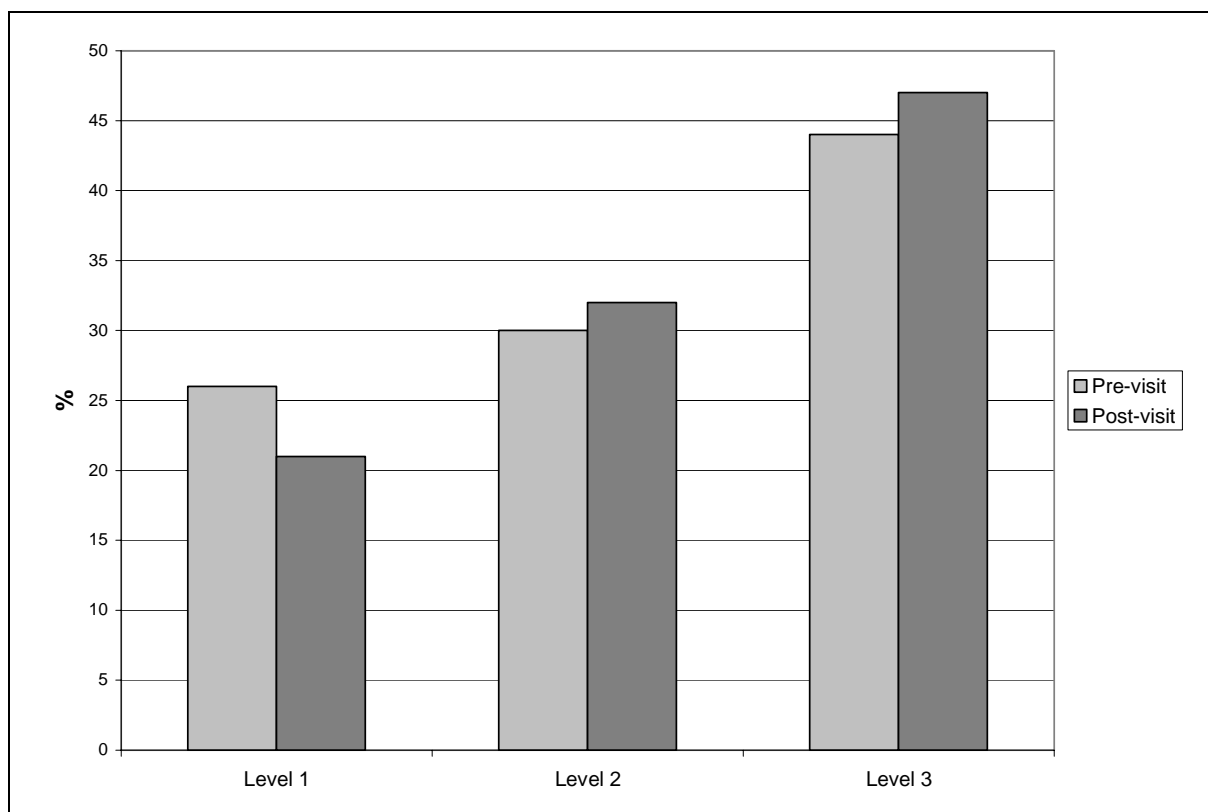


Figure 5.11 Students’ conceptions of the cause of day and night (n=34)

Several studies (e.g. Baxter, 1989; Dove, 2002; Kikas, 1998a; Sadler, 1998; Sharp, 1996) have asked students to explain the cause of day and night, usually as part of a larger study. The most influential piece of research was conducted by Vosniadou and Brewer (1994) in which they postulated a series of mental models held by children ranging from age 6 to 11 years. All the 16 peer-reviewed studies used test questions, questionnaires or interviews to elicit information from their subjects, often encouraging them to draw diagrams. Only three used models as part of the interview process. The intention of my asking the question in the way I did was to try and determine whether the students could relate direct observation of the Sun ‘moving’ across the sky to the concept of the Earth spinning. During each interview, after asking the initial questions, I showed the student a model of the Earth (a small globe) and handed her or him a small torch, which I said represented the Sun. I then invited the student to expand on what he or she had already said, but now using the model. I also probed as necessary, to determine the student’s own understanding of what she or he was explaining. In asking the question, I deliberately avoided referring to the *apparent* movement of the Sun across the sky, as I considered that this would cue the students towards a scientific rather than their own explanation. In my initial coding, I identified a type of explanation which I classified as ‘teleological’, whereby the student explained the reason why the Sun moved across the sky as being ‘in order to do something’, such as to give light or heat to the people on the other side of the Earth. Originally propounded by Plato and Aristotle, current adherents of teleology are mainly religious believers who argue that the purpose in nature can be attributed to the presence of a Supreme Being or God.

Although I consider that several statements made by students can be considered teleological, it is possible that the question “Why does the Sun....” was interpreted by some students to require an answer in which the Sun’s movement **does** have a purpose. However, when presented with a globe and asked for a further explanation, students understood this cue to mean that they now had to give an explanatory answer, which they accordingly did. As shown in Figure 5.11, prior to the visit nearly half the students were able to explain the apparent cause of the sun’s movement as being due to the Earth’s rotation without the use of the model as a support for this explanation. I regard it as important that such students were able to explain in scientific terms without the use of the model (and yet could also use it correctly to assist their explanation). The most interesting group of students were the ones (10 before the visit and 11 after the visit) who started their

explanation in a somewhat confused manner, and it was only when the model was available that they could provide the scientifically acceptable explanation of day and night.

For example Lara, in her pre-visit interview gave an explanation for the sun's movement as the Earth's revolution. As she is not presented as a portrait in Chapter 7 or 8 I show the transcript of her interviews here.

Lara: It's the Earth that's revolving around the sun.

Interviewer: Okay.

Lara: Which causes it to rise and [inaudible]

I then introduced the model, and asked her to explain the phenomenon using it:

Interviewer: Okay. So, if you have the sun here and that's the sun [the torch], you hold that. What's going on for the every day rising and setting?

Lara: The Earth is moving like this. No, yes, I'm right. And then the Earth rotates and then every year the Earth revolves

(scf10preint 61-69)

At this point the student, by manipulating the model is realising that while the Earth does revolve around the Sun, it also rotates. Further probing results in the student realising that the Earth's rotation is the cause of the Sun's apparent movement (day and night), and not its orbit.

Less than a quarter of the significant studies on students' and teachers' understanding of day and night reported in the literature used models as part of their data collection process. A recent paper by Schoultz *et al.* (2001) criticised Vosniadou and her associates for failing to use a globe when questioning children about the Earth and gravity (Vosniadou and Brewer 1992). Using a situated and discursive framework, Schoultz *et al.* claim that the introduction of a globe to an interview results in substantially different responses from children (ages 7 – 11) than in the Vosniadou study in which the children had to think abstractly. Schoultz *et al.* show that the children's conception of the Earth as a globe and gravity as an "explanatory resource" (p. 114) are more prevalent in young children than Vosniadou had found. Schoultz's findings have been criticised by Candela (2001) for excluding a cognitive explanation, and very recently Vosniadou has rebutted the claims made by Schoultz and colleagues. Vosniadou *et al.* (2005) conducted a study of grades 1 to 3 using a globe to represent the Earth. While they admit that the presence of the globe can assist with children's thinking, they consider that it can bias the results of the study, by providing a ready-made conception of the Earth.

In my study of children several years older than those studied by Vosniadou or Schoultz, I found that the presence of the Earth-Sun model was a valuable tool in the interview process. By the time children reach the age of 12 years, a globe would be the accepted ‘cultural artefact’ to represent the Earth. Therefore, the findings for my study are for children significantly older than those in the Vosniadou and Schoultz studies and can neither confirm nor disprove the claims of either side. What my results show however, is that the use of a model as a ‘prop’ to discuss the relative motion of the Earth and the Sun is very valuable, as it directs children’s thinking to respond to the question asked, rather than abstractly discussing the notion of the Earth’s orbit round the Sun, which seems to be the first thing respondents refer to when asked about day and night.

Parker and Heywood (1998) and Cameron (2003) have referred to the confusion of orbit and spin and the terms *revolve* and *rotate* by the participants in their studies. Parker and Heywood were working with pre-service primary teachers, many of whom admitted to being conceptually confused between orbit and spin, and used a variety of words such as *move round*, *goes round* and *turns*. 20 of Cameron’s 54 university students used the terms *rotation* and *revolution* incorrectly, these terms appearing to be more widely used in the South African context than orbit and spin. Similar confusion was prevalent in my study. In answer to “Why does the Sun move across the sky every day?” Sarah responded as follows:

- Sarah: Because our Earth revolves.
Interviewer: Okay. Can you show me with this? [hands student model] This is the ... There is the sun. Can you hold the sun up? What’s going on?
Sarah: The Earth is turning.

Here Sarah uses the term ‘revolve’ but actually means rotate. Having initially used the incorrect term, she then correctly uses the model to demonstrate night and day:

- Interviewer: Okay. So if Africa is facing the sun like that [student is pointing torch at Africa on the globe]. What’s on ...? What’s going on now in Africa? At this point.
Sarah: It’s daylight.
Interviewer: It’s daylight. Right. And the other side of the Earth?
Sarah: It’s night.
(scf12preint 117-133)

The importance of this confusion, whether it is conceptual confusion between orbit and spin or confusion of terms (rotation and revolution look and sound similar, which may

present difficulties for second-language English speakers) is that it has implications for researchers who use questionnaires (or interviews without a model present) to determine subjects' understanding of the day/night concept. There is considerable further potential room for confusion. Eight students (24% of the sample) used the phrase 'rotating around the sun', which could mean that the Earth rotates (on its axis), while it is orbiting the Sun. It doesn't necessarily mean revolving around the Sun. One student also used the phrase 'surrounding the sun', meaning the Earth goes round (orbits) the Sun. These examples demonstrate that educators and researchers need to be very careful in both their use and interpretation of what students mean when they express themselves. An example is Summers and Mant (1995), who asked a series of true/false questions which included *The Sun goes round the Earth once in 24 hours* and *The Earth moves around the Sun once in 24 hours*. While only 7% of the teachers agreed with the first statement, 32% agreed with the second. Although this appears to indicate that the teachers believe the Earth revolves around the Sun once a day, causing day and night their answer may merely represent confusion of the terms and not a misconception of how day and night occur.

5.8.6 The Moon Phases

Research into people's knowledge of the Moon's phases is extensive in the literature which shows that while subjects can describe the phases they do not necessarily know the order in which they appear or why they occur. Although I asked all students about Moon phases in the pre-visit interview, I only questioned 19 students about it after the visit, so the results are limited. Prior to their visit, only five students (15%) were able to give a satisfactory scientific explanation for the Moon phases (level 3), in which the sun's rays shining on the Moon as it revolves around the Earth was explained. A further four (12%) could give a partial scientific explanation (level 2.5), but these students also included a misconception in their explanation, such as the idea that the views of the phases are due to the Earth's rotation. The 7 students (20 %) at knowledge level 2 had either a limited explanation (2 students) or referred to misconceptions about the phases: either the Earth's shadow falling on the Moon (2 students) or something coming between the Moon and the Earth resulting in the Moon being 'eclipsed' (3 students). Over half the students (53%) did not know the cause of the Moon phases (level 1) and were prepared to state this (Figure 5.12).

Of the 19 students asked about the Moon phases in the post visit interviews, there was little difference in students' ability to explain the phases of the Moon. Neither of the

study sites discussed the phenomenon in any detail, so the lack of change in knowledge is to be expected.

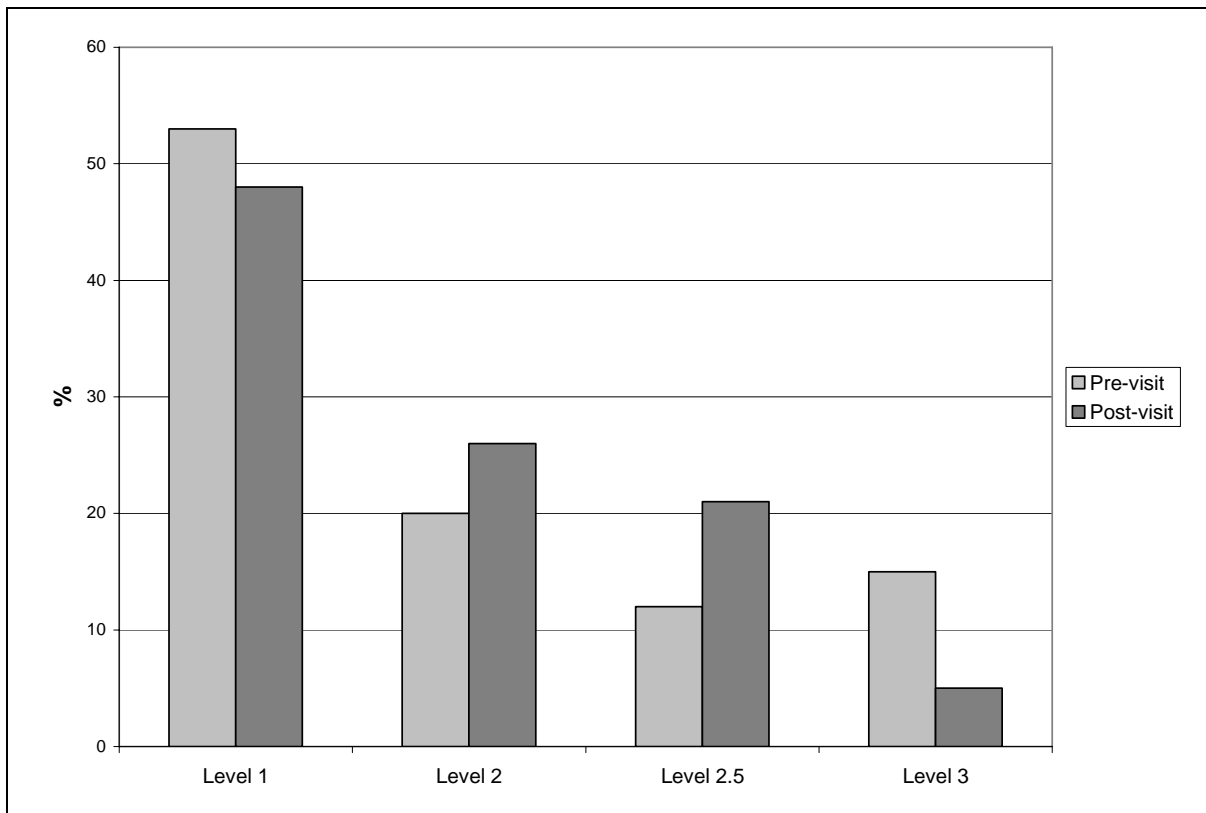


Figure 5.12 Students' explanation of Moon phases (Pre-visit n=34; post-visit n=19)

5.8.7 Parabolic/Satellite Dishes

Due to the physical dominance of satellite and parabolic dishes and the activity on 'whisper dishes' at HartRAO, I thought it appropriate to ask students about them. Prior to their visit, nearly half the students had a limited knowledge of satellite dishes (levels 1 and 1.5): they did not know where a dish might point towards, and had little or no idea of the reason for its shape. 38% could *either* explain the reason for the shape of the dish *or* where it might point to but not both (level 2), whereas only 4 students (15%) had a more sophisticated knowledge (level 2.5 or 3) of dishes (Figure 5.13). After the visit students had developed in several knowledge areas, with fewer students at the lower levels and nearly half who could explain where the dish points towards and the reason for its shape (though 19% needed probing to detect this knowledge). Most of students' prior knowledge of satellite dishes comes from their experience of seeing such dishes on buildings used for satellite television. Students who appeared to extend their knowledge as a result of the visit

are likely to have done so due to the activity using the whisper dish as well as observing the radio telescope pointing to stars in space.

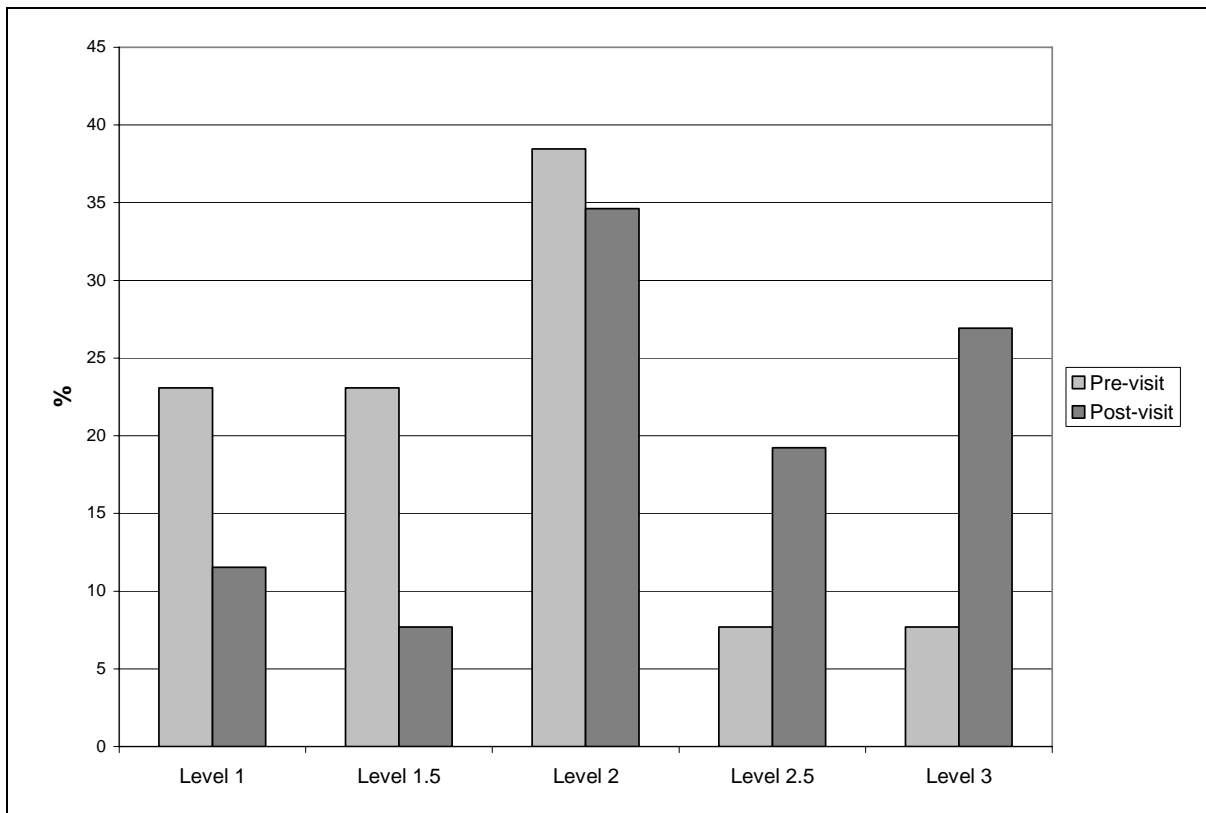


Figure 5.13 Students' conceptions of parabolic/satellite dishes (n=26; only HartRAO students)

5.9 Summary of collective learning

For the 5 main Big Ideas (gravity, stars, Sun, Solar System, size and scale) there is a shift from level 1 towards levels 2 and 3 between the pre- and post-visit interviews (Figure 5.14). Broadly, this suggests that students changed their knowledge of Big Ideas from a less to a more scientific notion. In the cases of gravity, stars and the Solar System the shift was most marked from level 1 to level 2 (more than 15%). In the cases of the Sun and size and scale the shift was greater towards level 3 (more than 15%). However, the Solar System was based on relatively small numbers of students and interpretation of changes in level should be approached with caution.

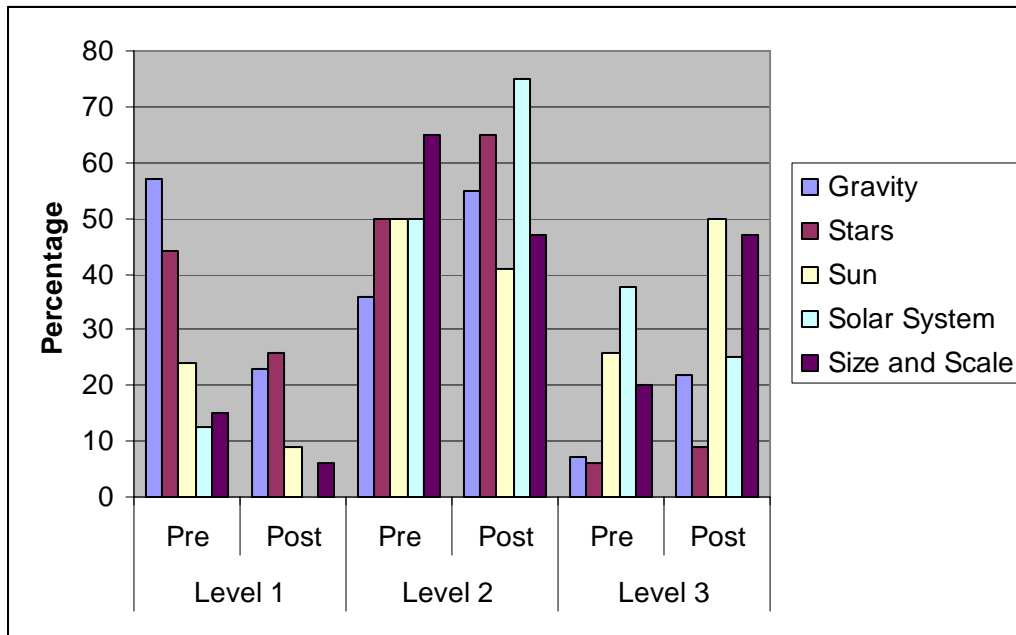


Figure 5.14 Summary of percentage changes in levels for 5 Big Ideas

The changes in knowledge level for the two significant ideas of ‘day and night’ and the Moon phases, as well as the dominant artefact the satellite dish are shown in Figure 5.15 which shows a similar trend to that of Figure 5.14, although the shifts involved for day and night are less marked than those for the 5 main Big Ideas. The Moon phases show a shift from level 1 to level 2, but no shift towards level 3.

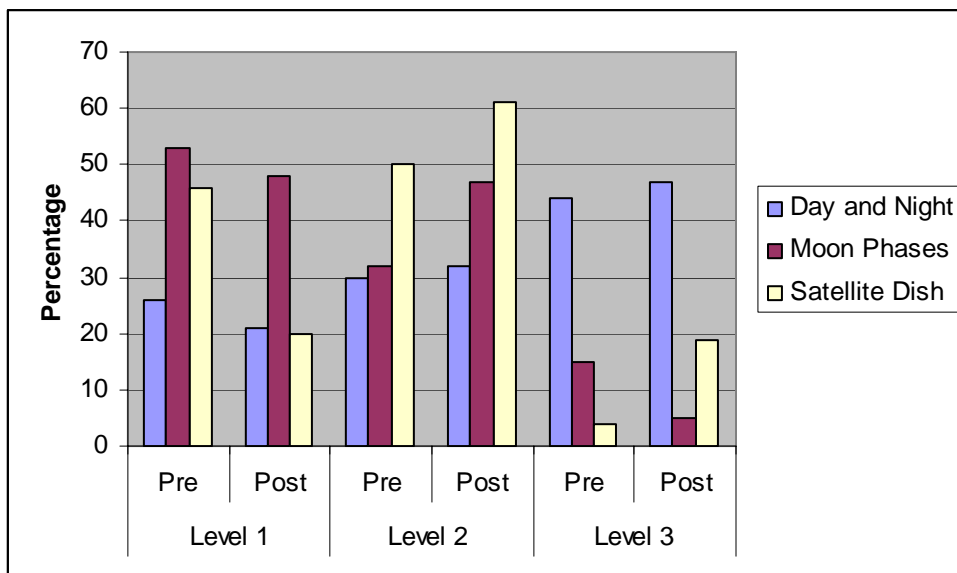


Figure 5.15 Summary of percentage changes in levels for significant ideas and dominant artefact.

These shifts suggest that (at the least) short-term increases in students' knowledge have occurred between the pre- and post-visit interviews, and that it is likely that the visit itself was responsible for the change. My results confirm the findings of other researchers such as Anderson *et al.* (2000) and Lucas (2000) who have also noted changes in knowledge due to science centre visits. However, these Australian studies also involved post-visit activities conducted by teachers with students on their return to the classroom, not available to the students in my study. Falk and Dierking (2000) also relate various evaluation studies they have conducted that demonstrate increased learning by visitors on exiting museums.

The findings presented in this chapter answer my first research question "To what extent do students learn in the process of a visit to a planetarium and the visitors' centre of an astronomical observatory?" They demonstrate that learning does occur over the course of a visit, and that in the case of some Big Ideas (particularly gravity, stars, the Sun, size and scale, and the satellite dish) the learning itself is significant. In terms of science literacy, the lower dimensions ("knowing a lot of science") of Durant (1993) and Shamos (1995) are being addressed by both the planetarium and HartRAO.

However, in addition to determining *what* is learnt during a visit, my intention in this thesis is to demonstrate *how* knowledge is acquired. The following chapters return the reader to the theoretical framework of human constructivism which underpins the study, analyse the theory in terms of the cognitive, affective and conative domains, and present analyses of learning by selected students.

Chapter 6

6 A Human Constructivist Analysis of Learning

“That people learn in museums is easy to state, harder to prove” (Falk and Dierking 2000). Using Human Constructivism as a framework for identifying how learning can occur, this chapter demonstrates a typology of learning at my study sites. Combined with the notion of Big Ideas from Chapter 5, it provides a framework for categorising the students according to their degree of learning about astronomy.

6.1 Introduction

Chapter 4 provided a context for my study, showing the visits to the planetarium and HartRAO from the viewpoint of two students. It also presented some findings from the study in narrative form, enabling the reader to gain some insights into how students experience a visit to a science centre. Chapter 5 provided detailed findings of what students collectively learnt, showing that the majority of them were able to increase their knowledge and understanding of Big Ideas in astronomy after their visit. Although Big Ideas were used as an organising tool for compartmentalising the astronomy knowledge, the concept knowledge levels I identified in Chapter 5 were derived from the data, using inductive coding of the Personal Meaning Maps and interview transcripts. While this method was satisfactory for finding out **what** students learnt, it was not so easy to tell **how** students were learning. I therefore drew on my theoretical framework of Human Constructivism, and used categories of learning previously identified by other researchers to classify how students learnt during the course of their visit. In other words, while I used bottom-up coding to identify what students were learning, I used top-down coding to ascertain how they learnt. Henning (2004) states that “the true test of a competent qualitative researcher comes in the analysis of the data” (p 101), and suggests that the design logic of the study needs to relate to both the forms of analysis and the actual data collected. This chapter describes how I analysed individual students’ learning and attempts to explain what sort of mental processes are taking place as the learning occurs. The chapter introduces categories of knowledge construction informed by the theory of human constructivism, gives examples of these groupings from the data, and ends by referring

back to Big Ideas to demonstrate how portraits presented in Chapters 7 and 8 were selected.

6.2 Human Constructivism and Conceptual Change

In Chapter 2 I described how constructivism is a powerful theory which underpins much current thinking about learning in museums. From a cognitive perspective, I identified one variation of constructivism, Human Constructivism (HC), which attempts to explain how people acquire scientific concepts by a combination of gradual accretion of knowledge as well as significant knowledge restructuring (Mintzes & Wandersee, 1998; Novak, 1988). Using the HC notions of subsumption, superordinate learning, progressive differentiation and integrative reconciliation which were described in Chapter 2, as well as Anderson's conceptions of knowledge 'transformation' (Anderson 1999, Anderson *et al.* 2003) I analysed my data to identify possible HC categories which could explain how the students in my study were learning concepts associated with astronomy at the study sites. However, as part of this analysis, I was mindful of Novak's learning principle 8 which refers to the idea that "thinking, feeling and acting are integrated" (Novak, 1988 p. 93), as well as subsequent research on the role of the affective and conative in conceptual change during informal learning (Alsop & Watts, 1997). Using these human constructivist and conceptual change studies, I devised a coding system accounting for cognitive, affective and conative processes which is shown in Table 6.1.

Table 6.1 Knowledge Construction categories defined in my study

Code Name and description	Domain of 'learning'	Code Antecedents from the literature
Addition – a concept which is new knowledge to a learner, incrementally added.	Cognitive	Addition (Anderson 1999, Anderson <i>et al.</i> 2003) Subsumption (Ausubel <i>et al.</i> 1978, Mintzes <i>et al.</i> 1997, Pearsall <i>et al.</i> 1997)
Emergence – a concept which emerges from a learner’s memory as a result of a subsequent experience.	Cognitive	Emergence (Anderson 1999, Anderson <i>et al.</i> 2003)
Differentiation – a process of modification of concept meanings.	Cognitive	Progressive Differentiation (Ausubel <i>et al.</i> 1978, Mintzes <i>et al.</i> 1997, Pearsall <i>et al.</i> 1997, Anderson 1999, Anderson <i>et al.</i> 2003)
Discrimination– demarcation of similarities and differences among closely related concepts	Cognitive	Merging (Anderson 1999, Anderson <i>et al.</i> 2003) Integrative Reconciliation (Ausubel <i>et al.</i> 1978, Mintzes <i>et al.</i> 1997, Pearsall <i>et al.</i> 1997)
Recontextualisation – the understanding of a concept modified by a changed context, but “with no significant clarification of meaning” (Anderson <i>et al.</i> 2003)	Cognitive	Recontextualisation (Anderson 1999, Anderson <i>et al.</i> 2003)
Superordinate Learning – a new concept learnt which links to other concepts already part of a learner’s cognitive structure	Cognitive	Superordinate Learning (Ausubel <i>et al.</i> 1978, Mintzes <i>et al.</i> 1997, Pearsall <i>et al.</i> 1997)
Enjoyable – the extent to which the learning experience is enjoyable	Affective	Palatable (Alsop and Watts 1997)
Germane – the extent to which the learning experience is personally relevant	Affective	Germane (Alsop and Watts 1997)
Salient – the extent to which the learning experience is prominent or important in the learner’s environment	Affective	Salient (Alsop and Watts 1997)
Wonder – the extent to which the learner is in awe or amazement	Affective	Not described
Conative - the extent to which the learning experience is put into action, is controlled or trusted by the learner.	Conative	Action, Control, Trust (Alsop and Watts 1997)

In their study of informal learning about radiation and radioactivity, Alsop and Watts (1997) proposed a new model for conceptual change which involved 4 ‘lenses’ through which the learning could be observed: the cognitive, affective, conative and self-esteem. As I explained in Chapter 2, I have replaced Alsop and Watts’ cognitive categories (which were taken from the Strike and Posner model of conceptual change) with categories derived from human constructivism. I have retained Alsop and Watts’ affective and conative lenses, but my data collection methods did not lend themselves to meta-awareness to enable me to use the self-esteem lens. Initial explanations of the lenses were discussed in section 2.8.3 and I now describe each of the categories listed in Table 6.1, with examples of data from my study corresponding to each code. Throughout the remainder of this thesis I shall refer to this framework as the Human Constructivist model.

6.3 Cognitive Domain

6.3.1 Addition

Like Anderson (1999) and Anderson *et al.* (2003), I found that students acquired concepts which were apparently new to them over the course of my study. By comparing the pre-visit PMMs and interviews with the post-visit data, students appeared to have taken up new knowledge after the visit, at least some of which was directly as a result of the visit itself. Human constructivism has used the term subsumption for this process, which has its antecedents in Ausubel’s meaningful learning (Ausubel *et al.*, 1978). I explained the process of subsumption in 2.8.2.1, and would prefer to use Anderson’s simpler term of *addition*, as it captures the essence of what appears to be occurring in the student’s cognitive structure: students are assimilating or *adding* new concepts to their existing knowledge without any major restructuring process. Addition was by far the most common form of learning observed in my study, two examples of which are as follows.

Brenda’s PMM shows several changes from the pre-visit to post-visit, including what I coded as 11 examples of addition. A small portion of her post-visit PMM is shown in Figure 6.1, with the additions highlighted.

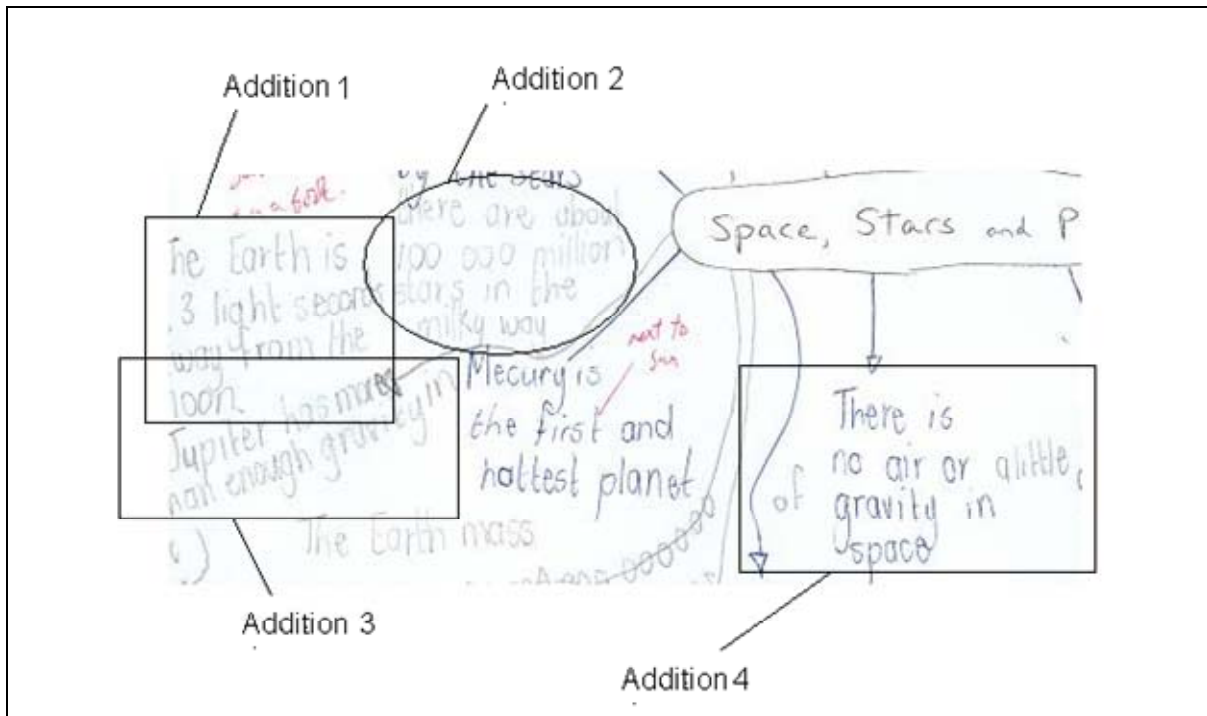


Figure 6.1 Part of Brenda’s post-visit Personal Meaning Map

Addition 1: Brenda has added a fact about distance – that the Earth is 3 light seconds from the Moon.

Addition 2: Brenda has added the fact that there are about 100,000 million stars in the Milky Way.

Addition 3: Jupiter has more than enough gravity [in it].

Addition 4: Originally in her pre-visit PMM she wrote “There is no air or gravity in space”. In her post visit PMM she changed this to “a little of” gravity in space. All four of these additions demonstrate new facts that Brenda has learnt during the visit.

The other example is from Siphos interview. In his pre-visit interview, Siphos view of stars was relatively naïve, thus:

Siphos: They are also something like fire in the night ... That makes a little bit ... Shines so that it must, the Earth must not be totally dark.....They are made from the sun. They are little pieces that are coming from the sun.

(swo05preint 126)

However, in his post-visit interview, Siphos had additional knowledge about stars:

Sipho: Stars are some are things that, are objects that are made with gases and other things, with hot gases which also are very hot also like fire, also the same as the sun.

(swo05posint 075)

The fact that he now could describe stars as being made of hot gases was an indication that he had acquired some additional knowledge about stars. In the first quotation he referred to stars as pieces coming from the Sun, in the second quotation he described them as being the *same* as the Sun.

6.3.2 Emergence

This category of knowledge construction was identified by David Anderson in his study and was not described by previous researchers using HC (Anderson *et al.* 2003). When students are tested or questioned prior to a visit to a science centre, there is likely to be considerable knowledge in their mind about a phenomenon that they are not aware of, and they do not refer to. During the visit, their experiences remind them of previously-learned knowledge, and after the visit they are able to refer to this knowledge when questioned. The key difference between emergence and addition is that students retrieve emergent knowledge from their memory, whereas addition refers to knowledge not previously known or remembered. This category of ‘emergence’ corresponds to other HC processes, in that knowledge is retrieved from the student’s memory and is structured together with the new-experience knowledge. This is likely to result in more substantial learning, as the previously-learned knowledge is affirmed by the new experiences. Martin Storksdieck suggests that this in fact is the commonest way in which people learn in museums, he suggests that visitors learn “by revisiting previously known information, by bringing previous but currently embedded knowledge to the forefront of their attention, thereby briefly “activating” this knowledge that was hidden in their long-term memory” (Storksdieck, 2004 p. 10). However, although this may apply to adults who have a greater amount of knowledge stored in their long-term memory, this is less likely with children, and both Anderson’s and my study suggest that addition is the commonest way in which children learn.

Examples of emergence were found in a number of students in my study, the most prominent being John, who on several occasions referred to being reminded of things he had learnt about before:

Interviewer: you said the trip reminded you of those things. Tell me a little bit about that.

John: Ja they reminded me of some of the things that I was thinking about like I remembered the red giant was huge in size, it has way more mass than our size and as the one lady said, she said that our sun couldn't have a supernova because it's too small compared to those other stars and then the the white dwarf, it's small in size and it spins faster. Quasar, I just remember when I used to remember I remember it because I looked it up in the dictionary so I could find out because I was reading about it and I still didn't get it and it said huge source of energy, lights, heat and that's sort of round red giants star.

(vho16prepm 03)

In my study I have categorised knowledge as having emerged only when students specifically state that the visit “reminded” them of something they previously knew. The distinction between addition and emergence was not always clear-cut, and this issue is discussed further in section 6.7.

6.3.3 Differentiation

Ausubel's original description of the process of progressive differentiation was “The process of subsumption, occurring one or more times, leads to *progressive differentiation* of the subsuming concept or proposition” (Ausubel *et al.*, 1978 p. 124 emphasis in original). This suggests there is an overarching concept in the learner's mind which becomes modified or changed as a result of the addition of new (subsumed) concepts, and indicates that there is a hierarchical relationship between progressive differentiation and subsumption. More simply, Anderson refers to progressive differentiation as a clarification of concept meanings (Anderson *et al.*, 2003), and in his paper does not attempt to identify hierarchies between concepts. In line with more traditional HC thinking I prefer to use the term differentiation (without the adjective *progressive*) to refer to modification of an overarching concept, for example Siphos knowledge of the Sun. Before his visit to HartRAO Siphos stated that the Sun is the biggest star, and didn't know what we can use the Sun for. However, after the visit his knowledge appears to have been modified substantially as shown:

Siphos: `The sun. The sun it is a star and it is born and also dies then after 500 billion years the sun will die and explode to be hundred times bigger than it is then it will have to swallow two planets which are Mercury and Venus.

Interviewer: Anything else about the sun you can tell me?

Sipho: I can say the sun is not the biggest star in our solar system, but there are other bigger sun, but the sun gives us more heat. The sun looks more bigger because it is the nearest star so the other stars look very, they are so far so they look you think that they are small, but they are not. Some of them are even more bigger than the sun.

(swo05posint 031 & 047-051)

In this sequence Sipho discusses the idea of the Sun's life history as well as the fact that it is not the biggest star, but the closest (although he makes the error of referring to our Solar System). Both of these ideas were covered during the visit to HartRAO and it is very likely that he differentiated his knowledge of the Sun directly as a result of the visit. His error in referring to the Sun not being the biggest star in our Solar System was fairly common in the study, with students confusing the concept of Solar System with galaxy.

I consider that the crucial difference between the processes of addition and differentiation is the extent to which new facts are integrated into a coherent whole (in the case of differentiation) or remain as isolated facts (in the case of addition). In differentiating their knowledge students are able to show a greater degree of understanding of a concept.

6.3.4 Discrimination

Human constructivists refer to this process as integrative reconciliation, but I here introduce the term *discrimination* as I consider it better captures the essence of the process. In the case of discrimination, students begin to outline similarities and differences among associated concepts. The example given by Pearsall and associates in fact comes from astronomy: they suggest that integrative reconciliation occurs when "individual learn about differences and similarities in the atmospheres or Earth, Venus and Mars for example, their knowledge structures become more interconnected, integrated and cohesive" (Pearsall *et al.*, 1997 p. 196). Anderson identifies *merging* as what he calls a similar process to integrative reconciliation in his study, where 2 or more separate conceptions are merged to provide an explanation of a newly encountered phenomenon. I did not encounter examples of merging in my study, and I question whether his process of merging is in fact very similar to integrative reconciliation. The process of merging conceptions is quite different from identifying similarities and differences between associated conceptions.

A common example of discrimination in my study was when students began to identify similarities and differences between the planets of the solar system. For example

Fatima and Judy referred to the planet names and a few facts about the planets in their pre-visit PMM. However, in their post-visit PMM they both distinguished between the inner rocky planets and the outer gaseous planets, as well as other similarities and differences between them. Another example was when students could discriminate between the different sorts of stars according to their size, density and other characteristics. According to HC theory, discrimination promotes linkages between learners' knowledge structures which enables more substantial knowledge construction.

6.3.5 Recontextualisation

Anderson identified the process of recontextualisation in his study where a student modified a concept as the result of the visit, but did not significantly clarify or add to his or her meaning of the concept – the concept was merely described in terms of the new context. It is distinguished from differentiation by the fact that meaning (even if erroneous) is not enhanced. Like the category of emergence, this code was developed by Anderson and has no equivalent in previous HC research.

I found relatively few examples of recontextualisation in my study. One example is Kitso who in her pre-visit interview explained how the Sun 'rotates around the Earth'. She repeated this idea in her post-visit interview, and, using the model Earth and Sun:

- Kitso: It's the biggest star. It provides light to the Earth and it rotates [said slowly] around the Earth [said as though memorised, in a sing-song way].
- Interviewer: Okay. Umm. So why does the sun move across the sky every day? What's going on there?
- Kitso: Because the sun, it rises. What? The sun rises and it sets. So, it moves. Because ... Isn't it ...? It... That's how life is, because there's the time. So, it's in the morning the sun rises and then.
- Interviewer: Okay. Show me what's going on here [showing Kitso the model]. If we're in Africa there, what's going on if that is the sun? What's happening? The rising and setting.
- Kitso: That is Africa, right, so, ... Umm, let's see...
- Interviewer: Show me how the sun rises and sets.
- Kitso: No wait, the sun rises from the... The sun sets from.... The sun comes this side, I know (/). So it's when it sets, so then ... Oh, yes, then this side it's night time then the ... so, as the sun is moving from Africa, we experience ... Like night time is coming now, fourish, fivish, and then it comes like this, then this part ...
- Interviewer: The sun goes around the other side?
- Kitso: Yes.
- [Student appears to demonstrate that the sun moved round the Earth].

(scf17posint 069-087)

In this case, she has not clarified her knowledge about the cause of day and night, and the HartRAO context appears to have produced uncertainty in her thinking.

6.3.6 Superordinate Learning

According to most reports of HC research, superordinate learning is an important concept of the learning process in individuals. It is therefore striking to note that Anderson and associates in their paper on theoretical perspectives of learning ignore it as a category of learning transformation. Further, they simplify the concept map of HC (Figure 2.2) presented by Mintzes and Wandersee (1998), and misrepresent the position of superordinate learning as resulting from subsumption. They also draw ambiguous linking lines between progressive differentiation and integrative reconciliation and superordinate learning. This makes it unclear whether progressive differentiation (and integrative reconciliation) results in superordinate learning or vice versa. Ausubel provides the simplest definition of superordinate learning: “An inclusive new proposition (or concept) is learned under which several established ideas are subsumed” (Ausubel *et al.*, 1978 p. 59). The principal feature of this category is that a new concept is learned which includes other concepts, some of which may already be known. In HC terms this involves strong restructuring in the brain in order to make sense of the new information learnt. Mintzes *et al.* describe superordinate learning as follows: “A new more general and inclusive concept is linked to more specific concepts already a part of the learner's cognitive structure; for example when students learn that visible light and radio waves represent different frequencies of electromagnetic energy” (Mintzes *et al.*, 1997 p.420). In some ways superordinate learning corresponds to Piaget’s equilibration, where a new balance is struck between existing knowledge and new evidence received from experience (Roschelle, 1995).

I found few examples of superordinate learning in my study. I think this is because I was dealing with relatively familiar concepts such as the Sun, stars, space and planets, which the study participants already had some knowledge about, from previous school learning. The possibility of them learning a completely new concept is therefore relatively unlikely; they are more likely to differentiate or discriminate existing concepts by a process of addition or emergence. However, I show two contrasting examples. The first involves Kitso, who appears to have gained a completely different understanding of the

planets. She tries to describe her previous understanding, and goes on to explain that her new understanding of what a planet consists of was a radical departure from her previous knowledge:

Kitso: What actually changed isthe planets. Because I thought planets No, ...I thought they were just a place. I didn't think of it as in I don't know which planet it is, but it's got soil but the soil is not so good to plant in and everything but I never thought that planets would have such things, y'know? I just thought ... It was one of those places where there was a whole lot of gravity and you see nothing, so Yeah, I've learnt like maybe the soil and most probably there's more to it and some of the planets are very colourful and bright. Quite attractive.

(scf17posint 143)

The second example is of a student learning how to tell time using a sundial. In a series of interview probes, Batsile describes how he experienced the demonstration of the sundial at HartRAO:

Batsile: I told them everything which they heard and how that we can measure time.

Interviewer: Tell me about that.

Batsile: It's that there are, the problem is I forgot the names

Interviewer: Don't worry about the name, just describe it, just tell me.

Batsile: It shows there are hours, months, ja there are hours, days and nights and time, you see we have to put it, the time only start at 5 ja at 5 and I don't know when it ends and then you have to put it on the month or in the middle of the month.

Interviewer: What do you put on the month?

Batsile: There's a steel which you have to put on the month and it will show what time is it.

Interviewer: It's a stick you put on the month?

Batsile: Ja.

Interviewer: Okay and then how does it show the time?

Batsile: By the shadow.

Interviewer: Shadow okay, shadow of the stick. So it will work when the sun is shining.

Batsile: Ja only when the sun is shining. The only problem which I don't get it's winter. I didn't really ask the question but I don't get it at winter there's no sun because how do you get time?

(swo53posint 250-274)

This student had no idea previously that the Sun can be used to tell time, and explains in some detail how this is done. He previously knew about the Sun as a star, and giving light and heat to the Earth. He also had some knowledge about the relative movement of the Earth and Sun, though he showed some confusion regarding this in his post-visit interview.

However, he used these existing concepts to link to a new concept of the Sun as a clock, providing an example of superordinate learning.

6.4 Affective Domain

For several years researchers have noted the importance of the affective domain in learning both in the formal schooling environment (e.g. Alsop & Watts, 2003; Hargreaves, 1996) and in museums (Dierking, 2005; Ramey-Gassert *et al.*, 1994). In my study I identified 4 categories in which students expressed different attitudes and degrees of interest and excitement towards the topic of astronomy and their visit to one of the study sites. When examining individual students in the portraits in Chapters 7 and 8 I have combined the different affective categories into one for the sake of clarity.

6.4.1 Enjoyable

In this category I identified anything the student enjoyed or disliked about the visit or topics they referred to in their interview. Alsop and Watts identified a similar category which they referred to as *palatable*, in which they determined “how agreeable how savory the material is” (1997 p. 639). However, the notion of enjoyment was a clear feature of the school visits in my study, as well as the enjoyment of a subject or topic at school. Two of my interview questions were “What things did you most enjoy/like most about the visit?” and “What did you dislike about the visit?” so I almost always heard about specific aspects that students liked or disliked. However, some students also referred to enjoyment when asked about anything they had thought about after the trip or anyone they had told about the trip. For example Fatima referred directly to enjoyment:

Interviewer: Okay. Umm. Other than today ... have you thought about the trip since?

Fatima: Yes, I did.

Interviewer: What do you think?

Fatima: I thought it was very interesting because I learnt more things and it's just very nice going there. I enjoyed it.

(scf15posint 145)

6.4.2 Germane

This category was adapted from the same element as Alsop and Watts (1997): they referred to *germane* as being the extent to which something is personally relevant. I used the code when students were able to say **why** they were looking forward to going on the trip, why they might have an interest in astronomy as well as whether they thought their ideas about

space had changed and how much they had thought about the visit after return. Any of these thoughts suggested an aspect of astronomy or the visit which they found to be of particular interest to themselves. For example after the visit Caroline described what she had told her mother and brother. From this I infer that the activities she described had some importance for her:

Interviewer: No. Okay. When you came back have you told anybody about the visit since?

Caroline: Yes. I've told my brother, I told my mom.

Interviewer: What did you just tell me one or two things you actually told them specific things you told them about.

Caroline: I told them we went to go see this satellite and moved and my friend and I ... we walked away. I told them little jokes every now and again and I told them about the rocket and the things we did and all that.

(vho11posint 227-233)

6.4.3 Salient

Although similar to the category of germane, this code was used by Alsop and Watts to refer to “how prominent, or arresting [a topic] is within the learning environment” (1997 p. 639). I used it where students could refer to an issue in the media or their environment which they identified as noticeable or important. For example in his pre-visit PMM Siphon wrote that “Last year the science people discover the other planet which was the smallest planet in the universe and that means we have 10 planets in our universe” (swo05pre 20) . Here, the student is referring to a recent development in astronomy that he has heard about, although he is confusing the term universe with solar system.

6.4.4 Wonder

A fourth category within the affective domain that I identified was that of wonder, where students showed amazement or awe at something they had learned about. This category is not referred to by Alsop and Watts, and while it may be similar to the category of germane, wonder shows a greater degree of incredulity or astonishment. For example Thapiso's response is typical of many students:

Interviewer: No. Okay. Is there anything you saw at Hartebeesthoek that really surprised you or changed your idea about space or planets?

Thapiso: It's like when like there were different kind of scales on the floor. When you like you can measure yourself, the weight of yourself in different planets and ja it was amazing because I didn't know that we can even measure ourselves even though we're here on Earth. (swo59posint 170)

The four categories described here constitute the affective lens through which I viewed student utterances about their experiences related to their visit. The importance of the affective domain for learning cannot be underestimated, and although empirical studies into the role of affect are relatively few (Alsop and Watts 2003), research in science education needs to move away from the notion that cognitive, affective and psychomotor functions are all separate and able to be compartmentalised. Advocates of affective study hold a view that “affect surrounds cognition”, and needs to be investigated as part of science education in the classroom, especially “at a time when students in the West are moving away from science” (Alsop and Watts 2003 p 1046). Disenchantment with science appears to be a worldwide phenomenon (Sjøberg, 2000) so the need for studies of affect is just as true for under-developed countries as for developed ones. Studies of affect in the informal science education environment are even rarer than those in the classroom. Dierking (2005) provides some recent evidence for the importance of affect in museum environments, and the portraits of students described in Chapters 7 and 8 of this thesis show how important it was in the visits to the planetarium and HartRAO.

The general category of affect relates to another typology I referred to in Chapter 2, that of scientific literacy. Shen (1975) referred to a level of scientific literacy that enables the person to appreciate (and possibly criticise) the achievements of science. Elements of the affective dimension of knowledge construction enable learners to appreciate aspects of astronomy and therefore ‘improve’ their level of scientific literacy, which according to Lucas (1983) and Rennie (2001) museums are uniquely positioned to do.

6.5 Conative Domain

Conation involves the desire to perform an action, and together with cognition and affect forms the three components of mind (Hilgard, 1980; Huitt, 1999). It relates to the intentional aspect of behaviour and the freedom to make choices about action (Mischel, 1996). The conative domain is similar to Strike and Posner’s notion of “fruitfulness” within their cognitive conceptual change model (1985), but emphasises the idea of action to a greater extent. In their study of villagers’ understanding of radioactivity, Alsop identified three factors which shaped how the participants related to the topic: action, control and trust (Alsop, 2000; Alsop & Watts, 1997). I have used similar categories to identify how the students in my study could potentially use their knowledge of astronomy for a purpose, but have combined the three factors together as my data did not support a

separate category of “*control* they perceived information allowed them” (Alsop, 2000 p. 204) or learners’ *trust* in their own understandings. In my study I used the category when it was clear that students actually carried out an action related to the topic of astronomy, for example some students used their visit experience to follow up directly on something they had been given or told about, such as Tlotlo who made her own home-made water rocket:

- Tlotlo: Ja, I did. I tried the water rocket, because it ... ja ...
- Interviewer: You did.
- Tlotlo: Ja. I liked it so I did it at home.
- Interviewer: Did you manage to. Did it work?
- Tlotlo: Ja, it worked.
- Interviewer: How did you get the parts, the right parts to put it together?
- Tlotlo: No, you know what I did I took a 2 litre bottle and a pump, I did that and it just. It’s like I put water then I just made the pump there and then ...it went high.
- Interviewer: Did you show anybody else?
- Tlotlo: Ja I showed my friends.
- (tsw02posint 025-057)

Similarly, some students identified that humans have the potential for action with respect to current discoveries that are being made. For example Nnaniki referred to the fact that “We can do research to see if we can live in one of the planets e.g. Mars” (tsw15pos 9). Similarly, I have adapted the idea of *trust* to include the extent to which student believe in both scientific and other knowledge systems such as religion and astrology. How students grapple with non-scientific beliefs can affect the extent to which they will accept the scientific knowledge which is the focus of the presentations at both study sites. For example in some students the visit brought out a conflict in their beliefs, such as Brenda:

- [Interviewer: And I can’t remember if you told me, are you religious? Do you go to church and stuff?]
- Brenda: Ja I do go to church.
- Interviewer: What do you think God has to do with the planets and space and sun?
- Brenda: Since I went to the trip it’s very complicated because from what I’ve learnt in HSS the world started as a small, tiny little thing and the water, that was written by I don’t know who something Darwin, but in the Bible it says it’s Adam and Eve and then comes the planet and all. I think it’s a lot complicating.
- Interviewer: Hmmm. So you’re not really sure.
- Brenda: Ja I’m not sure. I don’t know which one to believe, the Bible or evolution or something.
- (swo70posint 245-249)

In order for students to think more deeply about the relationship between their religious beliefs and scientific aspects of the Solar System and universe, I consider that the science centres themselves should assist this process. Just as constructivists use ‘discrepant events’ and ‘critical moments’ in science lessons to force students to confront their own misconceptions (Chinn & Brewer, 1993; Koballa, n.d.), so science centres can identify areas of astronomy and cosmology which support or conflict with religious beliefs. This might enable students to begin thinking about deeper issues of their own upbringing and culture in relation to the science that has been presented.

6.6 Coding for Human Constructivist categories

Using the cognitive, affective and conative domains I developed categories of student knowledge based on the human constructivist framework described in this chapter and shown in Table 6.1. I coded each student’s PMM and interviews using the categories as a typology of learning, highlighting every phrase or utterance which could be classified as an example of knowledge construction. I provide an example of such coding from the ATLAS.ti program in Appendix E. To ensure rigour in my analysis I asked another researcher to re-code a selection of my data based on the categories I had defined in Table 6.1. She initially found this a difficult process mainly because she was not familiar with the terms and concepts involved in human constructivism. Although at the start our congruence in coding was only 72%, discussion of the categories and theory of HC enabled complete agreement between us by the end of the process. I provide a brief reflection on the process of inter-rater reliability in section 7.3.

6.7 Problems encountered with the coding process

Whereas the coding system I developed for Big Ideas was an inductive process derived from the data, the procedure I followed relating students’ learning to human constructivism was deductive, fitting observed data to a pre-conceived theory. On the basis of observations and field notes made at my study sites I considered there was a close fit between human constructivism and the types of processes in learning that I observed during the visits. Inevitably, there were times when data observed appeared not to fit the categories described in HC, and this resulted in my adaptation of existing categories and the development of new ones. Further, there were times during the analysis when it was difficult to classify students’ utterances into categories. For example, in some cases, it is possible that what I have categorised as addition may be emergent knowledge that students

were either not aware of themselves, or did not voice as being something they knew before. Much of the time, knowledge categorised as addition is clearly new knowledge, for example all four of Brenda's addition examples in Figure 6.1 are facts that were referred to at HartRAO. There is a very strong likelihood that she learnt these facts directly as a result of her visit. However, there are cases where it is more difficult to tell, for example when I did not specifically probe students on their sources of information. Although I often asked whether students knew about a particular piece of knowledge prior to their visit, I did not always do so. In these cases, it is possible that information coded as addition may in fact have been emergent. Similarly, the interview questioning was sometimes not sufficiently probing, especially with reticent students, to later determine the extent of their knowledge construction. In order to reduce the effects of these coding difficulties, I discussed some of the cases with colleagues to determine whether my categorisations were valid. I also presented my work-in-progress to research forums at my university and regional conferences while my analysis was proceeding, to enable me to be as objective and impartial as possible.

The other main difficulty associated with coding was related to human constructivism and metacognition. Metacognition refers to the ability of people to consciously reflect on their learning. The literature suggests that although a form of metacognition has been identified in children as young as 5 years old (Larkin, 2000) it normally develops slowly until the age of 12 years, and is influenced by the learning environment and the extent to which it is consciously developed (Berk, 2003). There is evidence that South African students do not have well-developed metacognitive abilities (e.g. Case & Gunstone, 2002; van der Riet, Dison & Quinn, 1998) and I did not devise my interview questions to investigate metacognition. However, conceptual change and human constructivism both rely to some extent on the ability of the learner to reflect on their own learning, and if I had probed more carefully for metacognition during the interviews I might have found additional evidence for how students were learning at the study sites.

Despite the problems encountered in the coding process, the processes of credibility and trustworthiness that I described in Chapter 3 and discussed in this chapter demonstrate that the analysis of my data was rigorous enough for me to make the claims that I put forward in subsequent chapters. The following two Chapters, 7 and 8, consist of portraits of seven students who show a range of learning. The chapters attempt to show not only

what the students learnt about aspects of astronomy, but also how they learnt, and how their prior knowledge and interests affected their learning.

Chapter 7

7 How individual students learnt about astronomy (1)

This chapter describes the learning shown by four students who visited the Hartebeesthoek Radio Astronomy Observatory. Each of these students showed different levels of prior knowledge, and the portraits demonstrate the extent to which this affected their learning at the science centre.

7.1 Introduction

In order to demonstrate how learning occurred in my study, I present a number of portraits of students, with their learning described in cognitive, affective and conative terms. Using Table 7.1 I have selected portraits as characterising each of the categories of student learning in terms of Big and Significant Ideas. Having presented and discussed how learning occurs in each of these students, I will demonstrate how students' prior knowledge and interests have influenced their learning. I will then discuss the implications this has on learning at science centres such as those used in this study.

7.2 The Schools

7.2.1 Balfour Forest School (BFS)

Originally built and run as a school for white students only during the apartheid era, in 1990 Balfour Forest was declared a 'Model C' school, whereby it had some autonomy from the provincial department of education over its affairs, and was run by a Board of Governors. The school closed as a 'Model C' in 1993, and reopened as a normal public school the following year with 420 students, none of whom had stayed on from the old school. By 2003 there were 570 students (grades 1 to 7), and 18 teachers. This is a 'Section 21' school, which means that the School Governing Body was granted permission by the Provincial Department of Education to control their own finances. In 2003 the fees were R1600¹³ per annum. The class teacher, Mr. Peter Malomba had booked for the two grade 7 classes to visit Hartebeesthoek Radio Astronomy Observatory on 24 October. However, as discussed in Chapters 3 and 4, only the students who paid for the trip were allowed to go.

¹³ \$US 200 at exchange rates prevalent in 2006

In class 7x, out of a total of 36 students, 16 returned informed consent forms, and only 10 of these actually participated in the trip. Of the 39 students in class 7y, 21 signed consent forms, and 20 of these took part in the visit. During analysis of the results of my study I tried to get the academic results of the students who participated, but due to a stolen computer at the school and other related problems I did not manage to obtain them. It has not therefore been possible to relate learning at the science centre to students' overall academic achievement.

7.2.2 Lourdes Girls School (LGS)

This is a private Catholic school situated in the Western suburbs of Johannesburg. In 2003 there were 300 girls from grades 1 to 12, with 160 from grade 8 to 12. The school fees in 2003 were R1200 per month. The class teacher, Ms Charlene Pell had booked for her grade 8 geography class of 21 students to visit the planetarium on 14 October. 16 participated in the visit, all of whom completed the PMM, and I chose 8 students to interview prior to and after their visit. I later obtained academic results for all students in the class, and was able to compare their results with their learning as a result of the visit.

7.2.3 Achievement School (AS)

This private school started in 1997 as a primary school run on Christian principles, and has, due to pressure from parents, extended into the secondary sector. I visited the school at its old premises during 2003, but it moved to new and larger premises in 2004. Although students are required to wear uniform, it is relatively informal, consisting of a blue navy T-shirt and denim jeans. Class sizes are relatively small; the class I visited consisted of 16 students (seven boys and nine girls), but the classroom, due to the compact nature of the premises was cramped for this number. The class teacher, Mrs. Irene Baldwin, was also the teacher of the topic on space and the solar system, which was completed in term one 2003. 14 of the 16 in the class signed consent forms, and all of them went on the visit to HartRAO on 20 October. Eight of these students were chosen for interview.

7.2.4 Bokamoso School (BS)

This is a 'Middle School' (grades 7 to 9) in a township North-West of Pretoria. Under apartheid the township was developed for SeTswana-speaking people, and most of its inhabitants remain so today. The school opened in the early 1980s, and is a feeder school to a nearby secondary school. The students participating in the trip to HartRAO consisted

of the science club, and anyone who was prepared to pay the fee for the visit was allowed to go. I met with 18 grade 7 and 8 students on 7 November, all of whom completed their PMM, and selected 5 for interview. They visited HartRAO on 17 November, and I returned to re-interview on 3 December. However, as it was near the end of term, only 7 students attended the post-visit session, and I re-interviewed only 4 students. I was unable to obtain academic results for 2003 for the students. Several students in the Science Club entered the Southern Skies astronomy competition, and two won prizes, one of whom (Botho) was part of my sample.

7.3 Big Ideas and Individual Learning

In order to examine students' individual learning using a Human Constructivist framework I used my analysis of students' knowledge of Big Ideas in astronomy as a basis for categorising them as individuals. Instead of categorising their *collective* knowledge of concepts as shown in Chapter 5, I produced a summary of each *individual's* knowledge of Big Ideas, the results of which are shown in Appendix F.

For purposes of improving research rigour, I asked a colleague knowledgeable about astronomy and experienced in teaching and researching basic astronomy to assess the extent to which I had allocated students correctly into their pre-visit and post-visit knowledge categories. She examined data from five students and agreed with 83% of my categorisation. Those she initially did not agree with we discussed and reached a consensus. In addition, a teacher experienced in the teaching of basic astronomy who has also done some research in the area also assisted in the validation of my allocation to categories. The inter-rater reliability between her and myself was 78% for data from six students, with the main area of disagreement being in the dominant artefact of the parabolic/satellite dish. This turned out to be differences in interpretation of categories 2 and 3. Again, with discussion we reached a consensus of nearly 90%, and I am satisfied that my own coding is reliable. Some qualitative researchers such as Henning (2004) are highly sceptical of the notion of inter-rater reliability. Nigel King suggests that such independent scrutiny should happen early in the coding process to improve the coding template and discussions then take place between the coders to further revise the template (King, n.d. retrieved 20 July 2006). However, I consider that even if this approach is taken, a check by an independent coder late in the analysis process is a useful method of ensuring

a more rigorous study, as changes in a researcher's mind occurs over time, with the result that the initial coding template can be altered without the researcher noticing.

On the basis of the data in Appendix F, I then placed students into categories using the combined extent of their pre- and post-visit knowledge of Big Ideas. My first attempt at categorisation split students' pre-visit knowledge into low, medium and high categories, and their post-visit knowledge into the degree to which they had decreased, remained the same or increased their knowledge. All students showed either the same knowledge or an increase in knowledge, and the differentiation between categories was based on the number of knowledge levels by which students increased. This original categorisation scheme is shown in Appendix G, and was discarded because I considered that it did not capture their change in knowledge in a sufficiently fine-grained manner. Instead, I decided to calculate the mean of the pre- and post-visit knowledge categories for each student, and these are shown in Appendix F as mean pre- and mean post-scores. I then plotted scattergrams of pre-visit mean scores (x axis) versus post-visit mean scores (y axis) for all students (Figure 7.1).

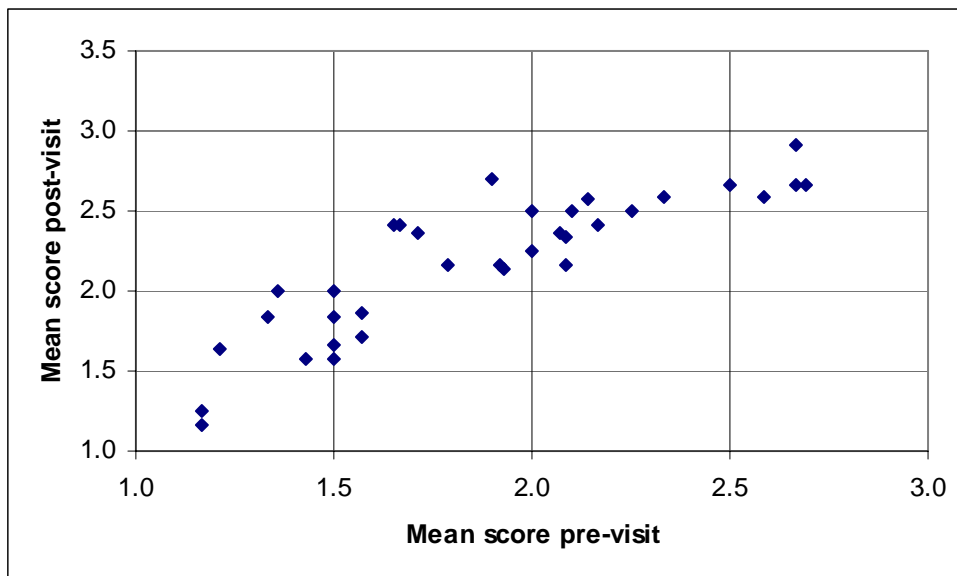


Figure 7.1 Scattergram of students' pre- and post-visit mean scores

Figure 7.1 shows that students' pre-visit score correlates closely to their post-visit score (correlation coefficient is 0.88). This suggests that the extent of students' pre-visit knowledge determines their post-visit mean score, for example if an individual's pre-visit score is low, then their post-visit score is likely also to be low. However, the graph also shows that all post-visit scores are either the same as or better than their pre-visit scores. I

am using ordinal data and some statisticians do not recommend calculating a mean for such data (Gorard, 2001), as the difference in score between each rating is not equal. For example, in Table 5.3 the difference between knowledge levels 1 and 2 is not the same as between levels 2 and 3. For this reason I recalculated the mean scores using the Rasch technique (Boone & Rogan, 2005), which allows non-linear data to be converted into linear data. Appendix H shows the same data as Figure 7.1, but recalculated using the Rasch procedure (resulting in a different scale). However, the points plotted are very similar to those in Figure 7.1, and the correlation coefficient is 0.90. On the basis of this similarity, I regard the means calculated in Appendix F as credible, despite the fact that I have used ordinal data to calculate them. I then used Figure 7.1 to identify students about whom I could write word portraits which describe their detailed learning. Word portraits are used mainly in ethnographic research as a technique to present data “in which the information is integrated in the format of a description of a person, but with information about others and about the context” (Henning 2004 p 112).

I devised a set of criteria which I used to choose the most appropriate students for the writing of portraits for Chapters 7 and 8:

- An approximate 20% sample¹⁴ of the total student group.
- Students who showed no change in learning.
- Students who showed change in learning.
- Students across the full range of mean scores, from low to high.
- Both study sites should be represented.
- If I made a choice between two or more similar students on the continuum, I chose the one who exemplified interesting or unusual human constructivist learning.

On this basis I chose 7 students (Figure 7.2) identified on the graph by their pseudonyms.

¹⁴ This is in line with other similar studies e.g. Anderson (1999) wrote 5 portraits out of a total of 28 students in the class.

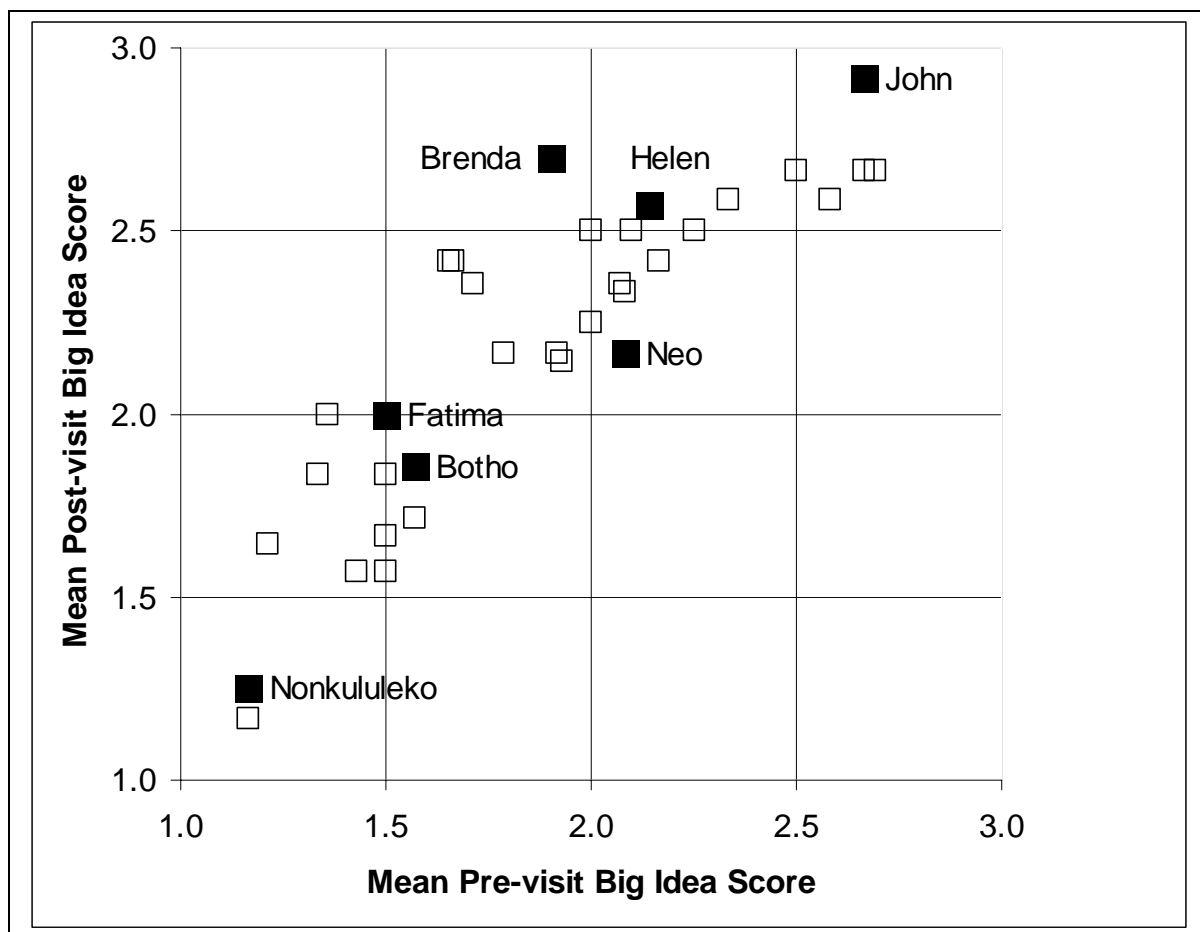


Figure 7.2 Graph showing students across the range of learning about whom portraits are written.

Although Figure 7.2 is a good graphical representation of how students fit on the learning continuum, I also categorised the students into a tabular scheme as a more convenient way of describing their learning. This scheme (Table 7.1) shows the extent to which students increased their knowledge about Big Ideas. The pink-shaded area shows that no students demonstrated an overall *decrease* in their knowledge about these ideas after the visit. This is significant in that the visits did not impart substantial misconceptions to students which made them change whatever correct knowledge about Big Ideas they might have had. The yellow-shaded section of the table identifies the 13 students (38%) who performed at the same level in their pre- and post interviews, while the blue-shaded area shows the 21 students (62%) who exhibited an increase in their knowledge of Big Ideas. Students identified in red are those whose portraits appear in this chapter and Chapter 8, and are referred to as *portrait students*.

Table 7.1 Categorisation scheme for students (n=34) based on their pre- and post-visit knowledge of Big Ideas concepts.

Post Visit Mean Scores	D	2.6-3.0		Brenda	Helen, Paul, Judy	John, Susan, Antonia, Richard
	C	2.1-2.5		Sibongile, Sarah, Bhekiwe, Banyana, Julius, Thapiso, Nnaniki, Vicky, Ross	Neo, Lara, Sipho, Douglas, Phillip	
	B	1.6-2.0	Fatima, Tlotlo, Kitso, Zanele, Mpho, Ntobeko, Batsile, Fane	Botho, Caroline		
	A	1.0-1.5	Nonkululeko, Theresa			
		1.0-1.5	1.6-2.0	2.1-2.5	2.6-3.0	
		A	B	C	D	
		Pre Visit Mean Scores				

The mean pre-visit score was 1.9 (SD=0.46) while the mean post-visit score was 2.2 (SD=0.45). Like the scattergrams in Figure 7.1 and Figure 7.2, the table provides evidence that students' knowledge levels either remained the same or increased as a result of their visit to one of the study sites. The lowest knowledge level I assigned to each Big Idea (as shown in Table 5.3) was level 1, representing a relatively limited knowledge of the idea. Table 7.1 shows that even if students have this relatively limited prior knowledge of Big Ideas (Pre-visit A) it is possible for them to move to the next level (Post-visit B), which eight of the ten students at this level accomplished. The table also shows that students at the level of Pre-visit B (12 students, or one third of the total) can readily move to Post-level C, as nine achieved this and one moved to post-D. The eight students with more substantial prior knowledge (pre-visit C) also appear to be able to increase their knowledge (although less easily than those in the pre-visit B category) as 3 of them were able to move to the Post-visit D category. My study was not intended to be a comparison between the planetarium and HartRAO, and it is important to note that students visiting *either* study site were able to increase their knowledge of Big Ideas. Comparing Table 7.1 with the schools at which the students were studying shows some broad trends. Students from Balfour Forest (BFS) are distributed across the table, but with less representation at the post-D level. Lourdes Girls School (LGS) students mostly show improvement, and are found at the higher levels of the table. The eight students from Achievement School (AS) are

dispersed across the table, while the four from Bokamoso School (BS) are at the lower levels. I make these observations to demonstrate that a student’s position on the table is not solely a reflection of the school at which they are studying.

Table 7.2 Categorisation scheme showing student numbers from each school

Post Visit Mean Scores	D	2.6-3.0	BFS 1	LGS 1 AS 2	LGS 2 AS 2
	C	2.1-2.5	BFS 4 LGS 2 AS 2 BS 1	BFS 4 LGS 1	
	B	1.6-2.0	BFS 4 LGS 2 BS 2	AS 1 BS 1	
	A	1.0-1.5	BFS 1 AS 1		
		1.0-1.5	1.6-2.0	2.1-2.5	2.6-3.0
		A	B	C	D
Pre Visit Mean Scores					

The changes in knowledge shown in Table 7.1 are with respect to knowledge of *Big Ideas*, while my study aimed also to determine change in astronomy knowledge that students *themselves* identified, as shown in the PMMs. So although the findings about Big Ideas are interesting, they lack theoretical depth, and in my study I had planned to try and understand student learning about basic astronomy in a more nuanced way. The value of Table 7.1 is to provide a categorisation scheme for a more detailed examination of students’ learning. A detailed examination reveals not only what students learnt about the Big Ideas but also how students learn and what contributes to this learning (Chapters 7 and 8).

7.4 Use of Astronomy-Related Vocabulary

Data on students’ knowledge of Big Ideas was obtained mainly through the pre- and post-visit interviews described in Chapter 3. I analysed students’ Personal Meaning Maps principally in order to determine what individual students learnt during their visit, as described in Chapters 6 to 8. However, as recommended by John Falk (Falk 2003) I was also able to use the PMMs to determine the change in students’ use of vocabulary, as this should document “the extent of a person’s awareness and understanding of the concept” (Adelman *et al.* 2000 p 39).

Views on scientific vocabulary are varied. Pushkin (1996) suggests the need for the science education community to use the existing scientific terminology appropriately and

accurately, while others propose that “the meaning for terms is varied and always has to be negotiated” (Slisko & Dykstra, 1997 p. 656). Proponents of ‘talking science’ suggest that students develop their science language in the same way as they find out their way through the real world, by developing it through their experiences (Roth, 2005). The extent to which students used scientific words in their PMMs is a reflection of their own ability to participate in the science class. However, it is possible for them to use astronomy-related words, yet only know them as words, and not be able to ascribe any meaning to them, as some students demonstrated in their interview when I asked them about what they had written.

I determined the change by counting astronomy-related words used by students in their pre-visit PMM and counting the additional words used in their post-visit PMM. The results for all 34 students are listed in Appendix I, and a summary is provided in Table 7.3.

Table 7.3 Summary of increase in astronomy-related vocabulary shown by students (n=34)

Number of words used in pre-visit PMMs		Additional number of words used in post-visit PMMs	
Mean	Standard Deviation	Mean	Standard Deviation
20.3	7.5	6.8	4.0

As the sample was not randomly collected I have made no attempt to use statistical tests on my data, and they are difficult to compare with reports from the literature, which do not provide raw figures, but only the results of paired t-tests (Adelman *et al.* 2000, Falk *et al.* 1998). The standard deviations in Table 7.3 show that there is considerable variation in the mean number of words used by students both prior to and after their visit to the science centre, reflecting the very individual nature of what students learnt. Students such as Lara, Douglas and Neo wrote down more words in their post-visit PMM than they did in their initial PMM, while Zanele, Bhekiwe and Caroline only increased by one word. Overall, the mean figures suggest that students increased their astronomy-related vocabulary by one third, which is a useful benchmark for future studies of this nature.

I mapped the extent of students’ vocabulary from their PMMs on to the data summarised in Table 7.1, but this demonstrates that the mean number of words used by students in the different categories shows little relationship to their prior knowledge. The only trend

evident is that students with the highest level of prior knowledge (category D) do apparently use more words in their PMMs and increased these by the greatest amount (Table 7.4). This suggests that counting words used by students in their PMMs is **not** a reliable way of assessing their concept knowledge or understanding, except perhaps for students who use a large number of words.

Table 7.4 Mean number of astronomy-related words used by students in the pre-visit and additional words used in post-visit PMMs categorised by Big Ideas scores

		Pre	Post	Pre	Post	Pre	Post	Pre	Post
Post Visit Mean Scores (additional words)	D	2.6-3.0				23	7	31	11
	C	2.1-2.5		23	5	13	9		
	B	1.6-2.0	17	6	15	5			
	A	1.0-1.5	20	8					
		1.0-1.5		1.6-2.0		2.1-2.5		2.6-3.0	
		A		B		C		D	
		Pre Visit Mean Scores							

7.5 The Students

Table 7.5 (based on Table 7.1) shows the students I selected whose learning about astronomy I will describe in detail.

Table 7.5 Students selected for whom portraits were written, using the categorisation scheme of students developed in Chapter 6.

Post Visit Mean Scores	D	2.6-3.0	Brenda	Helen (3)	John (4)
	C	2.1-2.5	(10)	Neo (5)	
	B	1.6-2.0	Fatima (8)	Botho (2)	
	A	1.0-1.5	Nonkululeko (2)		
		1.0-1.5	1.6-2.0	2.1-2.5	2.6-3.0
		A	B	C	D
		Pre Visit Mean Scores			

Numbers in (brackets) show total students in each category

Of the students who were selected for portraits 6 of the 7 are female. This is a slightly higher number than the proportion of females to males in the study (25/34, or 74%), but the alternative choices for representative students also tended to be female. Two students (both from Lourdes Girls School) visited the planetarium, while the remainder visited HartRAO.

For each student I have described in the portrait why they were chosen as being representative of their category, and have provided a reduced version of their post-visit PMM for examination (all 7 PMMs are shown full-size in Appendix J). Each student’s pre-visit PMM was in blue pen, with red ink comments by me, the interviewer. Their post-visit PMM was added to or edited by the student in pencil (grey), with additional comments by the interviewer in green. In the portraits, all the students’ words are quoted verbatim, including spelling errors from their PMMs and grammatically incorrect phrases from their interviews.

7.5.1 Portrait of Nonkululeko (swo26)

Table 7.6 Position of Nonkululeko on Big Ideas classification table

D	2.6-3.0				
C	2.1-2.5				
B	1.6-2.0				
A	1.0-1.5	Nonkululeko			
	Post	A	B	C	D
Pre	Mean	1.0-1.5	1.6-2.0	2.1-2.5	2.6-3.0

Table 7.7 Nonkululeko’s knowledge of Big Ideas

Gravity		Star concept		Sun concept		Size/Scale		Sun movement		Moon phases		Parabolic/Satellite Dish		Average	
pre	post	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post
0	1	1	1	1	1	1	1	1	1	1	n/a	2	2	1.0	1.2

Nonkululeko was chosen as being representative of students in the AA category. According to my analysis of her PMM and interview, she went on the trip to Hartebeesthoek Radio Astronomy Observatory with little knowledge about Big Ideas in space and astronomy, and, compared with the other students, gained little from the trip. Both the students in the ‘AA’ category had the lowest mean score for big ideas of all the participants in the study (Nonkululeko from 1.0 to 1.2, Theresa remained at 1.2). However, it is important to note that Nonkululeko did gain *something* from the trip, which I hope to bring out in this portrait.

Nonkululeko is a 12-year-old grade 7 girl student and has attended Balfour Forest School since grade 1. Nonkululeko lives in a middle class suburb a few kilometres North-West of Johannesburg city centre, and travels to the school each day by minibus taxi. At home she only speaks isiZulu, a language which is commonly used by nearly a quarter of the population of South Africa (Statistics South Africa 2001).

Nonkululeko drew her PMM on 8th October and was interviewed on 15th October, 9 days before she visited HartRAO on 24th October together with the classes who attended. On 30th October, all the students who had been on the field trip did their repeat PMM during school time and I re-interviewed Nonkululeko several days later on 10th November. Nonkululeko was one of a few students whose interview was over two weeks after the visit, and this may be partly responsible for her apparent limited cognitive uptake. However, I do not consider it the primary reason, as other students who were interviewed at the same time as Nonkululeko fell into other categories (e.g. Ntobeko in AB and Thapiso in BC).

While Nonkululeko knew roughly *where* she was going on the visit to HartRAO and that it was related to ‘the planets’, she didn’t know *why* the class was going there. It is quite possible that her knowledge of the venue for the visit was due to the filling in of her PMM for me, rather than anything provided by the school. She professed to be looking forward to the visit, as “I want to know about planets and the ... the galaxy and all ...” (swo26preint 043). She also agreed that she was interested in the topic, but appeared to be just saying this because she thought I wanted to hear it, as her reason was another reference to knowing about planets. She was able to give an example of astronomy in the news, as she made a reference to a newspaper report of a new planet being discovered, which she remembered as ‘Clara’. However, she also went on to say that “the other planets, they come and visit Earth” (swo26preint 175) and I could not interpret what she meant by this. Nonkululeko had some experience of looking at the stars and planets, as she related a recent ‘tour’ she had been on where the organisers pointed out the constellation of Scorpio and the planet Mars. While she remembered that Mars “looked like a star but it was red” (swo26prepmm 059), she couldn’t remember what Scorpio looked like because “I didn’t see properly” (swo26prepmm 067).

Nonkululeko said that she liked school because “We learn many things” (swo26preint 195). Her favourite subjects were English because it “teach[es] me how to read and write” (swo26preint 207) and life orientation because it’s about people. In contrast her least favourite subjects were economic and management science and human and social science, because they are both hard and she doesn’t always understand them. When asked about her career plans, she said she would like to be a teacher “but aih it’s hard” (swo26posint 202). In her spare time, Nonkululeko said she watched television (soap operas and children’s’ programmes) and wrote in a small book, not a diary, but “my

personal details and music” (swo26preint 231). The most recent book she read was a teenage novel in English. Nonkululeko is not sure if scientists have ever found life outside the Earth, and thinks that there might be life on Mars. She was emphatic that aliens do not exist “There is nothing like aliens. They are just made up” (swo26preint 297), and does not read the horoscope. Nonkululeko considers herself religious (a Christian) but has never really thought about how her faith might relate to the universe.

In her use of astronomy words and terms Nonkululeko’s astronomy knowledge was about average. While she used 18 astronomy-related words in her pre-visit PMM (the mean for the study was 20, and for her school was 16) her post-visit PMM increased by 7 words, slightly above the school and study mean. All the vocabulary she used was common to other students in the study, but on the basis of her increase in vocabulary she appeared to have gained some knowledge from the trip.

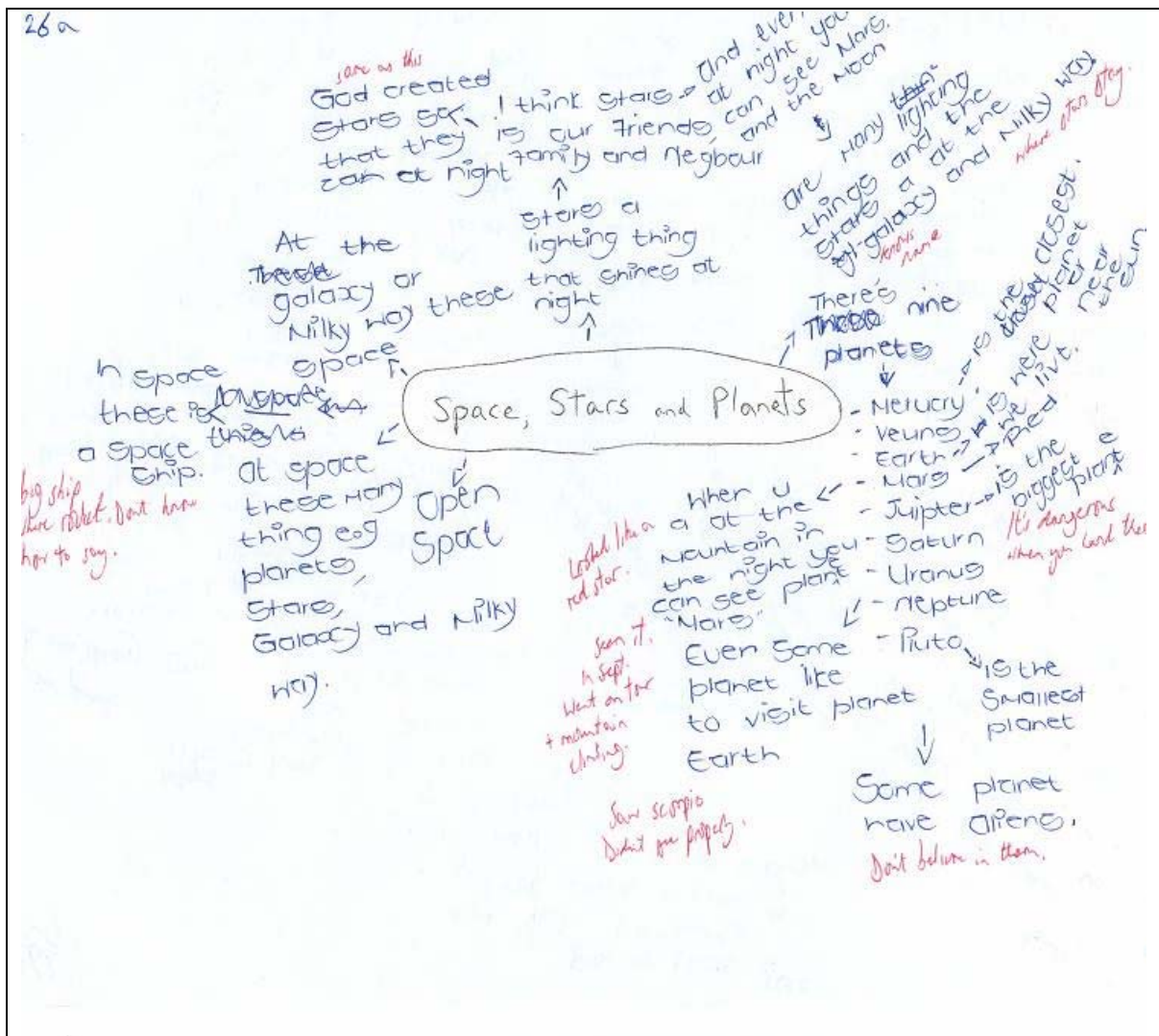


Figure 7.3 Nonkululeko’s pre-visit Personal Meaning Map

Nonkululeko's pre-visit personal meaning map (Figure 7.3 and Appendix J) was similar to those of many other students in the study. She listed the nine planets together with some brief facts about several of them. For example that Jupiter is the biggest planet and Mercury is the closest planet to the Sun. She referred to stars as being "a lighting thing" (swo26apre 11) created by God, and that they are our "friends, family and neighbour" (swo26apre 18). She also referred to stars being at the galaxy and Milky Way. She stated that space consists of open space, containing planets, stars, galaxy and the Milky Way. When probed about her PMM, she confirmed that "God created stars so that it can shine at night" (swo26prepmm 003). Although she knew the term galaxy she was unable to explain its meaning or its relationship to the term Milky Way. She further referred to a spaceship and rocket, although she found difficulty in expressing herself here. When I asked if she wanted to say it in isiZulu she said no, suggesting that she just found expression difficult, rather than it being a language problem, thus:

Interviewer: Okay. If you said that in Zulu, could you tell me more?

Nonkululeko: No.

Interviewer: You wouldn't be able to?

Nonkululeko: Yes.

(swo26prepmm 081)

She also appeared to have differing ideas on aliens. Having said she doesn't believe in them in the structured interview, she mentioned that some planets have them. She could not explain the discrepancy.

During the structured interview related to Big Ideas, Nonkululeko demonstrated very limited understanding of many concepts. Her idea of stars was limited to them shining at night and their shape ("like starfishes"), but did not know their size or composition (level 1). Nonkululeko's ideas about the sun were fairly minimal and naïve. She knew that it is big and yellow and can be used for drying things (level 1). However, her concept of big was not probed, and in a subsequent answer she thought that the Sun and Moon are the same size; overall she was classified for size and scale as being at level 1. She could not explain why the Sun moves across the sky each day, except to express that "because the sun needs places to go". She appeared to believe that it really is the Sun moving to "America and all those places" (swo26preint 79, 83), and was classified at level 1. Nonkululeko could describe how the Moon changes shape over the course of a week, but did not know why this is (level 1).

When asked about a satellite, Nonkululeko said she had seen one, but struggled to express herself further. When referred to a satellite dish, she was able to say that it is round and ‘half’, and points towards a spaceship, “because the spaceship gives us the programmes and all those things ...” (swo26preint 151), and was classified at level 2. She was the only student in the study who professed both to not knowing what gravity is, and not knowing the word (level 0).

After her visit to HartRAO, Nonkululeko added considerably to her PMM (Figure 7.4 and Appendix J), filling the reverse side of the paper with numerous facts.

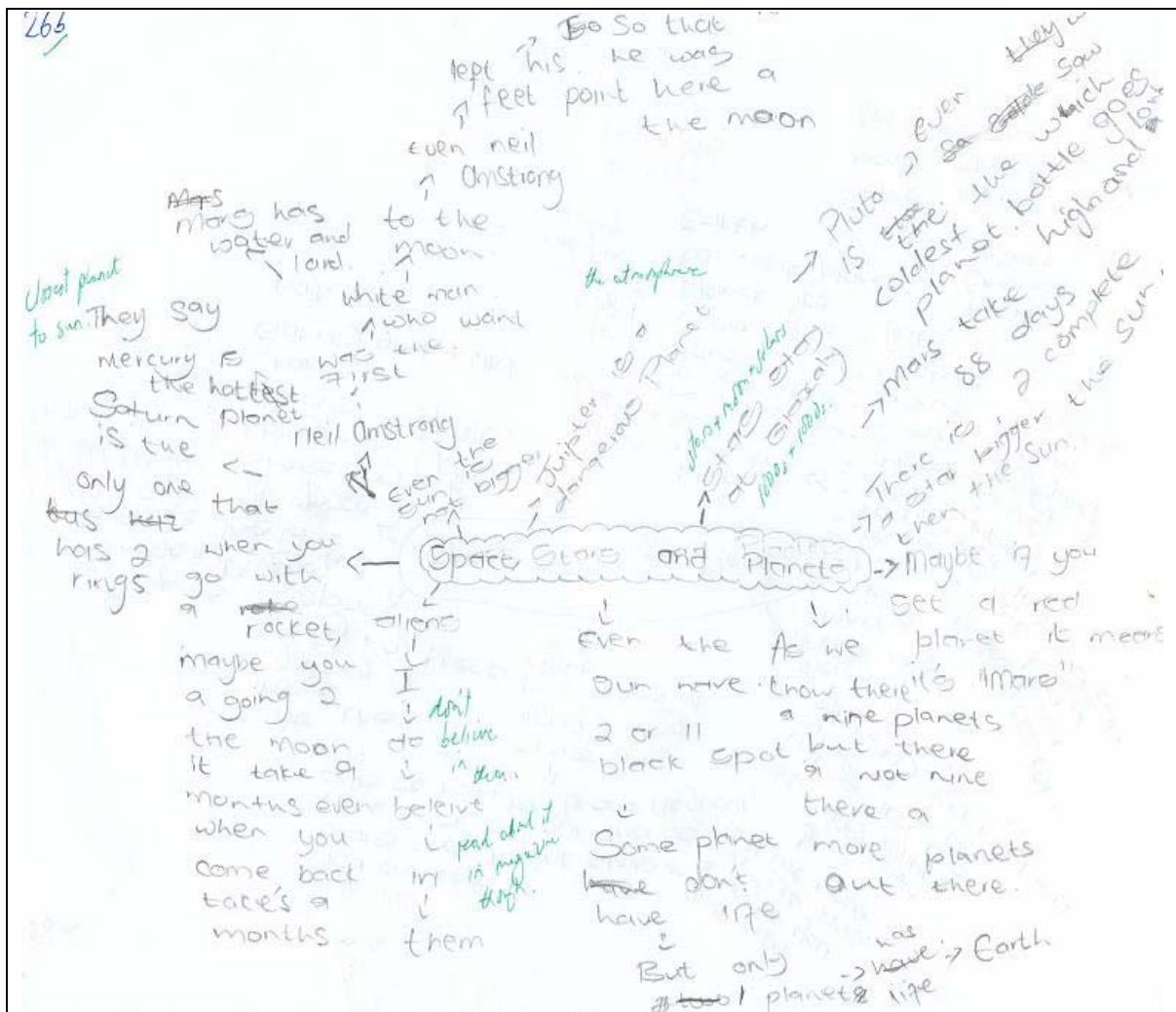


Figure 7.4 Nonkululeko’s post-visit PMM

Several facts were a repetition of her pre-visit PMM, such as her reference to the 9 planets, Pluto being the coldest, Mercury being the hottest and stars being in the galaxy. However, she wrote down several new pieces of information, including the following:

- Which bottles went high and low (reference to the Coke bottle rockets)

- Additional planets to the nine named ones.
- Additional facts about the nine planets
- Black spots on the Sun
- Various features of Mars: water, land, and orbit.
- A description of the Moon landing and the time taken to get there
- A star bigger than the Sun

Further probing of several of the ideas was not carried out to any great extent, due to time constraints in her interview. Her understanding of a galaxy was still minimal: “A galaxy I think is where the stars stays and the moon and the solar system and the everything” (swo26pospmm 35), but she understood that it would contain thousands and thousands of stars. Her belief in aliens was still ambivalent: in the post-visit PMM she wrote that she believed in them, but when questioned she said she did not, although she had read about them in a magazine. I consider that Nonkululeko’s changes to her PMM are supplementary facts that she has accumulated from her visit: examples of addition in human constructivist terms.

During the structured interview, several of Nonkululeko’s ideas remained the same or very similar to her pre-visit ideas. These included the following:

- Her concept of the sun as being ‘big’, shining by day and moving round the Earth each day;
- Although she now thought the Sun is bigger than the Moon, she could not tell which was closer to the Earth;
- Stars as shining at night;
- A satellite dish pointing to a spaceship in order to give us programmes on television
- An inability to talk about what gravity is or does

In these structured questions Nonkululeko was not able to articulate clearly any significant change in her knowledge about the Sun, stars, satellites or gravity. She did however state that stars are bigger than the Earth, whereas previously she could not tell their size. Table 7.8 shows Nonkululeko’s learning analysed using my human constructivist model. This and subsequent tables for the portrait students shows the frequency of HC codes identified in students’ pre- and post-visit PMMs and interviews. I include the pre-visit columns as it is possible for students to express affective and conative knowledge prior to their visit, for example their excitement before going or their personal preparation for the visit.

Table 7.8 Frequency of Human Constructivism codes for Nonkululeko

Knowledge Construction category	PrePMM & Interview	PostPMM & Interview	Pre Interview	Post Interview	Totals
Addition	n/a	10	n/a	4	14
Emergence	n/a	1	n/a	0	1
Differentiation	n/a	0	n/a	0	0
Discrimination	n/a	0	n/a	0	0
Recontextualisation	n/a	0	n/a	0	0
Affective	0	0	5	4	9
Conative	0	0	0	0	0
Totals	0	11	5	8	24

In Human Constructivist terms Nonkululeko showed several additions to her knowledge after her visit, but no other examples of cognitive learning in the HC framework, such as superordinate learning or differentiation. If Nonkululeko had been given a formal written pre- and post-test about simple concepts in astronomy before and after her visit to HartRAO, the results of her structured interview indicate that she would have shown no gain in knowledge. From a non-cognitive viewpoint, Nonkululeko admitted to enjoying playing with the rockets and was surprised that the whispering dishes worked and that the radio telescope can receive messages from space. She found the slide show on the Moon landings ‘boring’. After the visit she was unable to explain the purpose of the visit, but when prompted she agreed that both learning and fun were related to the visit’s purpose. She told me that although she would like to visit Hartebeesthoek Radio Astronomy Observatory again, she had told nobody about the visit, and had not thought about it since. In the study, she was the only student interviewed who professed to having not told anybody, and one of 3 who had not thought about the trip since (although only 22 students were asked this question). These negative affective aspects of her visit suggest that the visit did not have a strong emotional effect on Nonkululeko, and may be part of the reason for her minimal learning of Big Ideas from the visit.

However, the results of her PMM indicate that in fact she *did* learn something from the visit. She was able to describe how Neil Armstrong was the first (“white”) man on the Moon, and that he left a footprint showing “that he was here [on] the moon” (swo26bpos 23). These are examples of Shen’s cultural science literacy, where science achievements are appreciated (Shen, 1975). She also wrote (wrongly) that it takes months to get to and from the Moon. She was able to briefly describe a number of features of the planets: Mars takes 88 days to complete [orbit] the sun, Saturn has rings, Pluto is the coldest and

Mercury the hottest planet, Jupiter is dangerous as “when you put your foot on the ground you die because of the atmosphere” (swo26pospmm 07), and that there are more than 9 planets. She also noted that the Sun has black spots. It is likely, given Nonkululeko’s apparent limited interest in astronomy that she learnt all these facts from the visit to HartRAO rather than from any other sources.

Nonkululeko is a good example of a student who does not appear to be academically bright, although I was unable to obtain her school results. Her prior knowledge and understanding of Big Ideas in basic astronomy concepts such as the sun, stars and gravity was very limited, and appeared to show very little or no change as a result of the visit. For such a student, a visit to a science centre using a traditional pre-test:post-test assessment of learning would demonstrate that the visit was not ‘successful’, as the student would appear not to have learnt anything. However, what she did learn were the additional facts I have described. For Nonkululeko and other students who showed limited ‘formal’ learning, the principal (if not exclusive) type of learning is the incremental addition of relatively minor facts. Nonkululeko’s inability to link these with her existing knowledge structures (and show differentiation or emergence) is likely to be mainly because her prior knowledge of the topic is very limited. A challenge for both teachers and science centre educators is how to engage such a student more effectively during a school visit, probably by providing some pre-visit activities that will engage their interest, or by ensuring that the presentations at the centre (situational interest) are sufficiently stimulating.

7.5.2 Portrait of Botho (tsw04)

Table 7.9 Position of Botho on Big Ideas classification table

D	2.6-3.0				
C	2.1-2.5				
B	1.6-2.0		Botho		
A	1.0-1.5				
	Post	A	B	C	D
Pre	Mean	1.0-1.5	1.6-2.0	2.1-2.5	2.6-3.0

Table 7.10 Botho’s knowledge of Big Ideas

Gravity		Star concept		Sun concept		Size/ Scale		Sun movement		Moon phases		Parabolic/ Satellite Dish		Average	
pre	post	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post
1	2	2	3	2	2	2	2	2	2	1	1	1	1	1.6	1.9

Botho represents category BB, which comprises 2 students (Botho and Caroline) who visited the science centre with below-average knowledge of Big Ideas, and demonstrated

little change in their knowledge after the visit. Both students in this category showed a very similar profile: their knowledge level prior to the visit was a mean of 1.6, and this increased to 1.9 after the visit. They differed however in their use of astronomy-related vocabulary in their Personal Meaning Maps. While Botho increased hers from 11 to 20 words, Caroline only increased from 19 to 20 words.

Botho is a 13-year-old grade 7 girl student at Bokamoso School. Like most of the students in this township Botho speaks SeTswana at home, and no other languages. SeTswana is spoken by just over 8% of the South African population (Statistics South Africa, 2001). The school is relatively close to her home and she walks there every day. Botho drew her pre-visit PMM on 7 November, and was interviewed on the same day, 10 days before visiting Hartebeesthoek Radio Astronomy Observatory on 17 November. She added to her PMM on 3 December, some 16 days after the visit. Unfortunately I was unable to obtain Botho's academic results, but later found that she was awarded 3rd prize in the 2003 Southern Skies Challenge in the 'remembering' essay category. This involved writing a story about the night sky which had originated as a traditional story in her community.

Like the 3 other students at Bokamoso whom I interviewed, Botho was a member of the science club at the school, and the visit to HartRAO was arranged by the teacher in charge of the club. The visit was open to all members of the club; whoever was able to pay for the visit was allowed to go. Botho knew the purpose of the visit, that it was "to learn more about astronomies and astronomies are part of the galaxies, stars and planets" (tsw04preint 017). As a science club, the students had been preparing for the visit; after school on Monday and Wednesdays. Botho herself had "been preparing more about planets" (tsw04preint 025). This was in contrast to almost all other students in the study, who had made no preparation at all. Botho said she was looking forward to the visit because she wanted "to learn more about the Astronomy" (tsw04preint 045), but her manner did not suggest much excitement regarding the trip. Botho professed to liking school, principally for reasons of learning: "I think that school is important because education is a key to success so without education there's no life" (tsw04preint 237). Her favourite subjects were science and mathematics and her reason for liking them was that she wanted to become a doctor. Her least favourite subject was history "because I don't like past things" (tsw04preint 257). My impression of Botho was that she felt school was important as a means to furthering her future. She joined the science club because she liked

science and wanted to know more about it, and in her spare time she said she studied. I got the impression that she wanted to please me as the interviewer, by appearing to be studious. She said that in her spare time she plays, watches television (she likes cartoons) and reads novels (she wasn't specific about a title, despite my probing). Another indication of pleasing an 'authority figure' was her comment about her father and books: "My father likes to go to the library and when he comes from the library he give me some books to read so I read" (tsw04preint 293). Although she wasn't questioned specifically about aliens, Botho thought scientists had found life "at space" although she didn't think it had been found elsewhere in the universe. She professed to being religious, and, like most students, believed that God created the planets, space and the universe.

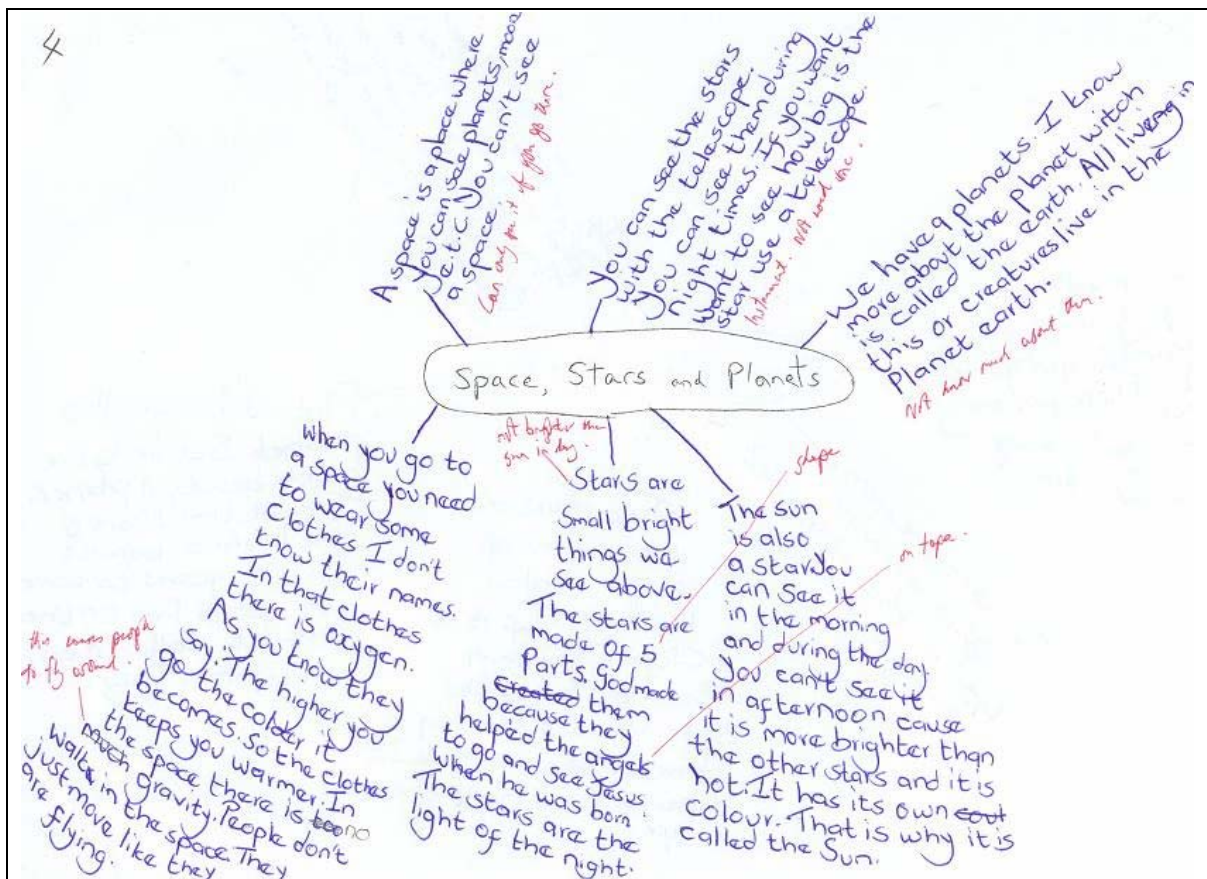


Figure 7.5 Botho's pre-visit PMM

Botho used only 11 astronomy-related words in her pre-visit PMM, but increased this by 9 words after the visit. These numbers were below-average for her school (18 and 11 respectively) and for the study prior to the visit (20), but just above the study's post-visit average (7). Botho's pre-visit PMM (Figure 7.5 and Appendix J) was unusual in that she wrote substantial sentences about relatively few ideas, and was one of only 3 students

(Nonkululeko was another) who referred to God in writing. In her PMM Botho wrote about space as a place where there are planets and moons, and that if you go there you need clothes to keep you warm and give you oxygen. She referred to there being ‘too much’ gravity there and people “just move like they are flying” (tsw04apre 25). She also discussed stars as small bright things that can be seen using a telescope that were created by God to help “the angels to go and see Jesus when he was born” (tsw04apre 21). She also wrote about the Sun as a star and its visibility, as well as the 9 planets, although the only one she named was Earth.

Botho showed varying levels of knowledge regarding Big Ideas in astronomy prior to her visit to HartRAO. Her knowledge of gravity was minimal: she was able to say that gravity causes a pen to fall down towards the ground, but had no idea about gravity on the Moon, Jupiter or the Sun. Her PMM indicated that she associated gravity with people appearing to fly, which suggests she had seen images of people encountering weightlessness. Her knowledge of stars indicated no substantial scientific understanding (lights at night), and a reference to their being made by God to guide angels to Jesus’ birth. However, Botho did know that the Sun is a star (and therefore presumably vice versa), that their apparent size is related to distance and that stars are about the size of the Sun. For similar reasons, her knowledge of the Sun was classified at level 2, and, with the help of the model, she could explain that day and night are caused by the Earth spinning. Regarding her idea of size and scale in the solar system, Botho showed some understanding that the apparent size of stars is due to their distance, but when probed on this she couldn’t explain why. She also knew that the Sun is larger than the Moon, and that the latter is closer although her explanation was quite interesting, as she invoked the idea that although we sometimes see a half moon, we never see a half sun. On these bases she was classified at level 2 for her knowledge of size and scale. Like about half the students, when asked about the Moon, Botho could describe its phases but she didn’t know why they occur; she suggested the weather as a possible explanation. Botho’s knowledge of satellites was minimal: she didn’t know what a satellite was, but could relate to a satellite dish. When questioned about a dish she knew it was related to television but didn’t know the reason for its dish shape, in what direction it faced, or where it was pointing to.

After the visit Botho added several facts to her PMM (Figure 7.6 and Appendix J), particularly about stars. She stated that stars are made of a gas called hydrogen, and that you cannot use a telescope to look at stars on a cloudy day. She noted that orange stars “is

gonna die soon” and that stars “are there during the morning”, but we can’t see them due to the brightness of the Sun (tsw04bpos 10). She also noted that stars make sounds, and when questioned about this she could describe the sounds made by different types of stars:

- Interviewer: Okay. And you see they make sounds. How did you ...?
- Botho: We have it at the other place and they said it depends on how big is the star and if it is big it make like booo, booo, booo.
- Interviewer: You heard the sounds?
- Botho: Ja.
- Interviewer: How did they, they recorded the sounds, what did they use to listen?
- Botho: I think they used the satellite.
- Interviewer: They used the satellite. You mean that big satellite dish.
- Botho: Ja.
- Interviewer: Okay. And you say you heard the big ones make that sound, what about a small one, did you hear any others?
- Botho: Ja we heard and this make like ting, ting.
- Interviewer: Okay. Did you know stars made sounds?
- Botho: No.
- (tsw04pospmm 49-71)

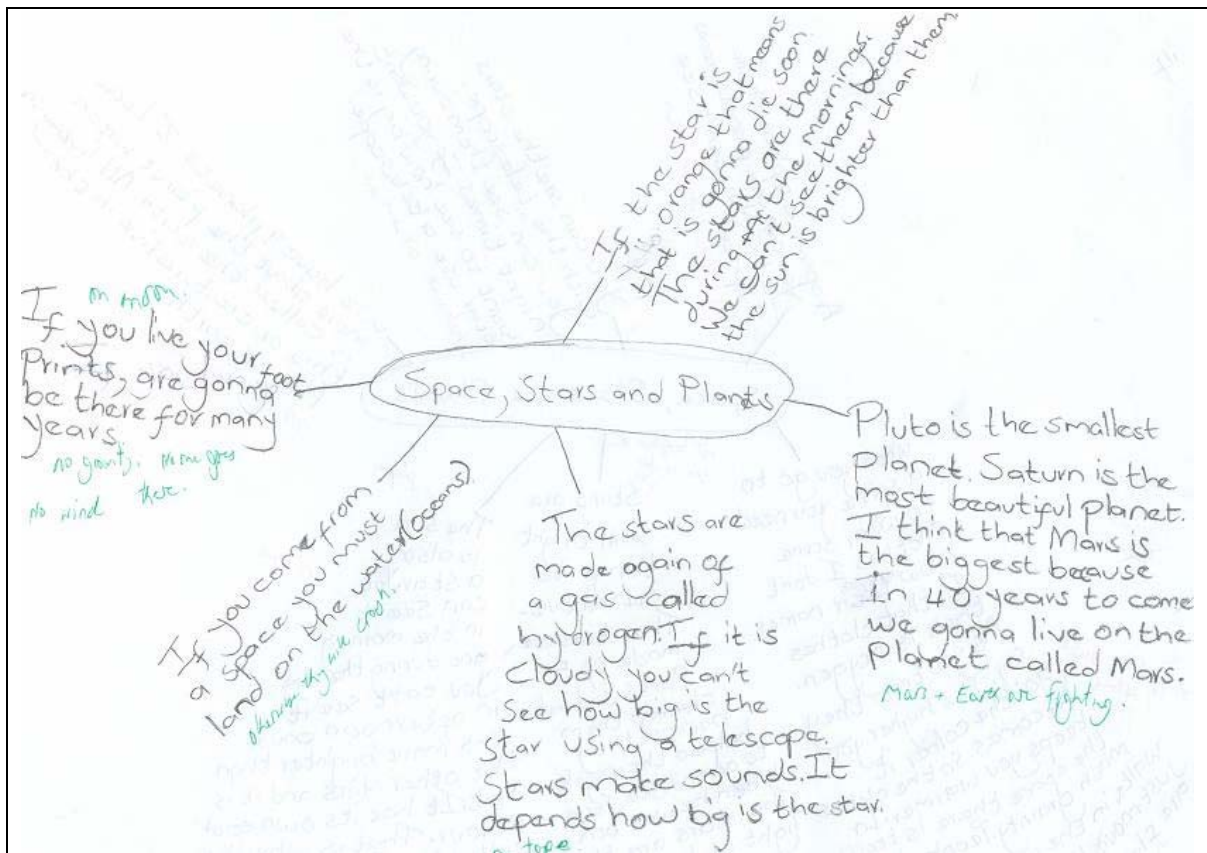


Figure 7.6 Botho’s post-visit PMM

Botho also made brief comments about footprints on the Moon, spacecraft splashing down in water on return from space and three planets she had not referred to in the pre-visit PMM: Pluto, Saturn and Mars. When discussing the latter planet, she referred to the ‘War of the Worlds’ slide show demonstrated at HartRAO. Unlike her PMM, in her post-visit structured interview, Botho changed few of her ideas.

- She stated that there is a little gravity on the Moon (whereas previously she had not known this) but did not know about Jupiter or the Sun.
- She noted that the Sun can be used as a sun dial to tell the time.
- She thought that the Moon changes shape “because of the seasons”.
- She made no changes to her ideas of stars (except those I have described from the PMM), size and scale or the satellite dish.

Botho is a good example of a student who, although she appeared not to learn any additional knowledge about Big Ideas, demonstrated that she did learn a limited amount from the visit. This knowledge increase is mainly evident in her post-visit PMM and associated interview. The facts she remembered from the visit are highly personal and relate directly to several of the exhibits and demonstrations at HartRAO. While Botho improved her basic science literacy in the form of these new facts, she did not show any evidence of change in her cultural science literacy (Shen, 1975).

Using the human constructivist categories of knowledge construction, Table 7.11 summarises how the changes in Botho’s knowledge occurred. From a cognitive viewpoint, she demonstrated several examples of addition, where she incrementally added small pieces of knowledge to her pre-existing knowledge. In most cases these additional facts were across a variety of concepts from gravity to the Sun to the Moon landings. However, there was one area which appears to have captured her attention more than others: various facts about stars. Whereas I categorised Botho at knowledge level 2 for her concept of stars prior to the visit, I considered that the additional information she provided in her post-visit PMM and interview enabled her to be placed at level 3. For the same reason, I suggest that her concept of star was considerably extended as a result of the visit, and was actually differentiated, her only example of cognitive learning which was not classified as addition. Unlike most other students except maybe Brenda, Botho showed only 3 examples of affective learning after the visit: surprise at the fact that stars die and the experience she told her parents about afterwards: the whispering dishes. Similarly, the visit did not *appear*

to have motivated her much into finding out more about astronomy (the conative aspect). However, her father, who she mentioned prior to her visit as borrowing books from the library for her, brought her a book about astronomy and she said she read about stars from it. It is therefore possible that in the fortnight between the visit and my interviewing her, Botho had gained some of the information about stars that she wrote in her post-visit PMM from the book that her father got her from the library. This is itself of interest, as it demonstrates that a student who represents those who appeared to gain very little from the visit did in fact acquire some knowledge about a specific concept which interested her: stars. A further conative aspect which did not emerge from the interview data was the fact that Botho entered the Southern Skies essay competition. This competition was held in 2003 as part of World Space Week to encourage people between ages 5 and 23 years to participate in astronomy. Botho won 3rd prize for the category which involved telling a story about the night sky and stars which she had heard in her community, which further reinforces her interest in stars.

Table 7.11 Frequency of Human Constructivism codes for Botho

Knowledge construction category	PrePMM & Interview	PostPMM & Interview	Pre Interview	Post Interview	Totals
Addition	n/a	8	n/a	5	13
Emergence	n/a	0	n/a	0	0
Differentiation	n/a	1	n/a	0	1
Discrimination	n/a	0	n/a	0	0
Recontextualisation	n/a	0	n/a	0	0
Affective	0	0	2	3	5
Conative	0	0	0	1	1
Totals	0	9	2	9	20

While Botho's conceptual change in Big Ideas was limited, she managed to extend her knowledge of stars, and the visit clearly motivated her interest in the topic. Like Nonkululeko, her knowledge gain appears to be mainly by addition, although in her understanding of stars she showed evidence of differentiation. From the affective and conative perspectives, Botho shows slightly more interest in astronomy than Nonkululeko, and her reading about stars and entering the competition shows that her interest in the topic was likely kindled by the visit to HartRAO. Botho is an example of a student whose affective and conative experiences during the visit were probably more important than the science learning about Big Ideas. Her interest in stars motivated her to enter and win a competition prize (which she did not discuss with me in her interview). This is also an

example of the sort of post-visit learning which is not fully captured in a study such as mine, which concentrated on learning during the visit. Falk and Dierking (2000) note that if students are reminded of the visit during the subsequent months after their return, this will further reinforce their learning, and it will become established in their long-term memory. Botho would therefore have been a good candidate for later follow-up.

7.5.3 Portrait of Neo (swo42)

Table 7.12 Position of Neo on Big Ideas classification table

D	2.6-3.0				
C	2.1-2.5			Neo	
B	1.6-2.0				
A	1.0-1.5				
	Post	A	B	C	D
Pre	Mean	1.0-1.5	1.6-2.0	2.1-2.5	2.6-3.0

Table 7.13 Neo’s knowledge of Big Ideas

Gravity		Star concept		Sun concept		Size/Scale		Sun movement		Moon phases		Parabolic/Satellite Dish		Average	
pre	post	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post
1	1	2	2	2	3	3	3	3	3	2.5	n/a	1.5	2	2.1	2.3

Neo was chosen as an example of a student in the CC category. According to my analysis of her PMM and interview, she went on the trip to Hartebeesthoek Radio Astronomy Observatory with above-average knowledge of Big Ideas, and, like both Nonkululeko and Botho gained relatively little from the trip (her mean changed from 2.1 to 2.3). She is representative of the five students in the CC category, although her post-visit knowledge is slightly lower than the other CC students, whose post visit mean score was 2.4.

Neo is a 13-year-old grade 7 girl student and has attended Balfour Forest School, a public primary school in the northern suburbs of Johannesburg since grade 1. Like many of the students at this school, Neo lives in a township in the northern part of Johannesburg, and travels to the school each day by minibus taxi. At home she speaks SePedi , a language spoken by 50% of the inhabitants of Limpopo Province, and the mother tongue of 9.4% of the South African population (Statistics South Africa, 2001) and some English. Neo drew her PMM on 8th October and was interviewed on 23rd October, the day before she visited Hartebeesthoek Radio Astronomy Observatory together with the classes who attended. On 30th October, all the students who had been on the field trip did their repeat PMM during school time and I re-interviewed Neo on the same day.

Neo stated that she was interested in space, and referred to its appeal several times during the interview. Her main interest was in observing planets and the fact that they have no life on them. She remembered that one of the planets, either Mars or Mercury had been in the news recently on TV (it was Mars). Neo enjoyed school, and regarded it as being important for going on to high school and beyond. Her favourite subjects were Science and Technology, and she related them to Mark Shuttleworth and the fact that she too would like to go to space. Her least favourite subjects were Economic and Management Science and Human and Social Science: “I think that I don’t like talking about the past because, what’s past is past. We have to look at the future....” (swo42preint 231). Neo’s career plans are to be a scientist, and quite ambitiously to “be the first Scientist to find anything that any Scientists haven’t found out of space” (swo42posint 185). Her main recreation is gymnastics, and she likes to watch sport on television. She doesn’t appear to read much, and only referred to a book she read last year, which covered the sun and moon. Neo knows that extra-terrestrial life has never been found, and thinks it unlikely that it exists anywhere else in the universe; she does not believe in aliens. She reads the horoscope in magazines, and although she doesn’t know how astrologers predict the future, she does believe that their predictions are sometimes right. She considers herself as being religious, and believes God’s relationship to the universe is such that: “I think that God made space and all ... Just for people to go and explore what’s happening in the ... In the Earth and on space. What’s going on” (swo42preint 341). In view of her own interest in the topic, this suggests a view of a created universe for the purpose of exploration by humans.

In her use of astronomy words and terms Neo’s knowledge of astronomy, while not being very extensive, was fairly sound. In her pre-visit PMM she used only 7 astronomy-related words, which was considerably below both the average for the study (20 words) as well as her school (16 words). However, her post-visit vocabulary increased by 11 words, approximately twice the school and study average. All the vocabulary she used was common to other students in the study, and Neo showed the capacity to express herself and her knowledge of concepts in astronomy.

As shown by the blue writing, Neo’s initial personal meaning map (Figure 7.7 and Appendix J) was relatively limited, but she did describe aspects of each of the principal words space, stars and planets. For example, she described space as a place “full of nothing”, with “no air or oxygen to breathe”, “no gravity to pull things down” and where no one can live (swo42pre 9, 16). Her description of the planets and stars was less

extensive, but included the Earth rotating on its axis (“the plant Earth roats on it aexs”) to cause day and night (swo42pre 13), as well as the sun being a very big star. In her interview based on her PMM, Neo expanded briefly on two of the planets: Pluto and Mercury, but otherwise added little to what she had drawn.

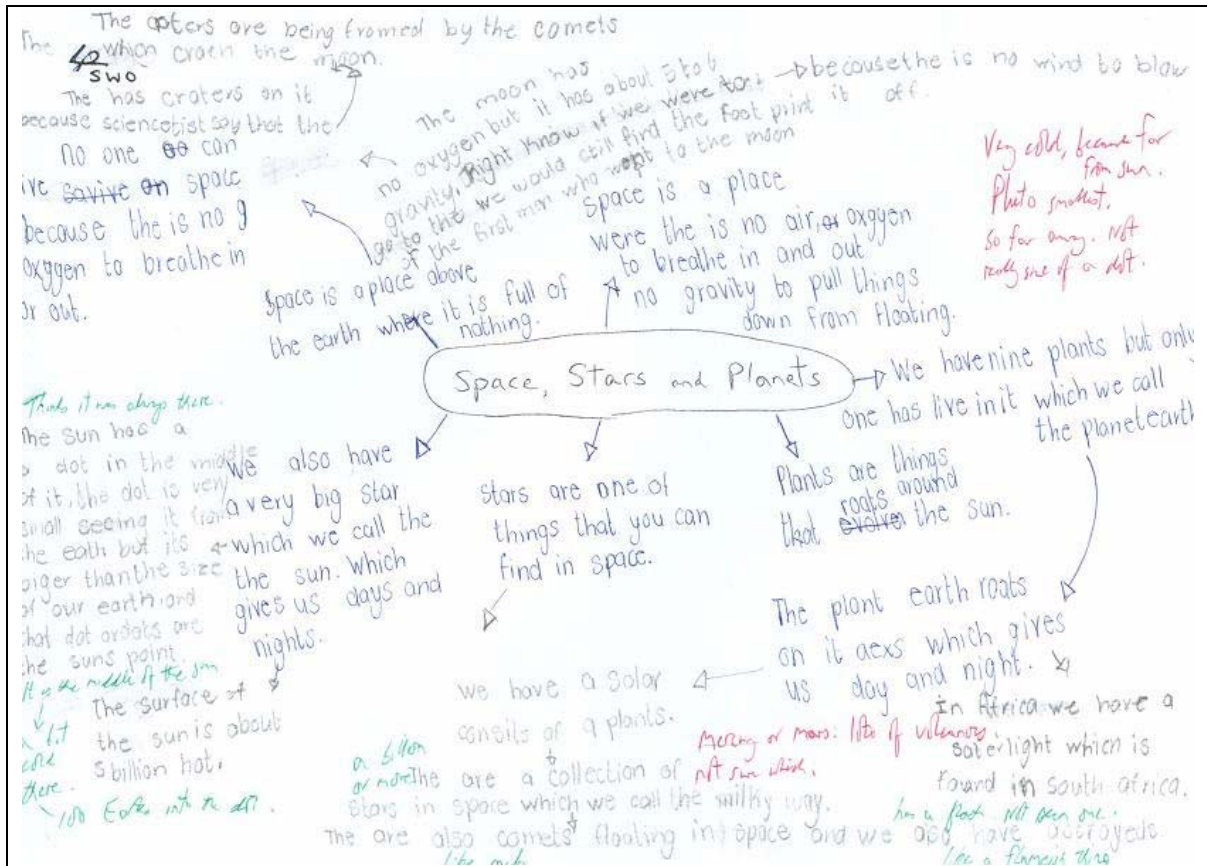


Figure 7.7 Neo’s PMM (pre and post)

During the structured interview related to Big Ideas, Neo demonstrated her understanding of several concepts in basic astronomy. Although she showed an initial teleological explanation for the sun moving across the sky every day (“It moves across the sky everyday so that we can know if it’s day or if it’s night”), she did provide a clear explanation of the Earth’s rotation as being the cause of the apparent movement (swo42preint 071), and was classified at level 3. Unlike most students in the study, she could also explain that the moon’s shape change over the course of the month was caused by the sun shining on the moon (level 3):

Neo: It’s because of the sun. If maybe the sun shines a little bit half or quarter of the moon. And that the moon is always full, it never cuts in half or anything. It’s always full. It’s only the sun, it depends on how the sun reflects on the moon. (swo42preint 095)

Only one third of the students were able to account for the apparent change in shape of the moon in their pre-visit interview. Further, Neo described how the sun was larger than the moon, but that it is further away from the Earth and hence looks a similar size in the sky.

However, Neo's knowledge showed some clear limitations, for example although she knew that the sun is a star, she regarded it as being 'bigger' than other stars, and did not elaborate on it further. I classified this knowledge on sun-star differences as being at a low level. She had very little idea of temperature, either room temperature or boiling points, and appeared to be guessing these and the fact that the surface of the sun might be 360°C, and was classified for the Sun concept as level 2. Further, Neo appeared to have a fairly limited concept of what a star is: she knew a star is like a sun, and that it is further away in space, but considered that the sun is one of the biggest stars, and thinks that the sun can reflect on the stars (level 2). Her knowledge of size and scale was her weakest area, as was classified as being at level 1. She understood that a satellite is some sort of object outside the Earth, but could not explain it further. She also thought that a satellite dish would normally point to the sun, because "most of the things need the sun to work. So, without it, maybe, if it can point to space, because space is blank, I think there would be nothing coming in or out" (swo42preint 171) (level 2.5).

Like most students, Neo could provide at least a limited definition of gravity, as some sort of force that pulls things down. However, beyond that idea her pre-visit interview shows minimal elaboration of the concept: she believed (like over 80% of the students) that there is no gravity either in space, on the moon, on Jupiter or on the sun (level 1). So we can see that prior to her visit to HartRAO, Neo both possessed some scientific knowledge of astronomy concepts (such as the moon phases) and also a number of either limited conceptions or misconceptions (such as her understanding of stars and gravity).

After her visit to HartRAO, Neo added several sections to her PMM (the grey pencil writing in Figure 7.7 and Appendix J). First, it appears that she now knew that there are such things as sunspots, and that although they look small on the sun, they are massive in size. This knowledge, which I identified as the HC category of addition, would have been a direct result of the visit to HartRAO, as a sunspot was demonstrated by the educator. It is likely that the demonstration made an impression on her, as she described the sunspot (or suns point as she initially called it) in her post-visit PMM as follows:

Neo: The sun has a dot in the middle of it, the dot is very small seeing it from the earth but its bigger than the size of our Earth, and that dot ordats [?] are the suns point

(swo42pos 20)

However, her description of the sunspot demonstrates her limited understanding of what it actually is. When questioned in the interview, she indicated that the dot is always there, and is the middle of the sun:

Neo: I think that is the middle of the sun and it's a bit cold in that sun spot and the sun spot is more bigger than our Earth, maybe about 100 Earths can fit into that dot.

(swo42pospmm 11)

It is important to note that Neo acquired a new concept as a result of the visit to HartRAO: the sunspot. In terms of human constructivist theory, Neo *added* or subsumed the concept of sunspot, and I regard this as an incremental increase in her knowledge of the Sun. She now had an additional fact at her disposal regarding the Sun: it has a sunspot. However, she also appeared to understand the concept of scale with respect to the sun, a sunspot and the Earth, in that she could relate the size of the sunspot on the sun to the fact that it is so massive that 100 Earths can fit into it. I consider this to be an example of differentiation, where her concept of the sun has been extended to result in greater understanding of scale with respect to the Sun, the Earth and sunspots. However, her idea of a sunspot is that it is the *centre* of the sun, where it is cooler. This misconception she has acquired was probably the result of the fact that the particular sunspot visible on that day happened to lie in the middle of the sun's disc.

After the visit, Neo made some reference to the Moon, which she did not do directly in the pre-visit PMM. I regard her reference to a number of facts about the Moon as being examples of human constructivist addition, as follows, using her words:

Neo: The moon has no oxygen but it has about 5 to 6 gravity. Right know if we were to go to the [Moon] we would still find the foot print of the first man who went to the moon because the is no wind to blow it off. The [Moon] has craters on it because scientetist say that the craters are being formed by the comets which crash the moon.

(swo42pos 15)

She already had referred to the fact that there is no oxygen in space in the pre-visit PMM, and here she extends this idea to the Moon. Additional facts which she has acquired are regarding gravity, the idea of the footprint of the first man to set foot there, and the reason

for craters on its surface. This description was a direct result of the moon landing slide show presented to Neo and her classmates, in which the footprints were stressed, and Neo has added to her knowledge by relating these facts on her PMM.

The last way in which Neo added to her PMM was to note some additional facts about the solar system, the Milky Way, comets and asteroids. In her interview she showed some concept of the size of the Milky Way:

Interviewer: How many stars do you think there are in the Milky Way?

Neo: Maybe about a billion because there are a lot of stars and some of the stars born some other stars so it grows every time.

(swo42pospmm 13-15)

She was also able to explain what she *thought* was the difference between comets and asteroids:

Neo: Comets are like rocks. I think that it's something maybe like when there was supposed to be another planet formed, but it wasn't formed so it create a comet. And then asteroids it's like some sort of like a flame or something. And so sometimes it just goes into flash and leaves some tail or some kind of colour especially in the night.

(swo42pospmm 19)

Her reference to the origin of comets indicates that she has conflated the concepts of comet, asteroid and meteor into one idea, and described a meteor trail in the sky, even though she stated she has never actually seen one.

During the structured interview, Neo further demonstrated that her visit to the radio telescope did result in some limited changes to her conceptions, and she acquired some new knowledge she did not apparently previously possess. Further knowledge that Neo acquired with respect to sun was that the temperature on the sun's surface is five billion degrees. While this is inaccurate (the core is 15.5 million degrees, but the surface is only 5800 degrees), her idea of the temperature has moved closer to the actual temperature than her previous idea, which was only 360 degrees. However, from her pre-visit and post-visit responses to questions, it appears she does not really have a scientific conception of temperature, as she refers to water boiling at "30 or minus 30" (swo42posint 037). In her post-visit interview, Neo also added the fact that in the future the sun will expand, contract and "there will be no sun anymore" (swo42posint 153). This is a direct recall of discussion by the HartRAO educators of what will happen to the Sun in the future. I regard all these ideas as being examples of addition of concepts.

Neo's conception of stars also differed after the visit to HartRAO. Prior to the visit, she understood the concept that stars appear so tiny because of their distance from the Earth (although this was not probed in detail), but she believed that most stars are smaller than the sun: "Stars are ... Maybe a little bit ... A little bit smaller than the sun, because the sun is one of the biggest stars." (swo42preint 131) However, after the visit she appeared to understand that star size varies: "Stars are in different sizes, some of them are small, some of them are big, some of them are medium and some of them are bigger than the sun" (swo42posint 077). She also remembered from the visit that stars are spinning, a fact she is unlikely to have encountered previously. Like the facts about the Sun, her increase in knowledge here is incremental, and appears to be occurring by addition.

Neo's understanding of gravity showed little change across the visit to HartRAO as she still believed that there is no gravity in space, or on Jupiter or the sun. She did however change her idea of gravity on the Moon. Whereas previously she believed that there is no gravity on the Moon, and that people float there, after the visit she stated "there's a little bit on the moon about five to six of gravity" (swo42posint 109). At some point, probably during the moon talk during the visit, she heard that gravity on the moon is one sixth of that on the Earth. She would also have seen slides of people walking on the moon, and not floating. I regard this knowledge acquisition as a further example of addition: she has acquired a new fact about gravity, but her overall understanding of gravity has not increased. Her idea of gravity was difficult to establish, but showed a private theory related somehow to heat, as when asked about gravity on the sun, she stated "warm air rises up" (swo42preint 195). Although aspects of her understanding of gravity with respect to the Moon appeared to change slightly as a result of the visit to HartRAO, her overall theory of gravity did not change. This is exemplified by her post-visit response to whether there is gravity on the sun:

Neo: I think there is a bit of, no there is no gravity on the sun because usually warm air rises up, but if there is some gravity there is little because warm air rises up so that's why there is no gravity.

(swo42posint 121)

In HC theory David Anderson refers to this type of knowledge construction as *recontextualisation*, whereby "a previously identified concept" is modified "without significant clarification of meaning" due to the changed context (Anderson *et al.* 2003 p 193). In this example from Neo, she struggles to explain why there is no gravity on the Sun in terms of her own 'theory' of hot air rising, which she expressed in her pre-visit

interview. Essentially she has altered her ideas a little, but her understanding of the concept of gravity has not been clarified.

Neo appeared to show similar recontextualisation in her concept of a satellite. Prior to the visit, she referred to a satellite as being out in space. After the visit, she concentrated her explanation on the satellite dish, and struggled to explain what a radio telescope does, as follows:

Neo: The word satellite it means that, all I know is satellite, but I don't know the meaning. Satellite we have satellite dishes like here in South Africa we have a satellite dish and it's the only one in Africa in South Africa so we get information so some of the, what they usually use it for it's like maybe they turn it on and then maybe it search for the star and maybe that star the astronomy will study that star and tell us more about it, maybe that star is a planet or something.

(swo42posint 093)

I regarded this as recontextualisation as Neo was able to modify her explanation of a satellite dish in the context of the visit to HartRAO. She had now seen a dish used in a new context, and had some idea of what the astronomers were using it for. She was however, but was unable to further clarify her understanding of satellite. When asked about the shape of the dish, Neo was able to explain how the shape enables sounds to be captured.

Neo: It's in that dish-shape so that all the information and all that comes in can get in because if it's straight like that nothing will come in, all the sounds and everything that they hear from space will just float around so that dish causes the information to come in and not to float around.

(swo42posint 097)

I regarded this explanation as an example of differentiation in which Neo was now able to explain how the shape of the dish enabled it to capture "information" and "sounds". Her experience of using the whisper dishes and the HartRAO educator's explanation of how they work may have contributed to her explanation, but she did not refer to these dishes explicitly in her account.

Neo showed relatively few instances of non-cognitive knowledge construction as a result of her visit to HartRAO. In the affective domain, prior to her visit, she stated that Natural Science and Technology were her favourite subjects at school, as one day she "want[s] to go to space and be like Mark Shuttleworth" (swo42preint 223). She also saw the trip as being personally relevant (germane), in that "I want to know more about our world and what's happening outside of our world" (swo42preint 027). Her particular

interest in the topic of astronomy was “The planets. What’s happening on other planets, because there is no life on it” (swo42preint 289). After the visit “I told my mother that we had a lot of fun and we learnt a lot” (swo42posint 169) and she related the use of rockets and the experience of star rotation to her mother. Neo showed no examples of conative learning after her visit.

Neo went on the visit to HartRAO with above-average prior knowledge in Big Ideas. Her pre-visit vocabulary and the ideas she demonstrated on her PMM were relatively restricted, but her understanding of the cause of day and night and the phases of the moon were fairly sound. She was also able to provide a basic definition of gravity, and had a limited but satisfactory conception of what a star is. After the visit Neo’s ideas about the sun, moon stars, asteroids and comets had all changed and been elaborated on. Like Botho, Neo improved her basic science literacy, but did not demonstrate any change in her cultural science literacy (Shen, 1975) as a result of the visit.

Analysing her learning using the human constructivist categories of knowledge construction, Neo’s frequencies for each code are shown in Table 7.14. Like both Nonkululeko and Botho, from a Human Constructivist perspective Neo experienced mainly as addition, in which she has accumulated additional small pieces of information which she has fitted in with her pre-existing knowledge. These include facts about the sun, the stars, comets and asteroids. In several cases she has differentiated this knowledge to clarify her understanding of concepts in a deeper way. For example her understanding of the size of the Sun and sunspots in relation to the Earth, her description of star sizes and her explanation of why the Sun and Moon look the same size in the sky all demonstrate an increased understanding of size and scale. Also, as a direct result of the visit, she developed a new but flawed understanding of sunspots. These examples of differentiation suggest that she is at a different conceptual level from both Nonkululeko and Botho, who showed only one example of differentiation between them.

Table 7.14 Frequency of Human Constructivism codes for Neo

Knowledge construction category	PrePMM & Interview	PostPMM & Interview	Pre Interview	Post Interview	Totals
Addition	n/a	7	n/a	7	14
Emergence	n/a	0	n/a	0	0
Differentiation	n/a	3	n/a	3	6
Discrimination	n/a	0	n/a	0	0
Recontextualisation	n/a	0	n/a	2	2

Knowledge construction category	PrePMM & Interview	PostPMM & Interview	Pre Interview	Post Interview	Totals
Affective	0	0	5	4	9
Conative	0	0	1	0	1
Totals	0	10	6	16	32

Like John (section 7.5.4) and Helen (section 8.1.3), Neo appears to have had some substantial prior experiences on which to base her additional knowledge. Yet she showed no evidence of her recollecting previously-known information (emergence) as a result of the visit. It is possible that my post-visit interview with her was not sufficiently probing to differentiate between addition and emergence. However, Neo did use her prior knowledge, but in two cases she recontextualised it as a result of her visit experiences rather than explicitly stating that the visit reminded her of things she already knew. How should a science centre try to make Neo’s visit most beneficial to her? While it was successful in promoting her knowledge construction in the form of differentiation, I suggest that it should explicitly aim to encourage emergent knowledge. Overt cues and reminders of prior knowledge would stimulate a student such as Neo to relate the new knowledge she is being presented with to her existing conceptual structures. This in turn is likely to cause her existing knowledge structures to be further differentiated, and so promote more effective learning.

7.5.4 Portrait of John (who 16)

Table 7.15 Position of John on Big Ideas classification table

D	2.6-3.0				John
C	2.1-2.5				
B	1.6-2.0				
A	1.0-1.5				
	Post	A	B	C	D
Pre	Mean	1.0-1.5	1.6-2.0	2.1-2.5	2.6-3.0

Table 7.16 John’s knowledge of Big Ideas

Gravity		Star concept		Sun concept		Size/Scale		Sun movement		Moon phases		Parabolic/Satellite Dish		Average	
pre	post	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post
3	3	3	3	3	3	3	3	2	3	3	n/a	3	3	2.8	3.0

John was chosen as an example of a student in the DD category. This means that, according to my analysis of his PMM and interview, he went on the trip to HartRAO already very knowledgeable about Big Ideas in astronomy I am investigating, and could not progress any ‘higher’ in my classification. However, I hope to demonstrate in this

portrait that John did still improve his astronomy knowledge, and was able to remember previously-learned knowledge as a result of the visit to HartRAO. His pre- and post-visit mean scores are very similar to the other 3 category DD students, although his post-visit score is higher (their mean is 2.7).

John is a white, 15-year-old grade 7 student attending Achievement School, a small private school in a Western suburb of Johannesburg. John lives in the same suburb as the school at which he has attended for four years, and comes from an English-speaking home. John drew his PMM on 15th October and was interviewed the following day, in a spare office at the school. He then participated in the class visit to HartRAO on 20th October. I visited the Achievement School on 21st October, and the whole class completed their 'repeat PMM' silently in the classroom, with me present. I re-interviewed John on the same day, so the whole process of data collection was less than one week in his case. John is two to three years older than the other students in the class, and was not regarded as an academic achiever at school.

In his pre-visit interview, John was the only student who had the idea that the visit to one of the study sites would be both educational *and* fun. The majority of students visiting Hartebeesthoek referred to the visit as being educational (88%, n=34), and only referred to fun in the post-visit interview. After the visit, John was also the only student who referred to the 'fun' aspect of the visit without being prompted. In the case of most other students, I specifically asked them if they thought having fun was part of the visit, *after* they had identified the purpose of the visit as being educational. They all answered in the affirmative, that having fun was one of the visit's purposes. It appeared from John's responses to questions that he was only motivated to learn things that to him were interesting and worthwhile, so from his point of view the 'fun' aspect of the trip was very important.

John stated he was interested in the topic of astronomy and space, and found the idea of space exploration fascinating. He was aware that during August 2003 Mars was going to be at its closest to Earth for a long time. He also was aware that a comet or meteor had been close to Earth in the past few years, and he attributed the recent rash of films about asteroid impact to that fact. John did not sound very enthusiastic about school, disliking Afrikaans most, and enjoying science technology and geography (now Human and Social Sciences). As a career, John is interested in becoming a geologist. For recreation John said he likes to read non-fiction, and he stressed that while he is happy to

watch fiction on television he doesn't like it in books as he said "I don't like imagining, I'd rather see it like on TV and stuff" (vho16preint 242). John thinks that primitive life such as micro organisms has been found on Mars as well as comets. He believes that extra-terrestrial life is possible, on the basis that the universe is so big, but he considered that it is unlikely that other life is as intelligent as humans, so the idea of aliens visiting the Earth is implausible. John was fairly scathing about the idea of astrology, his comment being "No, I don't like that, I think that's actually rubbish" (vho16preint 278). However, he considered himself religious, in that he does pray and believes in God, whom he considers created the universe.

In his use of astronomy words and terms John has both a broad and fairly deep knowledge of astronomy as compared with all other students in my study. The broad nature is demonstrated by his knowledge of astronomy-related vocabulary. On his pre-visit PMM he used 36 astronomy-related words, which was the second highest of all students in the study (the highest being 37 words by a student in the same school), and substantially higher than the average for the study (20 words). While his post-visit vocabulary only increased by 14 words, his total for both PMMs was 50, the highest of any student in the study. Further, John used seven words no other student used, such as dark matter, genesis and quasar, as well as six words only one other student used, such as nebula and neutron star. The significance of John's substantially developed vocabulary is that it provides a basis for him to articulate his understanding of concepts as shown in the interviews, and this is discussed in greater detail in Chapter 9. John's depth of knowledge was shown by his ability to discuss complex aspects of astronomy during his interviews.

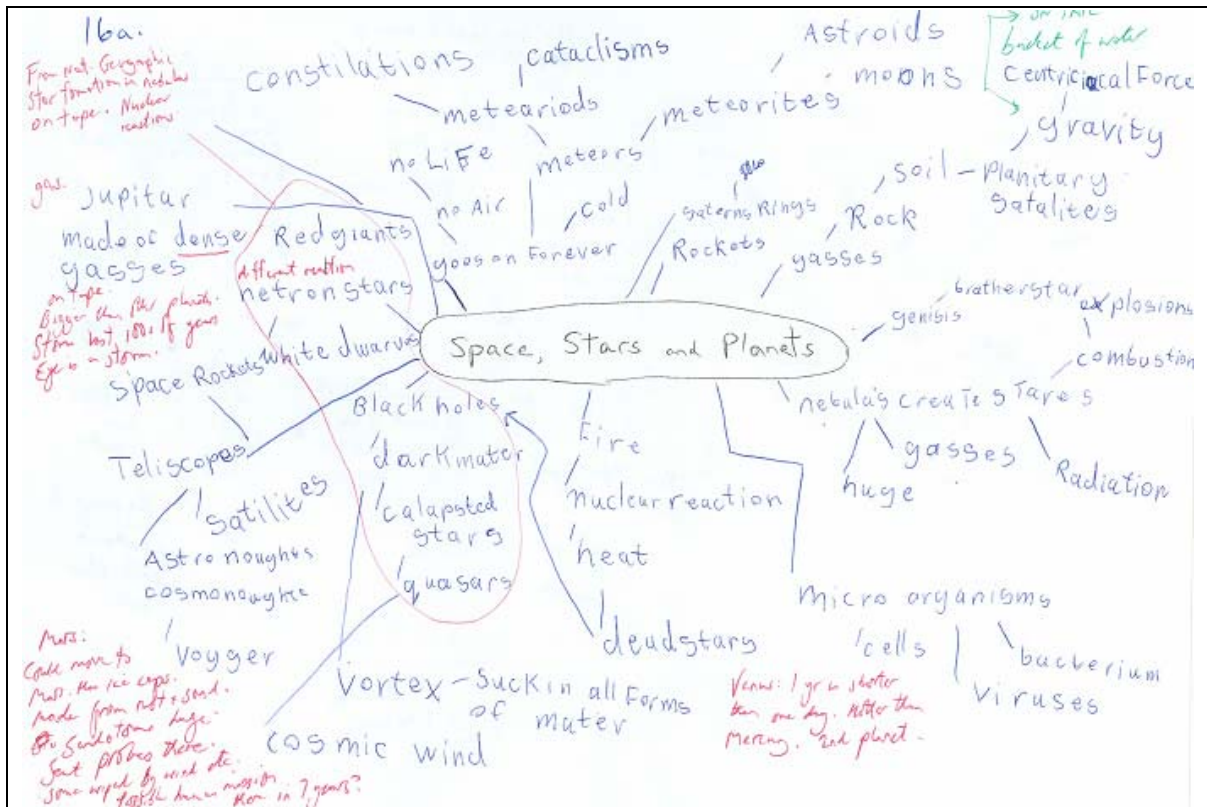


Figure 7.8 John’s pre-visit PMM

John’s initial personal meaning map (Figure 7.8 and Appendix J) was fairly extensive, but consisted mainly of astronomy-related *vocabulary* and did not expand much on the words he listed. During the interview however, he demonstrated knowledge of star formation in nebulae, and explanations for quasars, black holes and neutron stars. He indicated that this knowledge was gained from reading his father’s National Geographic magazine, and looking up the meaning of quasar in a dictionary. He did a project on black holes at school the previous year, and suggested that stars could possibly form within them. His description of star formation, while it referred to “gases and the nuclear reactions and certain different gases reacting with each other” (vho16preppmm 07), did not relate this to any role played by gravity in the process. When questioned about the planets he had written down, he listed facts about Jupiter, Saturn, Venus and Mercury. He had a fairly detailed knowledge of Mars, and again referred to National Geographic as a source of his information.

In the remainder of his interview his knowledge of Big Ideas was substantial when compared to other students. For example, when questioned on the difference between the Sun and the stars many students refer to visible differences, such as size, visibility by day and night, brightness and distance. John however, referred to Sun and stars being basically

the same, but he additionally referred to nuclear reactions causing them to 'burn'. His conception of the Sun was classified as being at level 3, one of only 8 students in the study (24%) who were able to describe the Sun in relatively sophisticated terms prior to the visit.

John however was not scientifically correct in all his pre-visit knowledge, for example he (like many other students) confused the term revolve with rotate. In his pre-visit interview, when asked why the Sun moves across the sky every day, he stated that "Because we are revolving around, no we, the Earth revolves around the Sun" (vho16preint 082). As soon as he was presented with the model Earth and Sun, he demonstrated correctly that the Sun moving across the sky was due to the Earth "turning" (rotating), rather than the revolution of the Earth around the Sun. The introduction of a three dimensional model appeared to be the stimulus for John to be able to correct his initial incorrect response to the question (level 2). Several other students in the study showed this development in their thinking as a result of the use of a model in the interview, and the issue is discussed further in Chapter 9.

Another misconception John demonstrated was that of the cause of the phases of the moon. In his pre-visit interview he referred to the Earth's shadow as being responsible for the change in moon shape over a month, and as he talked he also referred to the phases being caused by the Sun shining on the moon as it orbits Earth. As he spoke during his explanation he decided that the Earth's shadow was only involved in lunar eclipses. Like his explanation of the Sun's movement across the sky, John changed his reason for the phenomenon as his account progressed (even though there was no model of the Moon involved). Unfortunately, I didn't question him about the moon phases in his post-visit interview.

John explained in his pre-visit interview that a satellite is a body orbiting another in space, and that it can be artificial or natural. He understood that a satellite dish points to a satellite in space, and that the shape of the dish is "probably the most efficient shape to receive radio signals" (vho16preint 142). After the visit, John expanded upon his previous knowledge, for example "the bigger the dish the further the distance can be so I think to pick up radio waves" (vho16posint 079). He also was the only student to explain how the Earth is rotating at the same speed that the satellite moves around the Earth, so that a dish can remain in a fixed position (a geostationary orbit). His understanding of size and scale was also classified at level 3.

John's understanding of gravity was extensive before the visit to HartRAO. Without any prompting, he just wrote the word gravity in his pre-visit PMM, but did not elaborate on it. However, he explained in his interview that gravity is a pulling force, and, even before he was questioned about the cause of gravity, he clarified that the pulling force was related to the mass of the planet. He therefore could explain that gravity on the moon would be much less than that of Earth, thus:

John: I know it's one-sixth of Earth's, it's obviously not, you obviously could jump further and things like that.

(vho16preint 178)

He could also explain that gravity on Jupiter would be much higher than that of Earth (or the other planets) due to Jupiter's great size. John was the only student in the sample who, in addition to his knowledge of gravity, could identify that the Earth's gravity caused the moon to remain in orbit about the Earth, and that the moon's gravity caused tides on the Earth. Some students (mostly from John's school, suggesting that had learnt this from the teacher) knew some of the effects of gravity, but John was the only one who prior to the visit had such an extensive knowledge.

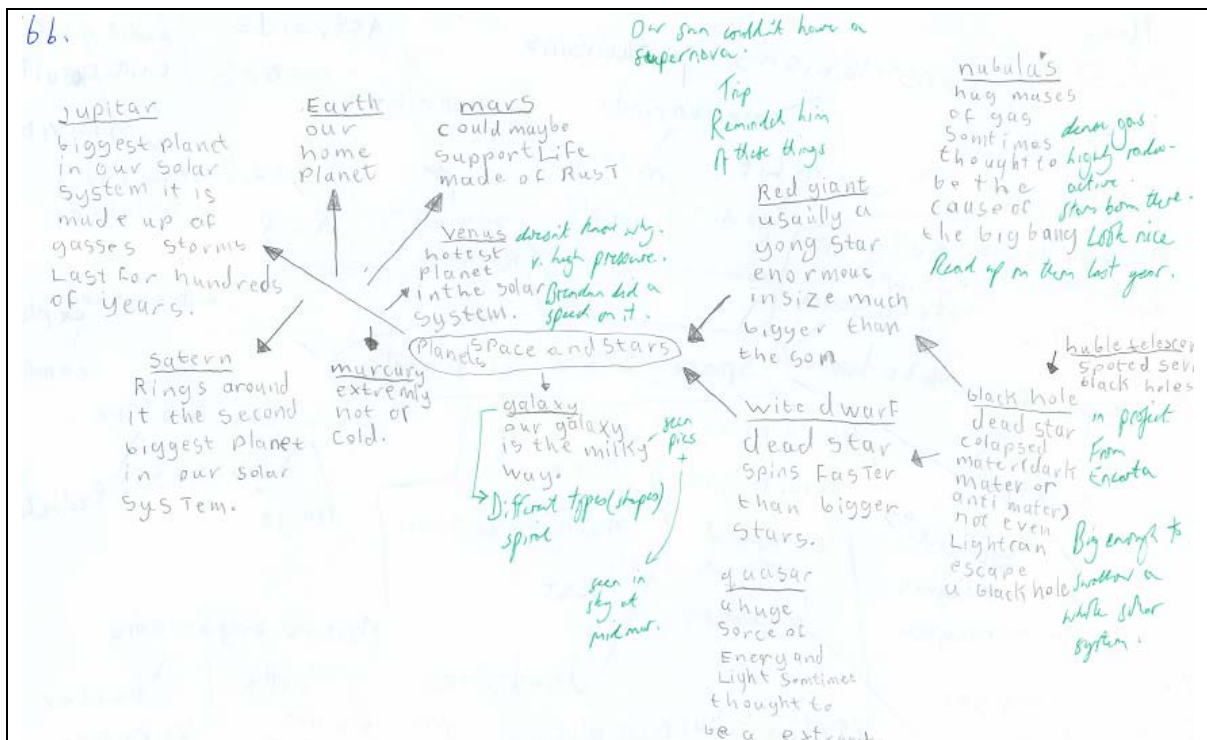


Figure 7.9 John's post-visit PMM

John's pre-visit PMM was so full of words that in his post-visit PMM he used the reverse side of the sheet to make several additions (Figure 7.9 and Appendix J). Six of these were

additional facts about the planets Jupiter, Earth, Mars Venus Saturn and Mercury that he didn't write on the pre-visit PMM. However, most of these new facts were not things he had learnt at HartRAO, as he did discuss some of them in his pre-visit interview. The other additions he made to his PMM were details about different types of stars and other cosmological phenomena: red giants, "wite dwarfs", "quasars", "nubulas" and black holes. He wrote a sentence about each one, and they were further discussed in his interview. What came out in the interview was that he already knew quite a lot about these phenomena, and that the visit had reminded him of his pre-existing knowledge. In the Human Constructivist framework this is an example of emergence, which John showed more extensively than any other student in the study. However, in some cases he combined his prior knowledge with what he knew already and developed his knowledge still further. For example, prior to the visit John already knew about white dwarf stars, which he listed on his PMM but did not elaborate on during the pre-visit interview, although he was asked about them. However, in his post visit PMM and interview John elaborated on them as being dead stars and the fact that they spin faster than bigger stars. This elaboration was a result of the reference made to them by the educator at HartRAO which John referred to in his interview. At HartRAO students were not only told about living and dead stars but also had the experience of spinning like a star on a turntable. For the majority of students, this was merely 'fun' – it was one of the aspects of the trip that three students specifically referred to as being enjoyable – but John could relate his prior knowledge of dwarf stars as being just "small" to the idea that small, dead stars spin faster than larger, living stars. He was then able to elaborate on this in his post-visit PMM and interview, providing an example of differentiation in his understanding of stars.

In his post-visit interview, John elaborated on three aspects of gravity. First he suggested that gravity on the Sun would be very high, and referred to the scales used at HartRAO that indicate a person's weight on a number of different planets (but not the Sun):

John: Phooo... don't remember the exact amount of gravity, but it's way stronger than the Earth's because if you check your scales there's around thousands of scales to the Sun so that must be pulling of gravity.

(vho16posint 099)

Second, when questioned on how the Earth's gravity affects the moon, John referred to Newton ("the guy with the apple") and how he postulated the way in which the moon orbiting the Earth is held in place yet does not fall towards the Earth.

John: But as he said the gravity of the Earth keeps on going fast I've forgotten I'm trying to think how to explain it ja. The gravity of the Earth just keeps on the mass or obviously the apple is going to fall to the ground so the gravity of the Earth. And let's say the moon has fallen and by the time the moon has got so far, where it would have fallen the Earth has already rotated underneath it so then it just carries on.

(vho16posint 107)

John was the only student in the study to be able to describe the concept of freefall. Again, I consider that this is another example of emergence, whereby John is describing the Earth-moon relationship which he has learnt about at some point prior to the visit to HartRAO, but which the consideration of gravity during the visit and my questioning about his understanding of gravity has encouraged him to elaborate on.

Thirdly, John was the only student who understood that everything has gravity, even a human being. In his post-visit interview he stated:

Interviewer: So what, does everything have gravity or is it just moons and planets and Suns?

John: Everything has gravity.

Interviewer: So have you got gravity?

John: Probably a really, really minute amount, but ja.

(vho16posint 121-127)

I did not probe where this idea came from, so it is not possible to tell whether it was prior knowledge (more likely I think) or whether it developed during the visit or questioning.

Regarding the Sun's movement across the sky, John followed a train of thought similar to the one he showed in his pre-visit interview, where he started with the idea that the Earth orbiting the Sun causes the apparent movement, but changed his explanation as he progressed:

Interviewer: And why does the sun move across the sky everyday? What's going on?

John: Because the Sun is going around, I mean the planet is going around the Sun.

Interviewer: Okay and so the night and day is the planet going around the Sun.

John: Yes and the planet turns.

Interviewer: Okay.

John: No, the night and day is the planet turning and the years is the planet going around the Sun.

(vho16posint 041-055)

It seems that during the answering of the question, once the interviewer repeats the answer, John reassesses his idea, and changes it to the correct one, in a similar way that he did in the pre-visit interview. In Chapter 9 I suggest that the use of interview and clarification by the interviewer of what the student has said, allows students to consider their answer and in some cases make changes to it.

So what did John learn on this visit to HartRAO? Table 7.17 provides a summary of his learning from the human constructivist framework. As we have seen, prior to the visit he was probably the most knowledgeable student in the study. Yet, according to his PMMs and interviews, the visit did still enable him to expand further on his pre-visit explanations. According to our definition of learning, this shows that John *did* learn during the visit, but for him, the learning was not so much an increase in factual knowledge (addition), but more an expansion or reorganisation of his prior knowledge. Using Braund and Reiss's definition of learning (2004), John deepened his awareness and ideas, and reflected on his visit in terms of his prior knowledge. In human constructivist terms John only *added* five new pieces of knowledge to his repertoire of facts, but he referred to 12 examples of where the visit reminded him of his prior knowledge, which he then expanded on. In his post-visit interview, John twice explicitly stated that the visit "reminded" him of things he already knew, but hadn't spoken of during the pre-visit interview. According to Falk and Dierking (1997, 2000), learning in museums and science centres is not only about the acquisition of new knowledge, skills and values, but often acts as a prompt for previously-learned facts, which are reinforced by the visit. According to Gallagher (in Falk and Dierking 2000) the physical context of the visit is responsible for the reminder of previously-learned information. This appears to be what happened to John; he stated that the visit reminded him of facts about stars and related details:

John: But some of the things changed like around (inaudible) because I remember ages ago I read about white dwarfs and all that stuff and black holes for a project. Now I forgot about those quite a while ago so now I knew that stuff.

(vho16posint 139)

This also conforms to the constructivist position on the re-construction of knowledge as memories are created, reconstructed and recombined (Roschelle 1995). John, as the student who visited HartRAO with apparently the greatest amount of prior knowledge, was also

the student who drew on this prior knowledge to contextualise what he experienced at the visitors' centre and radio telescope. In Piagetian terms John was *assimilating* knowledge: interpreting the visit experience on the basis of his previous understanding, much of it not remembered until the visit stimulated the memories. According to Piaget, John was fitting new sense impressions into a pre-existing cognitive structure, "building additional understanding and reinforcing known things" (Falk & Dierking 2000, p. 29).

Table 7.17 Frequency of Human Constructivism codes for John

Knowledge construction category	PrePMM & Interview	PostPMM & Interview	Pre Interview	Post Interview	Totals
Addition	n/a	3	n/a	2	5
Emergence	3*	7	n/a	2	12
Differentiation	n/a	1	n/a	2	3
Discrimination	n/a	0	n/a	0	0
Recontextualisation	n/a	0	n/a	0	0
Affective	1	0	6	3	10
Conative	0	1	0	0	1
Totals	4	12	6	9	31

* in his pre-visit interview John referred to how he had used books and other resources in his accumulation of knowledge about astronomy, and the questioning reminded him of this.

But John also needed the appropriate context in which to recall his previous memories, and the context of HartRAO was appropriate for John's emergent knowledge to be expressed. Falk and Dierking suggest that context which mentally cues one individual's memories might not prompt another person, as context is "always relative to the person" (Falk & Dierking, 2000 p. 32). It would follow that science centres will therefore promote emergent learning mainly in those people who have enough prior knowledge for the contextual cues to have some effect.

In conceptual change terms, John showed little affective learning after the visit, with most of the affective categories evident in his pre-visit interview. Similarly, he showed only one example of conative learning, where he referred to 'going on the Internet' and looking at the Hubble telescope photographs of galaxies. All three other students in the DD category showed a greater degree of affective learning than John. They all expressed great interest in astronomy and had stronger feelings regarding what they enjoyed about the visit than John. In this respect therefore, John is unusual: he was exceptionally clear when it came to his emergent learning, but he showed less strong emotions about what he had learnt.

In terms of his extensive background knowledge, John could be said to be already scientifically literate (in astronomy) before his visit, though he did improve this slightly – “small stuff” in his own words. There’s no evidence from his post-visit PMM or interview that he changed his cultural scientific literacy to any extent; again, this was already substantial prior to the visit.

7.6 Discussion

This chapter has described four students in some detail, from Nonkululeko who demonstrated very little prior knowledge of Big Ideas in astronomy, to John who displayed very substantial knowledge. Although categorised as being at different levels, each student described showed little change in their own knowledge of Big Ideas after their visit, suggesting that they hadn’t learnt much in the traditional sense of having assimilated facts about Big Ideas such as gravity and the Sun. With the exception of Nonkululeko, the students appeared to have some personal interest in astronomy, and their memories of the visit related to these interests. For example Botho was interested in stars and Neo in planets. There are however, differences between the students. Both Nonkululeko and Botho had relatively little prior knowledge on which to build additional comprehension of Big Ideas, and their learning consisted mainly of addition, with minimal other cognitive categories of learning. I would suggest that their very lack of prior knowledge in the area of astronomy meant that they were only able to construct additional incremental facts in their cognitive knowledge framework. The same students however, were both able to discuss enjoyable aspects of the trip, although Nonkululeko’s interest in the visit appeared to be minimal. In contrast, given that Botho entered and won a national astronomy competition after the visit, it would appear that students’ interest is not necessarily related to academic learning ability.

Neo and John also showed some similar features of learning. With their greater prior knowledge than Nonkululeko and Botho, both were able to build on what they already knew to not only add to their knowledge structure but to differentiate it. Neo differentiated several areas of her knowledge, including the Sun, stars and the satellite dish, whereas John showed differentiation in his understanding of gravity and stars. Neo however differs from John in that she mainly acquired knowledge by addition, whereas he drew on his very extensive previous reading about astronomy and found that what was presented at HartRAO reminded him of what he already knew, and extended it. In terms of

affective and conative learning, Neo and John showed very similar profiles after the visit, although Neo was more expressive in terms of enjoying the experience at the centre. Neither of them appeared to have been motivated to act on what they had learnt after returning from the visit, but it is possible that additional data collection might have detected this.

In contrast to the students described, who showed no apparent change in their knowledge of Big Ideas after their visit, Chapter 8 describes three students who all demonstrated change in their Big Ideas concepts.

Chapter 8

8 How individual students learnt about astronomy (2)

This chapter describes the learning shown by three students who visited the Johannesburg Planetarium and the Hartebeesthoek Radio Astronomy Observatory. Each of these students showed different levels of prior knowledge, and the portraits show how they improved their knowledge of Big Ideas as well as other aspects of astronomy.

8.1 Introduction

This chapter presents portraits of three students who all lie in the blue part of the classification scheme based on their Big Idea knowledge (Table 7.1), and who all improved their mean ‘score’ after the visit compared with their initial ideas. Chapter 7 showed that even when students did not apparently change their knowledge of Big Ideas, they were able to demonstrate other types of learning as a result of their science centre experience. Such other types of learning might normally be ‘hidden’ if the students are assessed only by traditional methods such as tests or questionnaires of astronomy content. This chapter shows that changes both in knowledge of Big Ideas and in other more individual ways can occur in some students. As all three students in this chapter changed their knowledge of Big Ideas, I have included an additional table in each portrait which summarises these changes.

8.1.1 Portrait of Fatima (scf15)

Table 8.1 Position of Fatima on Big Ideas classification table

D	2.6-3.0				
C	2.1-2.5				
B	1.6-2.0	Fatima			
A	1.0-1.5				
	Post	A	B	C	D
Pre	Mean	1.0-1.5	1.6-2.0	2.1-2.5	2.6-3.0

Table 8.2 Fatima’s knowledge of Big Ideas

Solar System		Star concept		Sun concept		Size/Scale		Sun movement		Moon phases		Average	
pre	post	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post
2	2	2	2	2	3	1	2	1	2	1	1	1.5	2.0

Fatima was chosen as an example of a student in the AB category. According to my analysis of her PMM and interview, she went on the trip to the Planetarium with little knowledge about Big Ideas in astronomy and yet increased her knowledge across nearly two categories: her average Big Ideas knowledge level increased by 0.5, from 1.5 to 2.0, on the borders of A and C. Category AB contains 8 students, and it was difficult selecting one student to represent the whole group. I selected Fatima on the basis that she showed substantial change (only Tlotlo in her category showed greater change with an average knowledge increase of 0.6) and that she was initially not *ignorant* about astronomy, but that she held a number of misconceptions about the solar system and space, many of which changed after the visit.

Fatima is a 14-year-old ‘coloured’¹⁵ grade 8 student and attends Lourdes Girls School, a private school in the western suburbs of Johannesburg. Fatima lives in a suburb in the western part of Johannesburg, approximately 10km from the school, and comes from an Afrikaans-speaking family. Fatima drew her PMM on 9th October and was interviewed on 13th October, the day before she visited the Johannesburg Planetarium as part of the class visit. On 16th October, all the students who had been on the field trip did their repeat PMM during school time and I re-interviewed Fatima on the same day. Academically, Fatima is a very high achiever, getting 85% in her year mark for all subjects in 2003, and it is interesting that this high mark was *not* reflected in her knowledge of Big Ideas in astronomy prior to her visit to the planetarium.

When Fatima was asked whether she was looking forward to the visit, she indicated in the affirmative, but did not appear particularly excited about the prospect of it. For her it seemed to be just a visit the class was going on. She had heard the planet Mars in the news recently “that we would be able to see it like now and then” (scf15preint 134), but she hadn’t attempted to look for it herself. She also remembered Mark Shuttleworth going into space and how “that looked like really cool” (scf15preint 134).

Fatima said that the part of school she liked was having her friends around her and learning about *some* subjects, accounting (which she enjoyed) and history (which she found easy) being her favourites. Conversely she found biology, geography and science hard and not enjoyable. Her recreational activities include gymnastics and reading fiction.

¹⁵ Under the former apartheid system coloured meant a person of mixed race. The designation is used here to indicate the community from which the student comes.

She thought that there might be life elsewhere in the solar system, such as on Mars, but did not believe in life elsewhere in the universe, and regarded the idea of aliens as ‘stupid’. She knew that astrology is “like how the stars and moon and the planets influence their lives” (scf15preint 240), and had some belief in it. As a Muslim she explained how important observations of the Moon are in working out the time for fasting (Ramadan), and stated that she believes Allah created everything.

In her use of astronomy words and terms Fatima’s prior knowledge of astronomy was above-average for the students in the study. Her use of astronomy-related words was 26 in her pre-visit PMM (study average was 20, school average 21), her post-visit vocabulary rose by 7, the same as the average of her school (7.6) and the study (7.2). She was one of only three students who used the words ‘axis’, ‘meteoroid’ and ‘crater’, and the only student to use the terms ‘heavenly body’ and ‘tides’ on her PMM. Her pre-visit personal meaning map (Figure 8.1 and Appendix J) was not extensive, but showed several basic facts. She listed the nine planets and stated that they rotate on their axes and revolve around the Sun. She further listed what you find in space, including planets, comets and galaxies. She stated that stars are balls of burning gas, that they form patterns called constellation and they influence your life. She believed that the biggest star is the Sun. Unlike any of the other students she stated that the Moon has an influence on the tides on Earth. When questioned further about this, she said that she learnt in geography that “some forces ...centrifugal forces, something like that” (scf15prepmm 11) influence tides in the oceans. She could clearly explain the difference between astronomy and astrology, and knew that the former “deal more with scientific things” while the latter “are more on the life” (scf15prepmm 31). She could state a few facts about the planets and knew that galaxies are “clusters of stars” (scf15prepmm 59) and that we ‘live on’ the Milky Way galaxy, a spiral. This PMM and her elaboration in the interview shows that Fatima had clearly learnt quite a lot about basic astronomy, apparently mainly from her school geography lessons, which she professed to find hard.

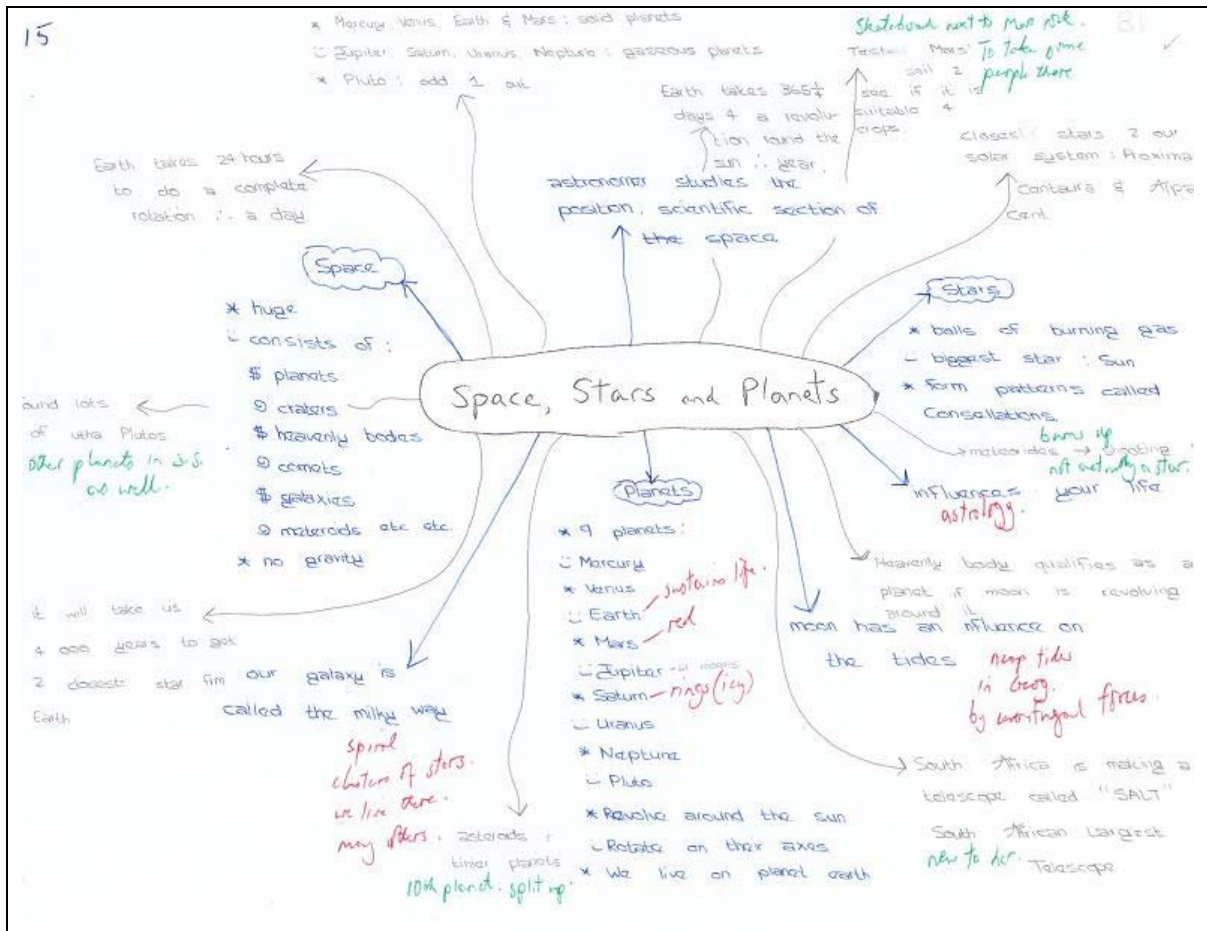


Figure 8.1 Fatima’s PMM (pre- and post-visit)

In her pre-visit structured interview Fatima appeared to have a number of misconceptions about aspects of astronomy. First, although she knew about stars and the names of some constellations, she was unaware that planets are visible in the night sky. Second, she referred to the Earth “rotating around the Sun” (scf15preint 086) as the reason for night and day. Interestingly, Fatima was the only student to correctly state on her PMM that planets “revolve around the sun” and “rotate on their own axes” (scf15pre 27 & 28). However, when asked to explain why the Sun moves across the sky every day, she referred to the Earth ‘rotating’ or ‘moving’ around the Sun as being the reason. She further demonstrated the Earth orbiting the Sun using the model, to explain the Sun’s apparent movement daily across the sky. Third, although she correctly referred to stars as being burning balls of gas, she then added (in response to “what are stars?”) “And then, I think, I think because of the moon’s reflection...” (scf15preint 114) indicating quite naïve thinking about the stars as somehow reflecting light from the Moon. Fourthly, in terms of scale, she had an idea that it would take only about 2 days for a spaceship to reach the nearest star beyond the solar system. The reality is that you can reach the Moon in about 2 days, but it

would take thousands of years to reach the nearest star. She also believed that stars are “smaller thanthe Moon” (scf15preint 118).

After her visit to the planetarium, Fatima added several phrases to her PMM, some of which she elaborated in her interview, including the following: She correctly stated the length of rotation of the Earth being 24 hours, and revolution around the Sun being 365¼ days. She referred to “lots of ultra Plutos” (scf15pos 15), which she explained as “there was like more Plutos that they found, like, other planets I think in the solar system as well” (scf15pospmm 039). She also suggested that asteroids might be the 10th planet which disintegrated. She discussed the fact that Mars’ soil is being tested to see whether it is “suitable for growing crops because they want to take some people up into Mars” (scf15pospmm 053). When asked further about this, she described a probe sent to Mars as being “what looked like a skateboard that went into the rock” (scf15pospmm 057), referring to the planetarium photograph of the NASA Mars vehicle sent in the 1990s. She gave the names of the two closest stars to our solar system – *Proxima Centauri* and *Alpha Centauri* – and stated that it will take 4000 years¹⁶ to reach the nearest one. She distinguished between the inner rocky planets and the outer gaseous ones (although Pluto is the odd one out), and said a body qualifies as a planet if it has a moon orbiting it. She referred to meteorites as shooting stars, and explained that it is not actually a star but a meteor which burns in the Earth’s atmosphere. She also referred the ‘South African Largest Telescope’ as being built, which she found interesting. Several of these facts show that Fatima developed a greater degree of cultural scientific literacy (Shen, 1975) in that the visit stimulated her interest in and appreciation of the achievements of science.

In her structured interview Fatima also elaborated on or changed a number of her pre-visit ideas (Table 8.3).

Table 8.3 Ways in which Fatima changed her ideas about concepts

Concept	Pre-visit idea	Post-visit idea
Planets visible in night sky	Planets not visible	Venus and Mars visible, appearing like stars
Constellation names	Orion, Southern Cross	Orion, Southern Cross, Sagittarius, Libra
Solar system	Sun with the nine planets revolving;	Planets; elaborated on asteroids

¹⁶ This figure is correct only if the space ship used can travel 20 times faster than our current ones, as explained by the planetarium presenter.

Concept	Pre-visit idea	Post-visit idea
	other heavenly bodies: the moon, comets, asteroids, meteoroids, meteors. Shape unsure.	and moons; also included stars. Shape unsure.
The Sun	A star, gives heat and light. Made of gases.	A ball of burning gas, a star and it's made up of hydrogen and helium.
Sun movement across sky	Because Earth moves around the Sun.	Accepted scientific explanation of Earth rotation
Stars	Balls of burning gas and the Moon's reflection. Smaller than the Moon.	As pre-visit, except no reference to Moon's reflection.
Time to reach nearest star	2 days	4000 years
Moon phases	Unsure of reason for phases	Still unsure of reason for phases

Like Helen from the same school, Fatima appeared to have increased her knowledge about several concepts as a result of the visit. Most of this increase appears to be her ability to remember facts she was told at the planetarium. Analysing her learning using the human constructivist framework, Fatima's frequencies for each code (Table 8.4) show that the main HC category of learning that Fatima demonstrated was that of addition, as follows:

Whereas previously she had not known that planets are visible in the night sky, after the visit she stated that Venus and Mars are visible, and that they look 'like stars'. In her post-visit PMM she referred to the 'ultra Plutos' which she clarified as being additional Pluto-like planets found by astronomers. A further fact about planets was her reference to possible crops on Mars and the idea that people might be taken to Mars. As all of these pieces of information featured in the planetarium show, I regard these as new facts that she added to her existing knowledge as a direct result of the visit to the planetarium.

Her knowledge of facts about the Sun increased a little. In her pre-visit interview she had referred to the Sun being a star, giving off light and heat, and made of gases, but she didn't know which ones. On probing, she could also not explain how the Sun gives off light and heat. After the visit, Fatima used the phrase "ball of burning gas" (scf15posint 053), and named the gases as helium and hydrogen. Whereas she used the phrase 'ball of burning gas' for stars prior to her visit, she did not use it to describe the Sun. After the visit she used the expression to refer to the sun as well. I consider that these additional facts that Fatima acquired about the Sun are examples of the HC category 'addition', in that they are small additional facts about a concept she already has some knowledge of. She

remembered from the planetarium that it would take 4000 years in the fastest possible spaceship we could build to reach the nearest star. She had previously stated that it would take 2 days to reach this star, and although she now remembered the new fact, she gave no other indication that her understanding of the concept of the enormous scale of the solar system had increased. In HC terms, she was adding a fact to her knowledge, and showed no sign of knowledge restructuring. Finally, in her post-visit PMM she noted the fact that “South Africa is making a telescope called ‘SALT’ South African Largest Telescope”, and she confirmed in the interview that this was new knowledge.

Table 8.4 Frequency of Human Constructivism codes for Fatima

Knowledge Construction category	PrePMM + Int	PostPMM + Int	Pre Int	Post Int	TOTALS:
Addition	n/a	10	n/a	4	14
Emergence	n/a	1	n/a	1	2
Differentiation	n/a	0	n/a	1	0
Discrimination	n/a	1	n/a	1	2
Recontextualisation	n/a	0	n/a	0	0
Affective	0	0	4	4	8
Conative	0	0	1	0	1
TOTALS:	0	1	5	8	27

Table 8.4 also shows that Fatima demonstrated 2 examples of the HC category emergence: In one respect, Fatima made a substantial shift in her knowledge, and that was her explanation for why the Sun moves across the sky every day. In her pre-visit interview, Fatima explained the Sun’s apparent movement as being due to the Earth “moving around the sun”. When handed the model Sun and Earth, Fatima both confirmed and confused her initial explanation by referring to the Earth “rotating around the sun”, but she demonstrated the Earth’s orbit around the Sun while doing this, suggesting she was confusing the term revolve and rotate. However, in her post-visit interview Fatima referred only to the Earth rotating (this time she demonstrated it spinning on its axis), and in her PMM she described the “Earth takes 24 hours to do a complete rotation [therefore] a day”. She further wrote “Earth takes 365¼ days 4 a revolution round the sun [therefore] year” (scf15pos 9 & 16). Neither of these pieces of information were described in the planetarium show, and the presenter never used the words rotate, rotation, revolve or revolution. Unfortunately, I did not probe Fatima about where these facts had come from, but it is likely that they were previously learnt pieces of information that she remembered after the visit to the planetarium. Both of the facts appear to be the sort of information one learns about in geography, and it may be (but cannot be proved) that the visit triggered their recall. I

therefore consider that her change in explanation for the cause of day and night, from movement around the Sun to the Earth spinning was likely to be the HC category of emergence.

Another additional fact that Fatima appears to have remembered as a result of her visit was regarding a 10th planet. In both her post-visit interviews she referred to the idea that asteroids were probably the remains of a 10th planet, which disintegrated. While the planetarium presenter made several references to asteroids, at no point did she state that they may have been the remains of a 10th planet, and she made no reference at all to a 10th planet, although she did talk about there being “another 600 Plutos” (Lourdes pltm 349) as additional possible planets as part of the solar system. Again, Fatima *may* have heard about the 10th planet elsewhere, and when asked about it after her visit, remembered that the disintegration of an additional planet is one explanation for the presence of asteroids in the solar system. This is again therefore a possible example of the HC category of emergence in Fatima’s experience.

Although Fatima showed mainly incremental knowledge acquisition, and two possible examples of emergence, she demonstrated one instance of what I classified as discrimination, where she restructured her knowledge to demonstrate the similarities and differences between planets. In her post-visit PMM and interview she explained the difference between the inner ‘solid’ planets, and the outer gaseous planets, with Pluto being the “odd one out” (scf15pospmm 011), and referred to the planetarium presenter describing this. She stated “The astronomer at the Planetarium said Mercury, Venus and Mars, they all have one thing in common because they are more solid, and then Jupiter, Saturn and Uranus and Neptune, they are more gaseous and then Pluto they’re not so sure because it’s like the odd one out.” (scf15pospmm 11). According to human constructivist theory, Fatima has established criteria for defining the different types of planet. Whereas previously she was able to list the nine planets, state that they revolve around the Sun, and rotate on their axes, she noted in her PMM her new understanding of the concept of a planet.

Fatima showed no other categories of human constructivist cognitive learning, but demonstrated several ideas which fall into the affective domain. In her pre-visit interview, Fatima made it clear that she disliked school subjects related to astronomy, notably science and geography. When asked why she didn’t like the subjects, she said “I just don’t understand sometimes and it’s harder for me to do” (scf15preint 162). Although she

professed to be looking forward to the visit, she appeared to be ‘lukewarm’ about the prospect. However, after the visit, Fatima expressed that she had thoroughly enjoyed the visit: “I thought it was very interesting because I learnt more things and it’s just very **nice** going there. I enjoyed it” (scf15posint 145). It appears that the visit reinforced Fatima’s personal interest: prior to the visit she stated that the stars interested her, and after the visit she regarded the stars in the dark as being the most enjoyable part of the experience. For Fatima, the situational interest (Hidi and Harachiewicz 2000) promoted by the planetarium experience was congruent with her own individual interest.

There is little evidence that Fatima showed much learning in the conative domain. She had an idea that if she was to teach this topic to grade 8 learners she would do what her teacher was doing, and “take them to the Planetarium and I’d try to make these things more interesting” (scf15preint 212). However, when asked how she might do this, Fatima could not elaborate on what she might do. Unlike some other students, Fatima was not inspired by the visit to carry out any activities suggested by the planetarium visit, although she was interviewed only 2 days after the visit, giving little time for follow-up on her own. In the category of ‘trust’, Fatima expressed her Islamic beliefs, and how important it is to observe the Moon in order to determine the Islamic months, especially the fast.

In summary, Fatima’s main ability after the visit was to remember accurately many of the facts she was shown during the demonstration. While her initial ideas about some of the astronomy concepts were wrong or misconceived, she was able to correct them effectively by the time of the post-visit interview, as she was able to remember much of what she had been told during the visit. This suggests that for visitors such as Fatima, the factual nature of the show was beneficial in terms of learning. Fatima also demonstrated two examples of HC discrimination which were not shown by students in Chapter 7.

8.1.2 Portrait of Brenda (swo70)

Table 8.5 Position of Brenda on Big Ideas classification table

D	2.6-3.0		Brenda		
C	2.1-2.5				
B	1.6-2.0				
A	1.0-1.5				
	Post	A	B	C	D
Pre	Mean	1.0-1.5	1.6-2.0	2.1-2.5	2.6-3.0

Table 8.6 Brenda’s knowledge of Big Ideas

Gravity		Star concept		Sun concept		Size/ Scale		Sun movement		Moon phases		Parabolic/ Satellite Dish		Average	
pre	post	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post
1	2	1	2	2	3	2	3	3	3	1	n/a	2.5	3	1.9	2.7

Brenda was initially chosen as being representative of the 9 students in the largest category: BC. These students went to the science centre with average knowledge of big ideas and increased their knowledge still further. It was difficult to choose a single individual to represent this group, and instead of choosing a student from the BC category I selected Brenda as a student who showed the largest change in score, improvements in 4 big ideas and a significant increase in her vocabulary. Brenda’s knowledge level of big ideas changed from a mean of 1.9 to 2.7, while the vocabulary she used on her PMM increased from 19 to 28 words.

Brenda is a 13-year-old grade 7 student studying at Balfour Forest School since grade 1. She is Sepedi-speaking, and says her family also speak some English at home. She lives in a township in northern Johannesburg and travels to school by minibus taxi each day. Brenda drew her PMM on 8th October and was interviewed on 21st, 3 days before she visited Hartebeesthoek Radio Astronomy Observatory with her class on 24th October. She completed her post-visit PMM on 30th October, and was interviewed the same day. Unfortunately it was not possible to obtain Brenda’s academic record from Balfour Forest School, as computers on which records were kept had been stolen in 2004.

Brenda knew where she was going on her impending visit, and that it was related to science and technology, specifically learning about practical aspects of the Earth, the planets, stars and universe. She said she was looking forward to the visit as it would give her a chance to learn more about the universe. Brenda’s main interest appeared to be in the names of planets and stars rather than scientific aspects of the topic. She said “These planets have got different names from ... I don’t know, I think it’s about Jupiter or Uranus. It was named after the Roman god of the sun or something. I really find their names interesting” (swo70preint 305). She remembered having heard about a meteorite possibly going to hit the Earth (the previous year) but hadn’t heard or read anything else related to the topic of astronomy recently. Prior to her visit and compared to other students, Brenda did not show particular fascination or interest in astronomy as a topic, but appeared to have a focus on astrology and the names of constellations and planets.

Brenda liked her school a lot, and explained that she liked not only learning from the teachers but also going to the library to look up information for herself. She said she liked all her school subjects, and did not have either a favourite or a least-favourite. In her spare time she has violin lessons, attends church and does her homework. Her favourite television programmes are comedies and drama (soap operas) and the most recent thing she had read for pleasure was a novel called *The Witch Child*. Brenda thought that no other life has ever been found beyond the Earth, but that life might be possible on Mars. She emphatically did not believe in aliens, but reads her horoscope and believes that what is predicted does come true for her. She believes in God, but does not think that space and the universe has much to do with God, except that he created them. She also thought that some of the names in the solar system were named after gods, but did not specify which gods.

Brenda's use of astronomy-related vocabulary in her pre-visit PMM was about average for the study at 19 words, while after the visit she used nine additional words, above the average for her school (5.4) and the study (6.8). She was the only student in the study who used the words 'horoscope' and 'Virgo' in her pre-visit PMM, confirming her particular interest in astrology. Her pre-visit PMM (Figure 8.2 and Appendix J) was not very extensive: she named the nine planets, stated that they revolve around the Sun, gave some brief facts (e.g. relative size, position) about Earth, Pluto, Mercury and Jupiter, made some observations about space (no air or gravity), named the Milky Way and referred to constellations as the 'horoscope'. In her interview she could not elaborate on the Milky Way except that its stars are white "and that's why they're called the Milky Way" (swo70preppmm 07). She gave some additional facts about Jupiter, Mercury and Pluto, and when asked what the Sun would look like viewed from Pluto she correctly stated "Very small. Like a small dot" (swo70preppmm 31). This indicates an ability to visualise position and scale from elsewhere in the solar system which is a sophisticated ability. Her capability of roughly estimating scale was further confirmed by the fact that "about ten Earths" could fit into Jupiter (swo70preppmm 53). Brenda remembered seeing the stars signs on a school visit to the bush ('at camp'), including Capricorn. She also referred to Mars being 'researched' to tell whether humans would be able to live there. Brenda stated that the topic of astronomy had been covered "usually every year we do it during the second term" (swo70preppmm 75), and she had clearly learnt quite a few facts about the topic. Her enthusiasm for school indicates that she learns relatively easily.

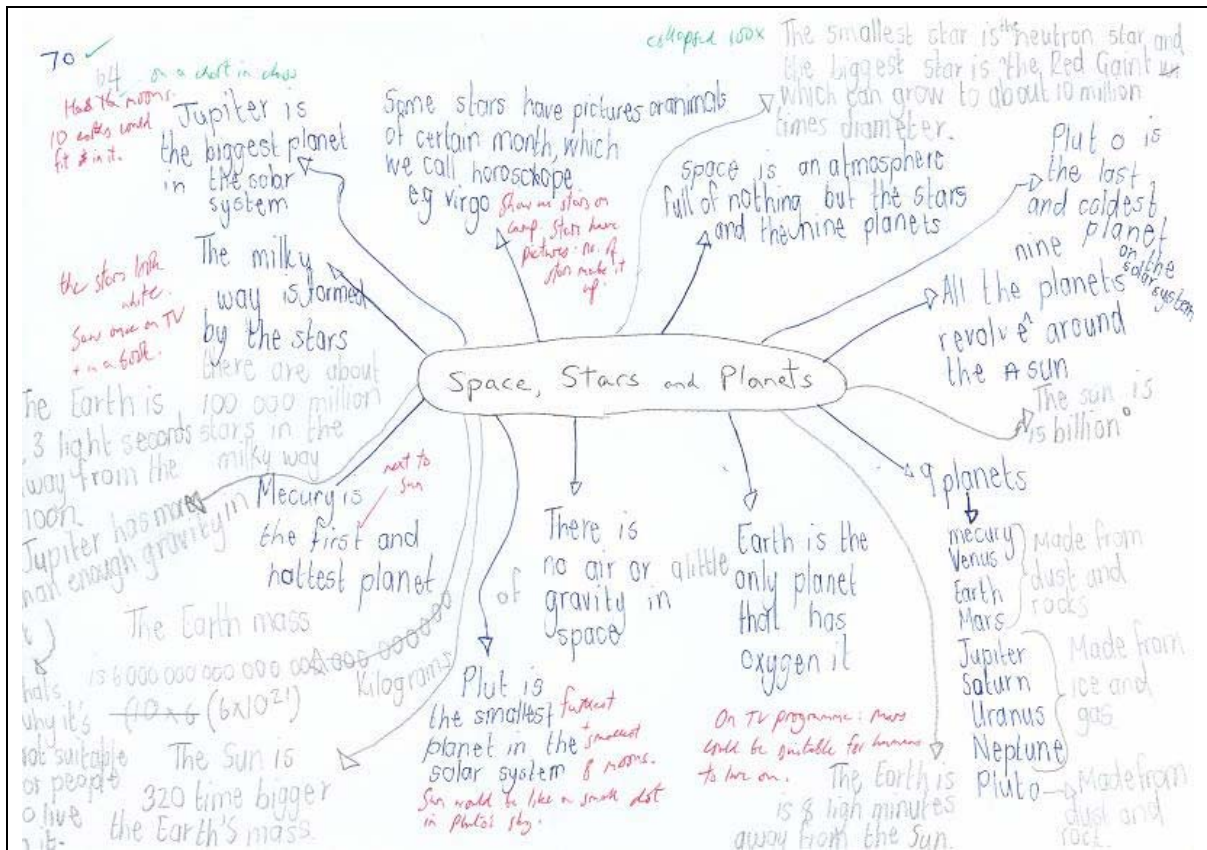


Figure 8.2 Brenda's PMM (pre and post)

Like Botho, in terms of Big Ideas in astronomy Brenda showed different levels of knowledge prior to her visit to HartRAO. While she didn't know much factual information about the Sun, she did know that day and night are caused by the Earth spinning on its axis. She knew that the Sun is bigger than the Moon, but was unable to explain why they look similar in size in the sky. Her concept of stars was quite naïve: she referred to them as 'lights in the sky', and although she understood that they are much bigger 'up close' than they appear in the sky, her idea was that they are about "as big as this room" in size (swo70preint 165). Similarly her idea of what the stars are composed of "When the planets are formed, the pieces that were left over, formed the stars" (swo70preint 169) indicates an unsophisticated notion, and she was classified at knowledge level 1 for stars. Regarding gravity, Brenda's knowledge was also at knowledge level 1, as she knew that it is some sort of pull ("the air that pulls us down from like floating around") and that "there's no gravity is space" (swo70preint 229 & 237). Because of this idea, she did not think there would be any gravity on the Moon or planets. In contrast, her knowledge of satellites was closer to a scientific notion: she knew that a satellite is an instrument in space sending signals. She knew that a satellite dish points to a satellite in space, but could not explain

how the shape of a dish is related to its function. Brenda knew that the phases of the Moon occurred, but could not explain why.

After her visit Brenda added several accurately-remembered facts to her PMM, including the following:

- Neutron stars as collapsed stars and red giants which have expanded massively (“10 million times diameter”).
- Several examples of scale and numbers in the universe:
 - The Earth’s mass as 6×10^{21} kg.
 - The relative size of the Sun and the Earth (320 times in mass).
 - The Earth 1.3 light seconds from the Moon and 8 light minutes from the Sun.
 - 100,000 million stars in the Milky Way
- Differences between the inner rocky planets and the outer gaseous ones.
- The fact that Jupiter has “more than enough” gravity and has 64 not 16 moons.

Similarly, in her post-visit structured interview Brenda had changed some of her knowledge about the big ideas and other concepts in astronomy, summarised in Table 8.7.

Table 8.7 Ways in which Brenda changed her ideas about concepts

Concept	Pre-visit idea	Post-visit idea
Gravity	Pulling force, no gravity in space or on Moon or Jupiter.	Pulling force, low gravity on Moon, high gravity on Jupiter & Sun, related to size, Earth gravity does not affect Moon.
Star facts	Lights in the sky, size of a room, composed of pieces of planets.	Lights in the sky, similar size to the Sun.
Sun facts	The biggest star, Surface very hot, used for energy.	Not the biggest star, surface 5 million degrees, sun spot of 4500 degrees.
Size and scale	Star size due to distance, Sun biggest star, stars size of a room	Star size ~Sun, reference to light seconds, minutes and years.
Day/night	Scientific conception	Scientific conception
Moon phases	Described phases. No explanation.	Not asked
Satellite & dish	Instrument in space, dish points to satellite in space.	As pre-visit.

Her PMM shows that Brenda appeared to be very adept at remembering facts and figures, and most of the knowledge increase she demonstrated on her post-visit PMM I classified as addition: she added several facts, particularly numbers, about stars, the Earth and the Sun to her existing knowledge. When taken together, I suggest that her understanding of size and scale in the solar system has been considerably enhanced by the additional facts learnt. Brenda herself confirmed this later in her interview, where she referred to the size of the Earth in relation to the Sun as being amazing: “I told them about the Earth. Like it’s about 3 and 24 zeros and like the sun eh 320 times bigger than the Earth, it’s very, very big. I couldn’t believe it” (swo70posint 217). Although Brenda does not quite remember the mass of the Earth correctly, and refers to it as 6×10^{21} kg in her PMM and “3 and 24 zeros” in her interview, her conception of the size of the Earth and also the size of the Earth and Sun in relation to each other have changed substantially from her pre-visit interview, where these were not mentioned. Similarly, Brenda has modified her understanding of scale by her reference to light seconds and light minutes. She remembers correctly that the Earth is 1.3 light seconds from the Moon and 8 light minutes from the Sun; facts which were referred to during the HartRAO visit. When questioned about this she demonstrates only a limited understanding of the concept of light seconds and minutes, but appears to have the basic understanding that they are units of distance, as shown in the following exchange.

Interviewer: If you say the sun is 8 light minutes from the Earth. What does that mean?

Brenda: A light minute is equal to 300 000 seconds per minute I’m not sure. Ja.

Interviewer: So what does a light minute mean? What do you actually mean by that?

Brenda: The distance between the sun and light because we do not use kilometres and metres in space. Ja. We use light years and light minutes and light seconds in space.

Interviewer: Right. So that’s a distance. It’s actually a distance. Okay. And it’s a measure of, if it’s a light minute it’s the one minute times what? Times?

Brenda: Times 3, I think it’s 300 000.

Interviewer: Okay. And 300 000 is what?

Brenda: Is 1 light second. It’s equal to 1 light second.

(swo70posint 103-117)

Together, I suggest that these changes in her understanding of size and scale are examples of human constructivist differentiation and superordinate learning. Brenda now has a significantly changed and enhanced understanding which constitutes a differentiated

understanding of size and scale. Brenda has also acquired a completely new concept (superordinate learning) of distance being measured in light units. This new concept includes (or subsumes) concepts of light and time (years, minutes and seconds) which Brenda was previously familiar with. Although I am not convinced that Brenda can explain *how* her new understanding of light units is a measure of distance, I consider that she shows substantial knowledge restructuring. The new concept of light units links to the familiar concepts of distance, light and units of time.

Brenda's knowledge of gravity changed quite substantially after the visit. While she still referred to gravity as "air that pulls us down", she now knew that there is a small amount of gravity in space, on the Moon and a large amount of gravity on Jupiter and the Sun. I regarded her learning about gravity as a form of differentiation, where she has learnt (by addition) some separate facts about gravity, and has modified her concept of it as a result. However, her true understanding of gravity is still quite limited, as she demonstrates in the following exchange:

- Brenda: Ja Jupiter has more than enough gravity. Ja it's not suitable for humans to live in....
- Interviewer: Okay. So what would it be like if we were there?
- Brenda: It would just push us down and up.
- Interviewer: Okay. So if we have gravity like we have here, the moon has a little bit of gravity and Jupiter has a lot of gravity, what's gravity related to? What causes it?
- Brenda: I think it's big and there's enough space for a lot of gravity. You can hold up more than enough gravity.
- Interviewer: Okay. Does the sun have gravity?
- Brenda: I think on the atmosphere of the sun because there's a lot of gravity.
- Interviewer: Right. Okay. Does the Earth's gravity have any affect on the moon?
- Brenda: I don't think so. I don't know.
- Interviewer: Okay. Does the moon's gravity have any affect on the Earth?
- Brenda: I don't think so.
- (swo70posint 149-165)

Like her understanding of size and scale, her appreciation of gravity has been enhanced by the experience at HartRAO, but she still appears to retain misconceptions, such as the fact that it is related somehow to an atmosphere.

Regarding stars, Brenda had a more scientific understanding after the visit in that she now knew that their size is similar to that of the Sun rather than a room: "Some of them might

be big as the sun [some] might be smaller” (swo70posint 085). She was not questioned about their composition or position but she had referred to neutron stars and red giants in her PMM. Although this collective increase in her factual knowledge about stars might be considered an example of differentiation, I do not think there is sufficient evidence in the data to strongly suggest this form of learning. As it stands Brenda’s knowledge of stars has increased, but they still appear to remain separate isolated facts, rather than comprehensive modification of a subsuming concept. In a similar vein, Brenda’s knowledge of the Sun also increased by the addition of new facts. She gave some figures for the Sun’s temperature (ranging from 5 million to 15 billion degrees Celsius) which she did not know in her pre-visit interview. She also referred to the presence of a sun spot (cooler than the rest of the Sun) and the fact that the Sun is not the biggest star, but there are others of a similar size. Again, I regard these as additional incremental facts that Brenda has learnt about the Sun. They may form the *basis* for a changed understanding of the concept ‘Sun’, but currently they remain separate facts about it that she has learnt. Brenda’s knowledge of day and night and satellites did not change after the visit, and I did not ask her about Moon phases in her post-visit interview.

Like most other students in the study Brenda mainly showed examples of addition in her knowledge construction. She accumulated numerous factual pieces of knowledge over the period between her pre- and post interview, and it is likely that the visit to HartRAO was principally responsible for this; only six days elapsed between the visit and the interview. In addition to the examples of differentiation described, Brenda demonstrated one instance of discrimination. In human constructivist terms discrimination is where a learner can identify similarities and differences between closely related concepts. Brenda demonstrated this in her PMM, where she stated that the 4 inner planets are composed of dust and rock, while the 4 outer ones (except for Pluto) are “made from ice and gas” (swo70pos 12). Brenda did not demonstrate many examples of learning in the affective domain: she expressed enjoyment at using the rockets and ‘cellphones’ (the whispering dishes), as well as wonder at the size of the Earth and Sun. Finally, Brenda did show two examples of learning related to the conative domain. She took some pamphlets which were handed to students at HartRAO and said that she had read them, and that “I think I’ve got a lot of information about the galaxies and the stars” (swo70posint 233). Significantly, her visit appeared to provide some conflict regarding Brenda’s religious beliefs and the science she learnt at the centre. In her pre-visit interview she did not think

there is any relationship between God and space, planets and the universe, although she believed that “He created them” (swo70preint 353). However, after the visit she was much less certain of her own views in this regard. She said:

Brenda: Since I went to the trip it’s very complicated because from what I’ve learnt in HSS [Human and Social Sciences] the world started as a small, tiny little thing and the water, that was written by I don’t know who something Darwin, but in the Bible it says it’s Adam and Eve and then comes the planet and all. I think it’s a lot complicating.

Interviewer: Hmmm. So you’re not really sure.

Brenda: Ja I’m not sure. I don’t know which one to believe, the Bible or evolution or something.

(swo70posint 245-249)

This suggests that her trust in the science presented at HartRAO, as well as what she has learnt at school conflicts with her religious belief. Alsop and Watts (1997) include the concept of trust in the conative domain, and I regard her views as significant in that the conflict she is expressing has the potential for further action or consideration on her part. Table 8.8 summarises how Brenda’s knowledge was transformed between the pre- and post-visit interviews.

Table 8.8 Frequency of Human Constructivism codes for Brenda

Knowledge construction category	PrePMM & Interview	PostPMM & Interview	Pre Interview	Post Interview	Totals
Addition	n/a	13	n/a	5	18
Emergence	n/a	0	n/a	0	0
Differentiation	n/a	0	n/a	2	2
Discrimination	n/a	1	n/a	0	1
Recontextualisation	n/a	0	n/a	0	0
Affective	0	0	2	2	4
Superordinate Learning	0	0	0	1	1
Conative	0	0	0	2	2
Totals	0	14	2	12	28

In summary Brenda demonstrated some substantial learning from her visit to HartRAO. In addition to the large number of individual facts she learnt and an extension of her astronomy-related vocabulary, Brenda (like Fatima) showed examples of both differentiation and discrimination. In human constructivist terms these examples of learning suggest greater knowledge restructuring, which is likely to result in more long term learning. Combined with her propensity for memorising facts, Brenda can be said to

have learned very effectively at HartRAO. She mainly improved her “knowing a lot of science” literacy (Durant, 1993) rather than showing any change in her cultural science literacy (Shen, 1975). Brenda’s interest in the topic appeared to be mainly confined to astrology, which was reinforced to a limited extent by the displays at HartRAO, but compared with her considerable cognitive learning, Brenda did not show much in the affective domain. She did however, demonstrate conative aspects which, like her knowledge restructuring, suggest a deeper engagement with the issues presented to her at HartRAO. As a student who went to the centre with some prior knowledge of big and significant ideas in astronomy, Brenda demonstrated an ability not only to extend her knowledge of these ideas still further, but also to combine the incremental additional knowledge she acquired into more substantial knowledge restructuring.

Both Fatima and Brenda demonstrate that the wealth of detailed information presented at the study sites is accessible enough for some students to remember after their visit. In Braund and Reiss’s terms (2004) both Fatima and Brenda engaged with their experience and deepened their knowledge and understanding of astronomy concepts.

8.1.3 Portrait of Helen (scf11)

Table 8.9 Position of Helen on Big Ideas classification table

D	2.6-3.0			Helen	
C	2.1-2.5				
B	1.6-2.0				
A	1.0-1.5				
	Post	A	B	C	D
Pre	Mean	1.0-1.5	1.6-2.0	2.1-2.5	2.6-3.0

Table 8.10 Helen’s knowledge of Big Ideas

Solar System		Star concept		Sun concept		Size/Scale		Sun movement		Moon phases		Gravity		Average	
pre	post	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post
2	2	2	2	2	2	3	3	1	3	3	3	2	3	2.1	2.6

Helen was chosen as an example of a student in the CD category. According to my analysis of her PMM and interviews, like Neo she went on the trip to the Planetarium with above-average knowledge about Big Ideas but unlike Neo increased her knowledge more substantially: her knowledge level of Big Ideas changed from a mean of 2.1 to 2.6. This increase was slightly more than either of the other two students in this category. Her pre-visit interviews show that she held various misconceptions about the solar system and space, some of which changed after the visit, whereas others did not.

Helen is a 14-year-old white grade 8 student and attends Lourdes Girls School, a private school in the western suburbs of Johannesburg. Helen lives in a suburb in the western part of Johannesburg, approximately 10km from the school, and comes from an English-speaking family. Academically Helen is a high achiever, getting an overall year mark of 78% in 2003.

Helen drew her PMM on 9th October and was interviewed on 13th October, the day before she visited the Johannesburg Planetarium as part of the class visit. On 16th October, all the students who had been on the field trip did their repeat PMM during school time and I re-interviewed Helen on the same day. Helen was looking forward to the visit as she had been told by others that “it’s fun” and she expressed a moderate interest in astronomy, finding “some of it” interesting, such as the following extract from her pre-visit interview:

Helen: That how big the universe is and that we don’t even know how far it stretches. I mean we have only discovered Pluto and there’s gonna be more planets after that. We’ll just have to look more to find more things.

(scf11preint 254)

She didn’t recall any space-related items in the news recently. Helen did not profess to enjoying school greatly, and found that being with her friends was the most appealing part of it, as well as writing tests, and receiving (good) marks back from her teacher. Her favourite subjects, in which she gets good marks were Mathematics and Accounting, while Biology and English were her least favourite, and she received the lowest marks for these subjects. It appears that, for Helen, enjoyment of a subject was closely related to her own achievement in it. She attached great importance to her friends, and referred to them on several occasions, including ‘going out’ with them as one of her principal two recreational activities, the other one being reading fiction. Helen’s career plans are to become a lawyer. Although Helen knows that extra-terrestrial life has not been discovered, she thinks there is the possibility of life elsewhere, but does not believe in aliens. She understands that astrologers use the stars according to the time of year to predict the future, and although she states that what they predict is “absolute rubbish” she does read her horoscope, and thinks they sometimes “guess correctly” (scf11preint 278). Helen considers herself religious, and like most students believes that God created everything, including the solar system.

In her use of astronomy words and terms Helen's prior knowledge of astronomy was reasonable, but not substantial. While her use of astronomy-related words was below the average at 16 in her pre-visit PMM (study average was 20, school average 21), her post-visit vocabulary rose by 9, which was above that of her school (7.6) and the study (7.2). Her personal meaning map (Figure 8.3) showed a number of interesting concepts. She referred to the phrase 'light year' in her pre-visit PMM which was used by only three others students prior to their visit, and although she couldn't explain why it is called a light year, did understand that it is a measure of distance. She made reference to distance in space and the solar system four times in her PMM, indicating an understanding of the importance of scale in astronomy. She also stated several facts about various planets, including the interesting observation that "each planet is tilted at a specific degree" (scf11pre 32). In the interview, she stated that this is so that the planets don't "bash into each other" (scf11prepm 03) and also results in the seasons. When probed how this causes seasons she gave a partially correct scientific explanation regarding how the sun shines on either the northern or southern hemisphere. Her understanding of gravity was similar to that of many other students: she understood that gravity is a pulling force, but considered that there is no gravity in space, on the moon or the sun. Her only reference to stars in her PMM was that they produce their own light.

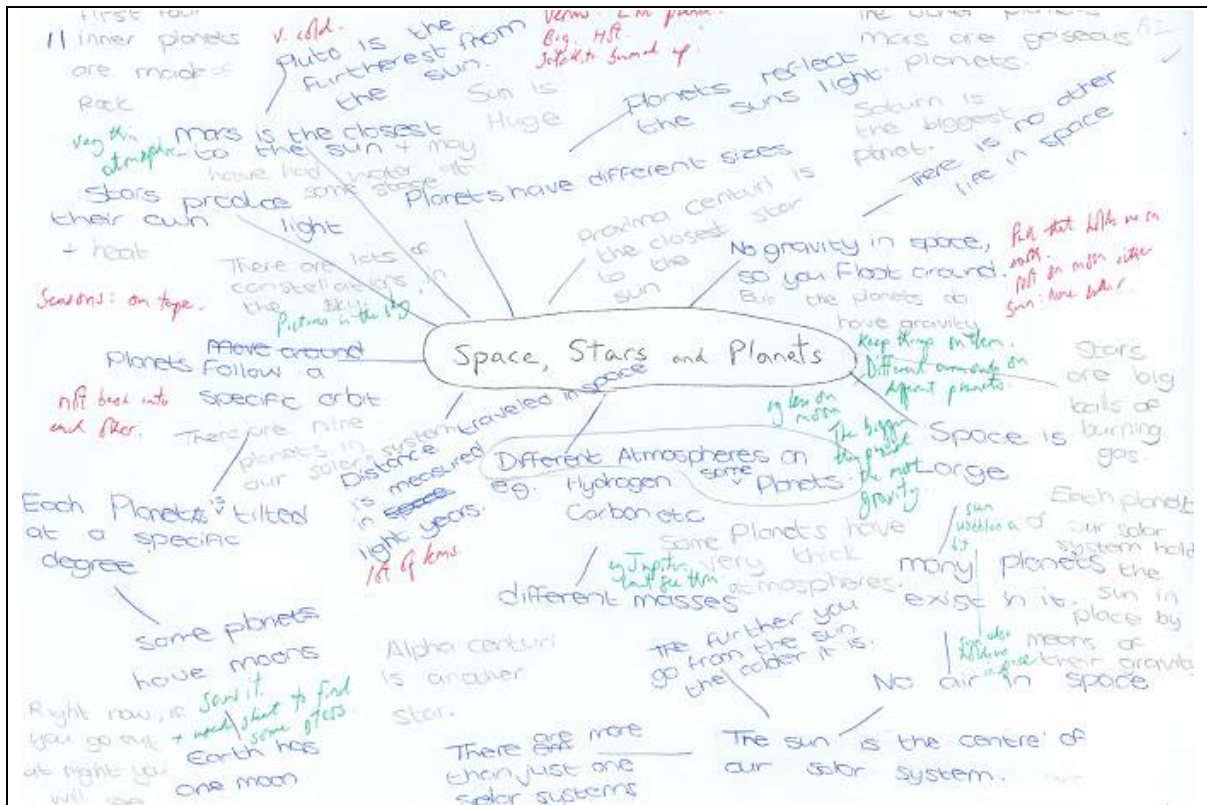


Figure 8.3 Helen’s PMM (pre and post)

In her pre-visit interview Helen demonstrated a number of aspects of her knowledge of astronomy. She knew that planets such as Mars, Jupiter and Saturn are visible in the night sky, and that they appear like stars. Her concept of the solar system was that it is round like a plum, and consists of the sun, nine planets and their moons (level 2). Like many other students, she also considered that ‘the stars’ are part of the solar system. She had a basic understanding of the sun: that it consists of gas, and releases heat and light (also level 2). When asked to explain why the sun moves across the sky, she became very confused, and could not provide a coherent explanation for the phenomenon. Her initial reasoning was that the Earth revolves around the sun, but when provided with a model sun and Earth, she found it difficult to elaborate, except to state that the sun moves from West to East across the sky, and was therefore classified as level 1. She was however, able to explain that the sun and moon look roughly the same size because the moon is a lot closer to us than the sun. Her concept of stars was quite well developed, that they are masses which produce their own light and heat, and that they are very distant from us, resulting in their apparent tiny size (although there are stars the size of our sun). However, she did have one misconception about stars: she thought that they might be made of rock, and did not relate them to being similar to the sun in composition, so was classified as level 2.

Like many students Helen struggled to explain why the moon shows phases, but she did appear to have a scientific idea (level 3), though not well expressed:

Helen: Because, umm, it reflects like the sun's light and its shadow, some, some parts are different, like it revolves around the sun, the Earth...and then the sun's light covers some parts of the moon and sometimes other parts like you can see only one part of the sun.

(scf11preint 182-186)

Helen's concept of distance, referred to in her pre-visit PMM was again demonstrated in her interview, and she guessed that it might take a spaceship about 100 years to reach the nearest star outside our solar system. This indicates at least a partial understanding of the scale in space, which is supported by her concepts of light year and that fact that starlight takes a long time to reach us here on Earth (level 3)

After her visit to the planetarium, Helen elaborated on a number of her pre-visit ideas. In Human Constructivist terms her post-visit PMM (see Figure 8.3) showed several examples of addition, where she listed new knowledge such as:

- The star Proxima Centauri being the closest star to the Sun
- Stars as being burning balls of gas
- Some planets having very thick atmospheres

Several of these additional facts and ideas were elaborated upon in the interview relating to her PMM. She did however, discuss several ideas in her PMM interview which appeared to show more substantial knowledge restructuring rather than simple addition. The main one of these was regarding the concept of gravity. Prior to the visit she had a very limited conception of gravity: that it was a pulling force (on Earth), but that there is no gravity in space, on the moon or elsewhere in the solar system. Her post-visit ideas were very different. First, she explained in her PMM and elaborated in her interview that the sun is held in place by means of the gravity of the planets, as well as the sun's gravity holding the planets in orbit. Although I used this as an example in section 5.6.1, it is worth repeating here:

Helen: Okay. The sun doesn't stand still. It moves around. If you look through a telescope you can actually see it wobble a bit from time to time. And because of our gravity. The sun ... Hold. The sun's gravitation holds us in place, but we also hold the sun in place by our, by the means of our gravitational pull. And the planets.

(scf11pospmm 07)

It is highly likely that Helen learnt this from the visit to the planetarium. The presenter spent some time explaining how the sun's gravity keeps the planets in orbit around it, as well as the idea that the sun is not stationary, but that it is moving in circles pulled by the gravity of the orbiting planets. Secondly, Helen changed her ideas about gravity on the planets in the solar system. In her post-visit PMM she referred to the planets having gravity, and in her interview she expanded on this idea. As she was probed about the concept, her idea developed, and she realised that she 'knew', at least partially, what caused gravity:

Interviewer: And ... Do they have the same amount of gravity or is it different on different planets?

Helen: They're different.

Interviewer: Okay. Why is that? What's it related to?

Helen: I'm not sure.

Interviewer: Okay. Like the moon or ... you don't know?

Helen: The moon is ... If we went like, right here ... Here ... Umm, we ... If, let's say, I weigh 40kg here [on Earth], on the moon I'll weigh about 10.

Interviewer: Okay.

Helen: Because the gravitational pull is less.

Interviewer: Okay.

Helen: And it pulls you more, yeah, it pulls you in.

Interviewer: Okay. And supposing you are on Jupiter? Would it be greater or lesser?

Helen: Greater, I think. The bigger the planet is I think, the more gravity you've got.

(scf11pospmm 45-67)

When asked where she learned what she was explaining, she admitted that she didn't know where, she just 'knew'. What she explained in this sequence was not covered during the visit to the planetarium. Like some other students in the study (for example John and to a lesser extent Fatima and Nonkululeko), the visit appeared to remind Helen of previously-learned knowledge, which she could now relate to the interviewer, but may not have been aware that she 'knew'. This is emergent knowledge in human constructivist terms. Further her relatively sophisticated understanding of the Sun holding the planets in place as well vice versa and additional ideas about gravity on the planets suggests that she has changed her own understanding of gravity sufficiently that differentiation has taken place. Table 8.11 shows Helen's learning classified in HC terms.

In the structured post-visit interview, Helen appeared to have changed her understanding of several concepts as a result of the visit. Some of this appears to be the result of a good memory, for example she remembered the figure given by the planetarium presenter for the time it might take a spaceship to reach the nearest star: 4000 years, as well as the names of stars referred to in the presentation: Alpha and Proxima Centauri. As in her PMM, I regard these as examples of addition, as they involve new facts learnt during the visit. However, Helen also showed two areas in which her explanation for a phenomenon changed considerably. The first of these was her explanation of why the sun moves across the sky. In her pre-visit interview she struggled to provide a clear explanation for this, and was at a loss to demonstrate using the model of the Earth and Sun, despite probing. However, she managed to explain the concept with ease in her post-visit interview, as shown in the following transcript:

- Interviewer: Okay. Umm. Why does the sun move across the sky every day?
Helen: It's because we rotate.
Interviewer: Uh-hmm. Okay. So, with the model we got here. If the sun is there, what's the Earth doing?
Helen: The Earth is going this way like a...
Interviewer: Okay. So what's actually causing the sun to move? Apparently ... Is it the moving round of the sun or is it the rotating?
Helen: Rotating.
(scf11posint 63-65)

This change in her explanation was not probed during the interview, but there are a number of possible reasons for it:

- The pre-visit interview resulted in her clarifying her own understanding after the visit was over;
- She sought out the explanation for herself after the pre-visit interview; or
- The visit helped her to clarify her own understanding of the phenomenon or reminded her of what she had learnt previously.

It is not possible to determine which of these applied in Helen's case, as I did not probe her in the second interview regarding her change in explanation. The first two reasons would be due to the research process itself, while the third could be claimed be a direct result of the visit, possibly an example of emergence. What is clear however, is that her explanation for this phenomenon did change after the first interview.

The second change in Helen's explanation was regarding the moon phases. While her pre-visit explanation had some scientific basis to it, she struggled to explain what she meant so that it was difficult to determine how well she understood the phenomenon.

However, her post-visit understanding was made quite explicit, and was as clear as anyone could be without the benefit of models or drawings:

Helen: Because ... Umm, the moon revolves around us, the Earth. And the sun's light ... Umm how can I say, the sun's light ...OK
You can only see the parts of the moon that ... Umm, the sun, that receives the sunlight. The sun's light. The shadow part you can't see.

(scf11posint 094)

As with her clarification of the sun's passage across the sky, something intervened to improve her explanation, but whether it was the visit or some other intervention prompted by the research cannot be determined.

Table 8.11 Frequency of Human Constructivism codes for Helen

Knowledge construction category	PrePMM & Interview	PostPMM & Interview	Pre Interview	Post Interview	Totals
Addition	n/a	7	n/a	4	11
Emergence	n/a	2	n/a	0	2
Differentiation	n/a	3	n/a	2	5
Discrimination	n/a	1	n/a	0	1
Recontextualisation	n/a	0	n/a	0	0
Affective	0	0	4	3	7
Conative	0	2	0	1	3
Totals	0	15	4	10	29

From an affective perspective, Helen most enjoyed the zodiacal constellation pictures, when they were superimposed on to the stars, and the experience of the planetarium itself. She stated:

Helen: I actually liked the way they made you go inside and that you could actually ... Like you felt like you could feel the planets. That they were right there.

(scf11posint 110)

In other respects however, Helen did not show a strong interest in astronomy either before her visit or when reflecting on it afterwards. The visit did however prompt Helen to take action (the conative dimension). She used the map handed out at the planetarium to look at the stars with her family after the visit. She said "It took me a while to figure it out, after I figured it out and it was very nice. I showed my family how to work out the stars and everything" (scf11posint line 162). She also reported that she saw the planet Mars. Although not voiced in her interview, this suggests at least a moderate interest in the topic

of the visit, as relatively few students were motivated to use the star charts provided by the planetarium.

Early on in the analysis Helen was chosen as an example of a student with considerable prior knowledge. However, she actually showed a relatively incomplete understanding of several astronomy concepts such as the Sun's apparent movement, gravity and star composition. Although she appeared to be moderately interested in space and astronomy, Helen's personal interest in the topic was not as high as several other students, such as Fatima or Botho. Despite this, the visit somehow made a significant difference to her understanding of aspects of astronomy. As well as a number of basic 'facts' that she remembered as a result of the visit, such as names of stars and facts about the planets, Helen seemed to have acquired a greater understanding of (and an ability to explain the movements of) the sun and the moon and how gravity works within the solar system. In human constructivist terms her increased knowledge and understanding by processes of addition, emergence and differentiation were built on a relatively sound foundation of prior knowledge which was more substantial than most other students. Given Helen's high academic achievement, it is likely that her emergent knowledge was greater than described here, as (unlike John) she didn't voice it.

8.2 Discussion

Brenda, Fatima and Helen show some similarities in their learning in that they all demonstrated greater change in their knowledge of Big Ideas than the students portrayed in Chapter 7. While the great majority of their knowledge was constructed using the process of addition, they also showed examples of differentiation and/or discrimination. They all appeared good at remembering specific facts presented to them during the visit, not just about Big Ideas, but in other areas related to astronomy. They also showed some interest in the visit, but none had a strong interest or fascination with astronomy. There were also some differences between them: while Fatima and Helen showed examples of emergence in which their pre-existing experience of astronomy was recalled as a result of their visit to the science centre, Brenda did not. Fatima and Brenda did not produce very detailed pre-visit PMMs, and they presented basic facts only. In contrast Helen's PMM was more extensive containing references to more unusual concepts such as light years, distances and numerous facts about planets. The main difference between the three of them was that

Fatima had many misconceptions prior to her visit, Brenda had fewer misconceptions but limited knowledge, while Helen had a substantial knowledge base.

Looking across all seven portrait students, Brenda and Helen's (and to a lesser extent Fatima's) depth of knowledge of Big Ideas such as gravity, day and night and the Sun has shown greater change than Nonkululeko's and Botho's. This change has resulted in limited but crucially different learning. In addition to the accumulation of several additional facts about astronomy both Brenda and Helen have managed to build on their knowledge structure in limited areas, enabling a greater degree of restructuring than was demonstrated by Nonkululeko and Botho. Neo and John, although they did not change their knowledge of Big Ideas to any great extent, had sufficient prior knowledge also to be able to learn using differentiation. While addition was common to all students, only students with sufficient prior knowledge were able to restructure their conceptions in the relatively complex ways demanded by differentiation and discrimination. Nonkululeko, Fatima and Botho showed the least prior knowledge of Big Ideas, while Neo, John, Brenda and Helen showed considerably more. I consider this difference a significant one which differentiates students who gain more from a science centre visit from those who show more limited knowledge construction. Both types of students learn by the process of addition, but those who are able to learn by the complex processes of differentiation (and discrimination) appear to show greater learning, and this is dependent on the degree of prior knowledge the student possesses. However, individuals learn in very different ways, and although prior knowledge plays a part, students' own personal interests and other factors not examined here also influence their learning. With the exception of Nonkululeko, all students had some degree of interest in the visit, and the context of each study site reinforced their interest to some extent. In terms of scientific literacy, all students improved their basic knowledge of astronomy ('knowing a lot of science') while only Fatima (and possibly Nonkululeko) showed any improvement in cultural science literacy (Shen, 1975).

This chapter has described in detail three students in terms of both what they knew and how they learned about astronomy during their visit to a science centre. It completes the main findings of the study which show the complexity and idiosyncratic nature of learning during a school visit. Learning is such a complex phenomenon that although I have been able to identify trends in learning and relate them to aspects of students' prior knowledge and interest, I have not determined straightforward relationships between particular

features of learners (e.g. the complexity of the PMM) and how they learn. Chapter 9 draws the threads of the findings presented in Chapters 4 to 8 together, and highlights issues of importance identified.

Chapter 9

9 Discussion and Implications

This chapter provides a summary of my study which draws discussion from the preceding chapters together and examines implications for the fields of astronomy education and museum research, for the science centres involved in the study and for methodology. It ends with a list of recommendations derived from the implications and suggestions for future research.

9.1 Introduction

Since Champagne's article three decades ago (Champagne, 1975) there have been questions regarding whether people visiting science centres actually learn anything or whether they 'just' enjoy themselves. Differing views on learning have been presented, from those of Uzzell (1993) and McClafferty (1995), who suggested that traditional learning of facts does not occur, to those of Falk & Dierking (1992) and Anderson & Lucas (1997) who suggested that to look for traditional learning is inappropriate for such contexts and the definition of learning should be broadened. Although the latter view has had more influence over the past decade, some scholars still contest whether learning *does* occur and have proposed using the term 'outcomes' instead of 'learning' (Ansbacher, 1998b, 2002a). The main aim of my study was to determine the extent to which learning occurs during a school visit to a science centre. My findings demonstrate evidence for learning by a number of psychological processes in the cognitive, affective and conative domains.

My thesis has highlighted aspects of learning about astronomy and processes of learning in museums and science centres. Discussion of my findings is presented in the following sections, in order of importance:

- Big Ideas in astronomy: how they can be used to structure learning the content of astronomy in the context of a science centre.
- How learning occurs during a visit to a science centre from a human constructivist perspective and the role of prior knowledge and interest in learning.
- Methodological Findings

- Misconceptions in astronomy and how a science centre can address (or impart) such misconceptions.
- Science Literacy.
- The role of vocabulary in learning.

In this chapter I examine each of the above issues and demonstrate how the findings in previous chapters help to answer my research questions and illuminate important topics and concerns in the areas of astronomy and informal learning. In the penultimate section, I address the implications of the findings for the science centres involved in the study and for the school curriculum. Finally I reflect on my study, both from a methodological and personal viewpoint.

9.2 Big Ideas in astronomy

9.2.1 Gravity

As explained in Chapter 5, I used the notion of Big Ideas in astronomy as a way to structure how I examined student learning in a science centre. For a full understanding of astronomy, by far the most important concept for students to learn about is the concept of gravity (Zeilik, 1994). Gravity differs from the other Big Ideas in that it is the only concept which is a true theoretical notion, rather than a tangible object (e.g. a star) or a comparative perception (e.g. size and scale). Gravity was addressed differently in the two study sites: at the planetarium there were a number of video sequences showing its effects and the presenter referred to the concept many times. At HartRAO there were several activities which involved gravity, but the educators did not draw as much attention to its importance in astronomical processes as was done in the planetarium. My discussion of how the students collectively learnt about gravity concentrates on HartRAO as the students visiting there were the ones who were questioned about their knowledge of gravity, while only Helen at the planetarium discussed gravity in detail, as the result of her writing about it in her PMM.

I found that all students except Nonkululeko had some idea about gravity as a pulling (or in some cases they referred to it as a pushing) force prior to their visit to the centre, and that they did not significantly change this idea after the visit. I attributed this to the fact that the centres dealt with the *effects* of gravity rather than attempting to provide a definition for it. What *did* change after the visit was that as a group the students moved to a more scientific

knowledge of gravity: prior to the visit 93% were classified as being at knowledge levels 1 and 2, whereas after the visit 77% were at levels 2 and 3. Similarly, there was a trend towards knowing that gravity on Jupiter is high and that the Moon has relatively low gravity. However, although there was a trend towards greater scientific knowledge of gravity, few students after the visit really *understood* what causes gravity. These findings suggest that by a series of activities and demonstrations, students' understanding of gravity can be encouraged to change, but that a more coherent and integrated effort needs to be made by the centre if true conceptual change is to occur. This suggestion reinforces the view of Feher (1993) who, in her critique of Borun's work on gravity misconceptions in a museum (Borun *et al.* 1993) suggests that only by using "networks of exhibits" (p 247) can visitors make better connections for themselves and "reorganize their ideas and construct new understandings" (p 247). In this respect, HartRAO is making a good contribution to this type of learning: it provides a series of related exhibits on the theme of gravity which appear to assist students to make some of the connections suggested by Feher. However, my view is that the exhibits could themselves be more conceptually connected with each other, and encourage the learner to relate (for example) their experience with the rockets to the Coke tins and the gravity scales. In the context of visits by school groups, this would mean that the HartRAO educators could draw attention to the relatedness of the activities and encourage the students to themselves form connections. I don't suggest this would *guarantee* a greater understanding of gravity, as such a complex and non-intuitive concept is always going to be difficult to comprehend. However, it does give a greater chance for understanding to take place, especially if built upon by the teacher on return to school.

9.2.2 Stars and the Sun

The stars and the Sun were addressed in very different ways in the two study sites: they formed a constant backdrop at the planetarium, and aspects such as names, composition, formation and distance were discussed. In contrast at HartRAO activities using the Sun's shadow and image as well as an activity related to star size and density were demonstrated. My study found that while students were able to provide a greater scientific knowledge about the Sun after their visit (change from 26% to 50% of students at knowledge level 3) there was less change in the case of stars (change from 6% to 9% at knowledge level 3) although students did move away from a minimal knowledge level. To some extent this is to be expected, as my criteria for knowledge level 3 for stars was more rigorous than for the Sun, and while both study sites provided demonstrations or activities on both, students

are likely to be able to relate more easily to the Sun given its importance in daily life in comparison to stars (Sharp 1996). For students to gain a full scientific understanding of stars in terms of their composition, position and size is likely to be beyond the scope of either the planetarium or HartRAO unless these concepts are prioritised as being important issues for school groups to learn about, which is probably not the case. In my analysis I have used stars and the Sun as a Big Idea in astronomy which I consider crucial for students to know about. I would suggest that the centres identify fundamental knowledge about the star-Sun concept that they want students to gain understanding of and use this as a basis for the development of a web of activities related to the concept. In the same way that a series of related exhibits or activities on gravity appeared to change students' knowledge quite effectively, so too could a similar themed set of items on stars and the Sun. These might include existing presentations such as star and Sun distance and appearance and uses, as well as additional evidence for their similarity (stars as suns and vice versa) and their massiveness and the gravity they possess. Again, I strongly recommend follow-up at school by the teacher.

9.2.3 The Solar System

While I identified the Solar System as a Big Idea, both the planetarium and HartRAO used it more as an organising principle than as a specific topic within their displays or as a concept in astronomy. At the planetarium the presentation was called the Solar System show, while at HartRAO facts about the planets and the relative distances was presented when the Solar System was "taken for a walk" to demonstrate its scale. My specific questioning about the Solar System of the students who visited the planetarium was not very effective, and the results do not demonstrate any insights into the eight students' ideas of the concept 'Solar System'. Instead, much of what students know about the Solar System was captured from their Personal Meaning Maps, where the majority listed the names of the nine planets and sometimes some facts associated with each. In these, students showed they could remember a number of additional facts about the planets, such as Mercury's proximity to the Sun, Jupiter's size and Pluto's remoteness. There is very little research published on people's knowledge of the Solar System, so comparison of my findings with the literature is not possible. My results therefore do provide some baseline data on children's knowledge of the Solar System to add to the work by Treagust and Smith (1989) and Sharp (1996).

As a Big Idea, I would suggest that the concept of the Solar System not be confined to factual information about the planets which make up our Solar System, but stress it as a principle in cosmology, as was done in the planetarium, that other stars are likely to have their own solar systems. This is relatively recent science which is not in the current school curriculum but is highly relevant to both the planetarium and the sort of research carried out at HartRAO.

9.2.4 Size and Scale

I consider that if students leave an astronomy science centre with only two major impressions they should have a better understanding of both gravity and the size and scale of our planet, the solar system and universe. From a conceptual viewpoint therefore, I believe that gravity and size and scale are the most important Big Ideas related to astronomy for students aged 12 to 15 years. Both the study sites incorporated size and scale into several aspects of their work, with the calculation of the distance to the nearest star (outside the solar system) at the planetarium and the pacing out of the distances between the solar system planets (at HartRAO) being the most prominent. My findings showed that students' appreciation of aspects of size and scale changed quite substantially from the pre- to the post-visit. Prior to the visit 80% were at knowledge levels 1 and 2, while after the visit 53% were at levels 2.5 and 3, suggesting that the sites were able to effect not just an increase in knowledge (such as the relative sizes of the Earth, Sun and Moon) but a deeper understanding of scale. A clear example of this is where Julius referred to the Sun being much bigger than the stars in his pre-visit interview, whereas after the visit he stated "[the Sun is] much closer than other stars that's why we see them as if they're very small because they are much further away from the Earth and the sun is the closest to the Earth that's why we see so bright lights" (swo36posint 030).

As I discussed in section 5.4.4, there are different views in the literature whether students of age 12 to 15 years are capable of comprehending the massive sizes and scale involved in astronomy. Given my findings that students are able to improve their understanding of size and scale after the visit I would claim that for students of this age group it *is* appropriate to cover this concept. Sadler (1998) disputed this, but provided limited evidence in his paper as support, and examination of the test he conducted has proved difficult, as it was never made widely available (Hufnagel, 2002). Like the concept of gravity, the approach by the study sites to provide a variety of experiences related to

size and scale is likely to be the most appropriate way of building students' knowledge and understanding of size and scale. Such an approach is supported by constructivist pedagogy, in which new knowledge is mediated by an educator, who provides a form of scaffold to enable learning to take place.

9.2.5 Day and Night

In Chapter 5 I identified the concept of day and night as a significant idea in astronomy which, in contrast to the Big Ideas, has been extensively researched over three decades. At both the study sites, the spinning of the Earth was referred to but not overtly stressed: at the planetarium the star projector speeded up the movement of stars across the sky on several occasions to demonstrate a particular point. At HartRAO the spinning was briefly discussed when the image of the Sun was projected, and when the sundial was being demonstrated. My findings show that there was little difference in students' understanding of day and night as being due to the Earth's spin from pre- to post-visit, with only two students moving from knowledge level 1 to either level 2 or 3. I believe that part of the reason for this limited change was because prior to the visit 74% of the students already understood the cause of day and night. Further, as the demonstrations and activities at the study sites did not highlight the Earth's spin with respect to night and day, students who struggled with the concept prior to their visit were unlikely to change it as a result of the visit. The fact that three students did change their views may have had more to do with emergent knowledge than knowledge at the visit being imparted. It is also important to note that one student (Batsile) changed from level 3 to level 1; a rare case of Big Idea knowledge being confused by the visit. My findings confirmed those of several other researchers (e.g. Sadler 1998; Dove 2002) that students of early teenage are aware of the cause of day and night, and that the most common misconception is that it is caused by the Earth orbiting the Sun. My findings on this Big Idea however are more revealing in terms of the use of a model in the research process, and the use of terms such as rotate and revolve, and these issues are discussed further in section 9.4.1.1.

9.2.6 Moon Phases

Like 'day and night' people's understanding of the phases of the Moon has been extensively researched over the past few decades, with most studies showing that true understanding of why they occur is rare unless specific instruction has been given. Although the Moon was discussed at both study sites the phases themselves were not

explained by the presenters, and I thought it unlikely that students would have a different understanding after the visit of why the phases occur. This was borne out by the findings, which show that 73% of the students (n=34) are at knowledge level 1 and 2 prior to the visit, and 74% (n=19) at the same knowledge level after the visit. Findings by other researchers show that people hold a number of misconceptions about the Moon phases which are persistent despite instruction, and I discuss some of these misconceptions in section 9.5.

9.2.7 Satellite/Parabolic Dish

Hartebeesthoek Radio Astronomy Observatory is dominated by the presence of the radio telescope, and part of my investigation involved whether students' knowledge of a parabolic dish would improve as a result of the visit. At HartRAO, as well as being shown how the radio telescope works students were given the opportunity to use whisper dishes whose parabolic shape works in a similar way to the telescope. The only published research study using whisper dishes determined that many visitors were unable to use their prior knowledge of reflection and focussing to explain how they work (McClafferty 1995). My findings show that while 92% of students were at knowledge levels 1 and 2 prior to the visit, 42% had changed to levels 2.5 and 3 after the visit, suggesting some shift in their own conceptions. Of the 42%, 23% (5 students) did need considerable probing for me to determine the extent of their knowledge about the dish, and it is possible that the students were more conducive to probing in the interview after the visit. They were now meeting me for the third time, and maybe felt more at ease to explain their thinking to me. This issue is explored further in section 9.4.1.3.

My suggestion is that HartRAO should take the opportunity to work more with the artefact of the parabolic dish so that students leave the site with a greater understanding of how it works. During the whisper dishes activity, the educator does relate the shape to the same shape of the reflector in a torch and car headlights, but also brings in the idea (jokingly to some extent) that students are using a cell phone. Jokes however, can have a detrimental effect on learning. Examining learning in a planetarium, Fisher (1997) found that visitors who saw a humorous show scored lower in a post-visit test than those who saw a non-humorous show. The educator also provides a small sign which explains how the whisper dish works, as well as pointing at the radio telescope and making a reference to DSTV. However, I suggest that additional *activities* could be provided that relate the

whisper dishes to DSTV satellite dishes (which all students are familiar with), other satellite dishes (such as those of telecommunications as seen on the hill when approaching HartRAO), parabolic solar cookers, as well as the 26 metre telescope itself. Depending on the grade level of the children, discussion could relate the light reflected by a torch reflector to sounds reflected by the whisper dish, electromagnetic signals of satellite dishes, heat reflected for cooking, to the faint signals from stars. In this way a series of activities (like those I have explained for gravity or stars and the Sun) could build students knowledge of parabolic dishes from a variety of perspectives to enable them to leave the site with an enhanced knowledge of dishes.

9.3 How Learning Occurs

Chapter 6 explained how I used my framework of human constructivism theory to analyse my data, and Chapters 7 and 8 described in detail how seven case study students learned during their visit. In human constructivist theory learning takes place by small incremental additions of knowledge by people, and, less commonly, by more substantial knowledge restructuring (Mintzes *et al.* 1997).

9.3.1 Cognitive Learning

From a cognitive viewpoint and based on previous human constructivist studies I used 6 categories of learning: addition, emergence, differentiation, discrimination, recontextualisation and superordinate learning. Table 9.1 shows the total number of instances of these categories of learning as shown by the case study students. Each instance of learning was recorded in either the student's PMM or interview, and in a few cases an example of learning might be recorded twice. For example Fatima noted on her PMM that the closest stars to our solar system were Alpha and Proxima Centauri and that fact was coded as addition. Further, she also briefly discussed the same issue in her interview, and it was again coded as addition. However, the table gives an approximate estimation of the frequency of cognitive learning categories identified.

Table 9.1 Summary of cognitive learning by case study students

Learning category	Nonku luleko	Botho	Neo	John	Fatima	Brenda	Helen	Totals	Percentage
Addition	14	13	14	5	14	18	11	89	68
Emergence	2	0	0	12	2	0	2	18	14
Differentiation	0	1	6	3	0	2	5	17	13
Discrimination	0	0	0	0	2	1	1	4	3

Learning category	Nonku luleko	Botho	Neo	John	Fatima	Brenda	Helen	Totals	Percentage
Recontextualisation	0	0	2	0	0	0	0	2	1.5
Superordinate Learning	0	0	0	0	0	1	0	1	0.8
Total	16	14	22	20	18	21	19	131	~100

The first feature that Table 9.1 demonstrates is that learning at the study sites was highly individualised and variable across the case study students, most of whom showed a range of learning types across the cognitive, affective and conative domains. In the cognitive domain addition refers to simple acquisition of facts about phenomena which a learner acquires incrementally over a period of time. In my study, this was by far the most common form of learning at both study sites. With the exception of John, all case study students showed from 11 to 18 examples of addition as a result of their visit, and this category forms two-thirds of the learning types observed across all the case study students. The importance of the process of addition cannot be underestimated. One of the common perceptions of learning in science centres is that ‘real’ learning as shown by the acquisition of knowledge is minimal, while other forms of learning such as a change in attitude or feelings is more common (e.g. Ansbacher, 2002b; Jarvis & Pell, 2005). However, my study confirms what Anderson (1999) demonstrated in his Australian study, that the incremental learning of numerous individual facts accounts for a substantial proportion of the learning when a school student visits a science centre. Further, my study suggests that these facts are accumulated as a direct result of the visit, without any preparation by the teacher or any follow-up activities after return to school. Others (e.g. Braund, 2004) have recommended that follow-up activities are an important part of the learning process, but my study suggests that learning in the form of addition *will still occur* in science centres such as those visited as stand-alone visits.

Discounting John’s figures, the second most common category of learning was differentiation, in which the learner creates a more complex understanding of a phenomenon by acquiring new concepts subsumed under a more inclusive concept. With the exception of Nonkululeko and Fatima, all case study students showed at least one example of differentiation, with two students, Neo and Helen, demonstrating 6 and 5 instances respectively. As I explained in Chapter 6 the main difference between addition and differentiation is that in the former, the facts are learnt in isolation, and the student does not make any connection between them, so they remain isolated additional facts.

However, in the case of differentiation, the knowledge is combined into a whole resulting in the development of understanding of a concept in terms of the subsumed parts. Human constructivist researchers refers to a category such as (progressive) differentiation as involving a greater degree of knowledge restructuring, unlike the weak restructuring of addition. However, it is the process of addition which initially allows the development of differentiation, as the different pieces of knowledge first need to be acquired before the restructuring can take place. My study suggests that differentiation is not a very common form of learning in the study sites, but it does occur, and this is again important for the kind of learning that takes place in science centres. A challenge for them would be to focus on encouraging this type of learning. Data from my study suggests that students can substantially restructure their knowledge, particularly in the areas of gravity, the Sun, stars and the Solar System.

Emergence, referring to recall of previously learned knowledge from memory, was the category of learning with the same percentage frequency as differentiation, but its relatively high frequency is due to one student, John, who showed the highest number of instances of emergence of any students across the study. Discounting John, emergence is a relatively rare form of learning, on a par with both discrimination and recontextualisation. As explained in Chapter 6, it is possible that some instances of emergence were classified as addition, as I normally only coded items as emergence when students specifically referred to remembering phenomena from previous experience. In contrast, Anderson in his study of school students learning about electricity and magnetism in a science centre (Anderson 1999) made conjectures when he identified emergence, assuming that the knowledge was pre-existing in the student's memory, and that the activities students were undertaking caused it to be retrieved. Although the frequency of emergence was low in my case study students (except John), the process of emergence is one which is likely to be important in museum learning and needs further investigation. John is clearly a special case. His portrait in Chapter 7 clearly shows several instances of how the interview questions remind him of not only what he learnt in the science centre, but also how the centre exhibits reminded him of previously learnt knowledge. For example when he is asked about some of what he has written in his post-visit PMM:

Interviewer: Uh hmmm. Okay really you've written quite a few things here, you mentioned that the red giants, the white dwarfs and the Quasar and you said the trip reminded you of those things. Tell me a little bit about that.

John: Ja they reminded me of some of the things that I was thinking about like I remembered the red giant was huge in size, it has way more mass than our size and as the one lady said, she said that our sun couldn't have a supernova because it's too small compared to those other stars and then the the white dwarf, it's small in size and it spins faster.

(vho16pospmm 001-003)

In this sequence, John combines knowledge that he acquired from the HartRAO (“lady said ... that our sun couldn't have a supernova” and the experience ‘being a star’ on the turntable) together with his prior knowledge about the size of a red giant to explain why the small dense star spins faster than the larger star. What is particularly interesting about John is that he is both knowledgeable and articulate enough to explain how he used his prior knowledge and what he had learnt at HartRAO to explain a new phenomenon.

Discrimination, where students identified similarities and differences between associated concepts, was rarely shown by students in my study. However, all students who showed discrimination were students who demonstrated improvement in their learning or were at level D in their pre- and post-visit analysis of Big Ideas (Table 7.1). These students included Fatima, Helen and Brenda, as well as Paul and Richard. The principal way in which students showed discrimination was by specifying similarities and differences between the planets in the solar system, for example Fatima stated this in her post-visit interview:

Fatima: The astronomer at the Planetarium said Mercury, Venus and Mars, they all have one thing in common because they are more solid, and then Jupiter, Saturn and Uranus and Neptune, they are more gaseous and then Pluto they're not so sure because it's like the odd one out.

(scf15pospmm 11)

The other main way in which discrimination was demonstrated was by students noting the difference between ‘living’ and ‘dead’ stars when these were discussed at HartRAO during the turntable activity. Although I have identified discrimination as a relatively uncommon form of knowledge restructuring it is (like differentiation) likely to be an important type. Human constructivist research suggests that greater knowledge restructuring results in concepts being retained in the long-term memory (Pearsall *et al.*, 1997).

Recontextualisation is the process in which a student modifies their understanding of a concept as the result of a visit, but does not improve on their knowledge or understanding in the process (Anderson 1999). In my study it occurred relatively uncommonly and, of the

case study students, only Neo showed examples of it. Of the other participants in my study, recontextualisation mainly occurred in the A and B Big Idea categories. Recontextualisation, although not merely the addition of new facts, does not appear to be a strong form of knowledge restructuring in the same way that differentiation and discrimination are. Anderson (1999), although he identified it in his study, suggested that it could be argued that it is merely a form of differentiation, and not a separate category of its own. However, I do find it a useful category in that it identifies when students are thinking about a concept in the context of the visit, but not making any substantial change to their knowledge of that concept. For example Ntobeko knew in the pre-visit interview that a satellite dish points to a satellite in space. However, after visiting HartRAO and seeing the radio telescope she was less sure about where a DSTV dish points to, she thought it might be ‘space and stars’, or to a spaceship – she wasn’t really sure. This is an example of how the visit has caused some confusion in the student’s mind about something they **did** know beforehand, and are now less certain. This sort of conceptual confusion is discussed in some detail in section 9.5.

Among the portrait students superordinate learning was demonstrated only by Brenda (Table 9.1), and I found only two examples of it in other 27 students (section 6.3.6), suggesting it is the least common form of cognitive learning in the study. Anderson did not use a category of superordinate learning in his study, and my findings suggest that it is not easily demonstrated in an informal learning environment. Superordinate learning involves a significant and rapid shift in understanding of a new and inclusive concept, and this is difficult to achieve in a museum during a short visit (Rennie, 2001; Wellington, 1990).

One of the implications for science centres which emerges from my study is that while addition is likely to be the dominant form of cognitive learning, centres should make efforts also to promote learning which involves more substantial knowledge restructuring. Although my study does not make any claims for long-term learning, other research suggests that significant knowledge restructuring is likely to promote more permanent learning in the long-term memory (Pearsall *et al.*, 1997).

9.3.2 Affective and Conative Learning

All students in the study showed several examples of affective learning (Table 9.2). The main types of affect noted in the case study students were enjoyment of (or wonder

about) different aspects of their visit, specific aspects of the trip that they found personally important to them, and issues related to astronomy in the informal learning environment (such as television news) that they had noticed.

Table 9.2 Summary of affective and conative learning by case study students

Learning category	Nonku luleko	Botho	Neo	John	Fatima	Brenda	Helen	Totals
Affective	9	5	9	10	8	4	7	52
Conative	0	1	1	1	1	2	3	9
Totals	9	6	10	11	9	6	10	61

Many scholars have suggested that the affective domain is of great importance in learning (Alsop and Watts 2003), but relatively few studies have examined it in the informal learning environment, and those that have mainly involved general museum visitors and family learning rather than school groups (Dierking 2005). Dierking suggests that (with respect to learning) the affective domain comprises motivational, emotional and personal satisfaction, elements which correspond to some of the affective issues I examined.

Table 9.3 and Table 9.4 show the activities and demonstrations at the study sites which students enjoyed most. At HartRAO the three most popular activities were the water rockets, the star turntable and the whisper dishes. It is important to stress that these were *activities*, which probably accounts for their popularity, and the finding supports the notion of students wanting to have fun during their visit. The findings on cognitive and affective learning suggest that HartRAO has achieved a successful balance between the entertainment and education aspects of their school visits, where students have had fun and learnt at the same time. At the planetarium the most enjoyable presentations were those involving the stars.

Table 9.3 Activities at HartRAO which resulted in affective learning

Activity/presentation at HartRAO	Enjoy	Germane	Wonder	Total
Rockets	15	4		19
Star turntable	4	3	2	9
Whisper dish	5	2	1	8
Planet facts, Solar System for a walk	3	3		6
Slide show	4	2		6
Radio Telescope	3	2		5
Mars & Mars show	2	2		4

Activity/presentation at HartRAO	Enjoy	Germane	Wonder	Total
Size and scale			4	4
Star descriptions	4			4
Sun facts, Sun dial	1	3		4
Coke cans and scales	2	1		3
Satellite laser	1	1		2
Lecturers nice	1			1
Telescopes	1			1

Table 9.4 Presentations at the planetarium which resulted in affective learning

Presentation at planetarium	Enjoy	Germane	Total
Stars in night sky	3		3
Stars spinning	3	1	4
Constellation pictures & names	2	1	3
Dust cloud photos & formation of SS	2		2
Mars photos	1		1
“How much is out there”	1		1
More planets		1	1

No students expressed remarks classified as ‘wonder’. The data in this table includes comments from students at St. Augustine School.

Part of the importance of the entertaining activities is that they can be related to situational interest. Situational interest is the ability of the context (‘situation’) to develop in people an interest in themes being presented (Hidi & Harachiewicz, 2000). While situational interest can occur in any educational environment, it has been studied mainly in the classroom and less in museums (Dierking, 2005). Limited research suggests that student interest in the topic of astronomy might be relatively high (Jarman & McAleese, 1996). While a science centre cannot predict what degree of personal interest each student will enter with, it can aim to impart situational interest to its visitors. If it is successful in doing so, this may in turn raise student motivation for the topic, and lead to greater achievement in science, a desperate need in developing countries such as South Africa. It appears that hands-on activities are effective ‘triggers’ of situational interest for many students who visited HartRAO. Further research could aim to examine such triggers in detail, and determine what can be done to maintain such interest to promote motivation.

The case study students showed few examples of learning in the conative domain. However, the conative learning shown by Botho and Helen, where they actively followed up issues discussed at the study site are further areas which relate to interest and motivation, and should be developed by the science centres. Similarly, the conflict experienced by Brenda between the science presented at HartRAO and her own religious beliefs has potential for further action. The planetarium director once remarked that, during a presentation, if students ask her “where is God in all this?” she does not answer the question directly (C. Flanagan pers. comm.). Instead, such a question might be an opportunity to spark some additional thinking on the part of the student, to encourage debate after the show. In these ways the conative aspect of learning can be encouraged, as Braund and Reiss’s definition of learning (2004) includes aspects of the conative dimension, such as “an increase in the capacity to reflect” and “the desire to learn more” (p.5).

While previous studies examining the relationship between education and entertainment have taken different positions (as I elaborated in section 2.5), the findings from my study suggest that they are entirely compatible, confirming the conclusions of some researchers (e.g. Brunello, 1992; Falk *et al.*, 1998).

9.4 Methodological Findings

My study shows a number of findings related to the methods which are important to highlight as part of this chapter.

9.4.1 Issues in Interviews

9.4.1.1 Models

In Chapter 5 I described how, when I questioned students about day and night in the interview, I introduced a model of the Sun (a torch) and the Earth (a small globe) and asked them to explain their initial thinking about why the Sun moves across the sky using the model. I found that nearly one third of the students changed their (initially rather confused) explanation of the cause of day and night as soon as they were referred to the model. With the model as a ‘prop’ these students were able to give a more scientific explanation for the phenomenon, which they were unable to do without it. This is highly significant for other research studies in the area of astronomy, as the subject involves an understanding of relatively complex three-dimensional interactions between bodies. My findings suggest that if questions involving apparent or relative motion are asked of people

either by questionnaire or interview in the absence of a supporting model, the resulting answers may relate to their memory of a diagram in a book or at a lecture. In the case of 'day and night', respondents of an appropriate age (probably 10 years and older) need to decide whether it is the Earth orbiting the Sun or the Earth spinning on its axis which causes day and night. Instead of engaging with the question in a meaningful way, respondents in my study began by answering what appeared to be the first idea that came into their mind, which in 13 cases out of 20 was that the Earth revolves around the Sun (although their use of language was sometimes unclear – see section 9.4.1.2). Only when the model was presented did they then suggest that day and night are due to the Earth's spin or rotation rather than its orbit. The fact that only 3 of the 16 peer-reviewed research studies of day and night used models as part of the data collection process suggests that their data may be biased towards their respondents' 'first thoughts' which may well be erroneous. Wagenschein's notion of *synthetic stupidity* (Engeström 1991) which I introduced in Chapter 2 is relevant here. In Wagenschein's premise the representations of the Earth and Sun that students learn about in the classroom are completely unrelated to the Earth and Sun which they experience in everyday life. Engeström argues his case for students' representation of the Moon phases, but I consider it applicable to the case of day and night too. In response to my question, instead of thinking through a response which makes sense in terms of a 24-hour cycle of night and day, students think back to an image of the Earth orbiting the Sun, and respond with "empty sentences" (Engeström 1991, p 155) about the Earth 'revolving around the Sun'.

The clear implication this has for studies of astronomy learning is that researchers need to ensure that they are collecting data that is salient for the participants rather than the first thoughts that enter their minds. This implication would mean that such studies need to involve not just students responding verbally, in writing or by drawing a diagram but by talking through their thinking with the help of a model. This is what Schoultz suggests in his article (Schoultz *et al.* 2001) critical of the methods of Vosniadou and collaborators, though he also critiques the nature of the interview itself. In her rebuttal, Vosniadou maintains that there *is* a place for questioning in the absence of an artefact such as a globe (Vosniadou *et al.* 2005), to investigate children's thinking in the development of their own mental models. While this might be relevant for the investigation of mental models in the young children (ages 6 to 11) Vosniadou and Schoultz were working with, by the time children reach age 12 it is highly likely they have a more sophisticated view of basic

astronomy concepts (Roald and Mikalsen 2001, Trumper 2001a). Using models is therefore likely to be the most appropriate way of engendering responses to questions posed by researchers, to avoid the dangers of synthetic stupidity.

9.4.1.2 Language

I explained in Chapter 3 that my research did not use theories around language to provide a conceptual framework for the study. However, during the process of data collection I found that in some cases students' inability to communicate effectively in English meant that they were not able to express themselves as fully as they might have done in their home language. Where possible I gave them the chance to express themselves in the language they were most comfortable with (when I was accompanied by an interpreter), but none availed themselves of this opportunity. Indeed I found on occasion that students were unable to use common seTswana words for some of the astronomical phenomena we were discussing¹⁷, and were more comfortable using English.

There was one aspect of language, which was common to students across all languages and all schools, and that was the use of the terms for orbit and spin. In Chapter 5 I discussed the difficulty many students had in expressing themselves particularly the use of terms such as *rotate* and *revolve* to describe the passage of the Earth around the Sun and the turning of the Earth to cause day and night. In 1998, Parker and Heywood noted that "the recognition of this problem is conspicuous by its absence in research literature" (1998, p 516). I consider that this is still the case, as although some instructional materials¹⁸ recognise the issue and attempt to assist students in their understanding only Cameron (2003) and briefly Stahly *et al.* (1999) have referred to it in a research context. If Parker and Heywood found it to be a problem among English trainee teachers one can imagine that the issue is likely to be greater for teenage students in South Africa, many of whom are learning in another language. The issue has significant implications for teachers as well as the educators at the planetarium and HartRAO, as they need to use strategies to clarify the terms for students. My recommendation would be that **only** the terms *orbit* and *spin* should be used, so that the similar-sounding *revolve* and *rotate* are avoided in the context of

¹⁷ I have a basic knowledge of seTswana and checked students' knowledge of words such as 'moon' and 'star' if their home language was seTswana.

¹⁸ e.g. the National Center for Mathematics and Science at the University of Wisconsin-Madison and the Capital Region on Science Education Partnership See the Modeling for Understanding in Science Education course at www.wcer.wisc.edu/NCISLA/MUSE/index.htm and www.crsep.org/PerplexingPairs/AnotherPerplexingPair.RotationandRevolution121102.pdf

teaching about astronomy. Parker and Heywood (1998) found however, that even when this strategy is adopted the teachers in their study still confused the two terms conceptually. Clearly, more effective techniques would need to be implemented, and I have referred to two helpful programmes in footnote 18.

The issue of confusion of terms however, also has significant implications for researchers into people's understanding of astronomy concepts. Researchers who choose to use only questionnaires or interviews for determining people's conceptions of the processes of rotation and revolution, *without a model present*, are likely to gather unreliable data, and much of the data already collected and interpreted over the past three decades may be partly flawed. A critical review of the studies conducted is therefore a strong recommendation from this thesis.

9.4.1.3 The interview as a situated event

In Chapter 3 I explained how I planned and executed structured interviews with students during my data collection, and in Chapters 5 to 8 I described the findings emanating from the interviews. Although I consider I adopted the right strategy for my data collection, my analysis shows that the structured nature of the interviews was somewhat constraining, and in retrospect I consider that I could have been less structured and more probing in most cases. This would have made some of the data more fruitful for deeper analysis, and probably enabled some discourse analysis in addition to the content analysis I carried out.

I also need to recognise that my interviews were a situated event in the sense used by Schoultz and colleagues (Schoultz *et al.* 2001). The setting for interview was at the school, in an office or classroom, despite the fact that I was examining informal or out-of-school learning. I, as the interviewer, was the dominant party who acted like a teacher, along with my intellectual and cultural capital. Further, I was asking questions, some of which were possibly abstract and difficult, adding further to the imbalance in power relations in the interview situation. For these reasons, Schoultz and colleagues would argue, the interview was not an objective method of enquiring into the interviewee's mind to probe their knowledge of astronomy concepts, but "simply another social practice, and a highly problematic one as well" (2001, p 116). However, when conducting the interviews, I consider I ameliorated some of the possible contextually alien aspects of the situation, and was closer to the type of interview conducted by Schoultz and colleagues than the interviews of Vosniadou that they critique. I did not start by firing a barrage of questions on abstract astronomy at the students, but asked about the forthcoming (or recent) visit, in

order to set the scene for the interview. As in the case of Schoultz, the globe was on the table at the start of the interview, and I introduced this model into the questioning at an early stage, which I hoped provided a further ‘prop’ for students to assist with their answers. I also used the students’ own productions, their previously-drawn Personal Meaning Map as an additional support which provided a focus for questioning later in the interview. I therefore acknowledge the nature of the interview process, and although I interpret the results from a cognitive viewpoint, like Candela (2001) I also accept the sociocultural context of the interaction which gave rise to them. Further, the use of interviews allowed students to ‘hear’ what they themselves were saying, as in all interviews I repeated at least some of their words after they uttered them, or repeated the idea they were talking about. This allowed them to reflect on what they had just said, and in several cases this caused students to change their explanation. Although it is equally possible for students to read over what they have written in a questionnaire, there is no ‘other voice’ (the interviewer) to repeat their ideas, and facilitate the process. This would appear to be a clear advantage of interviews over questionnaires for encouraging reflective thinking while responding to questions, again discouraging Wagenschein’s *empty sentences* (Engeström, 1991).

My final comment on the interview process is that in retrospect I consider I should have interviewed the educators at HartRAO and the presenter at the planetarium, in order to gain an understanding of their perspective of what they were trying to get across during the visits by the school groups. Although my observations made at the centres were recorded, my interpretations of what the presenters were doing may be quite different from their own intentions. A future study of this sort should follow methods recommended by researchers such as Cox-Petersen *et al.* (2003), where not only students and teachers are interviewed, but also the museum staff. In this way a clearer contextual background could be obtained for the study, which would provide a richer description of the overall findings.

9.4.2 Personal Meaning Mapping as a technique for data collection

As explained in Chapter 3, I chose to use PMM as a technique to complement my other data collection method of structured interviews. The structured interviews focused on the Big Ideas in astronomy, and could be regarded as a form of ‘pre- and post-test’ related to a traditional expectation of cognitive learning. In contrast, the method of PMM creates less expectation of what the learner *should* know, in that there are no questions to respond to,

and is a less ‘threatening’ form of assessment. Developed by John Falk in the late 1990s, PMM is analogous to concept mapping, but is more suitable to the museum environment, and requires no preparation on the part of the participants (Adelman and Falk 2000, Falk 2003). From this point of view PMM is an extremely relevant method for use in a study based on a constructivist epistemology, as it allows the participant complete freedom in writing what they like on the map, and constructing their knowledge in their own way. Falk (2003) recommends a particular method of analysing PMMs, which involves looking across four dimensions of learning: extent, breadth, depth, and mastery. While Falk suggests that PMMs can be analysed both quantitatively and qualitatively, most of the studies in which they have been used have been dominated by quantitative techniques (e.g. Adelman *et al.*, 2000; Falk & Storcksdieck, 2005; Falk *et al.*, 1998). My study being qualitative in nature, implied that I forego extensive quantitative analysis, and make individual learners the units of analysis. In this respect the personal meaning maps and accompanying interviews were very helpful, as they provided details of the sort of learning not captured in my structured interviews. In addition, although not analysed for all the dimensions suggested by Falk, I was able to use the PMMs to assist with some descriptive statistical data, such as the number of astronomical vocabulary words (*extent* in Falk’s terminology) used by each participant in the study. I found no particular drawbacks in using PMMs as one of my data collection methods, but I have the following recommendations for their use by future researchers:

- Where possible, spend adequate time in preliminary analysis of the PMM prior to the initial interview. Similarly, spend adequate time in analysis of the PMM before the second round of data collection, and prior to the second interview. Unfortunately, in the sequence of data collection involved in museum visits, this is not always possible.
- In a pilot study, experiment with the two alternatives of handing the original PMM back to the participants for addition/correction and asking them to complete a new PMM. Falk strongly recommends the former for museum visitors, for ethical reasons due to their time constraints and the inconvenience they are being put to. For school groups time is less of an issue and they are ‘used to’ formal and informal testing as part of their school work. A comparison between these two alternatives might therefore be of value.
- It would be worth doing some additional ‘testing’ of the technique as part of the piloting. For example, if a PMM is given to a group of people, who then repeat the

procedure some time later, with no intervention between the two processes, is there any difference between what people complete on the PMM? To what extent does the very act of completing a PMM result in possible changes in people's thinking about the topic?

- It would also be worth researching the technique as a possible teaching tool in a similar way to how concept maps are used in the classroom (McClure *et al.*, 1999). Advantages of Personal Meaning Mapping are that the technique does not have to be taught, that it is congruent with constructivist pedagogy, and that its informal nature is less intrusive in the classroom.

9.5 Misconceptions

Chapter 2 showed that many studies conducted on learning over the past three decades have confirmed that people hold numerous misconceptions about various aspects of astronomy. Some of the studies identified the misconceptions only, while others showed that despite some form of intervention, many of the misconceptions remained persistent. My study did not set out to identify and catalogue misconceptions, but it does show that most of the students hold misconceptions similar to those identified by previous researchers. However, I do not wish to discuss my findings in the light of researchers such as Vosniadou and Brewer (1994) and Roald and Mikalsen (2001) who investigated misconceptions as the principal object of the research. Neither do I think it appropriate to use researchers who looked at a 'before and after instruction' scenario (Parker & Heywood, 1998; Trundle *et al.*, 2002) as a basis for discussion. All these studies, as well as Minda Borun's study of gravity in the museum (Borun *et al.*, 1993) appear to be based on the fact that misconceptions are a *faulty* form of scientific knowledge which needs to be rectified. Instead, I take Jeremy Roschelle's view that all prior knowledge (including the misconceptions) forms a basis for the construction of scientific knowledge, and that we need to find ways of incorporating the misconceptions into the science rather than trying to eradicate the 'faulty' notions (Roschelle, 1995; Smith, diSessa & Roschelle, 1993). This view is consistent with my conceptual framework of human constructivism, where I have attempted to demonstrate how students build their knowledge, even if some of the resultant construction is not scientifically correct. I therefore present two examples of how students built on their prior knowledge to construct new conceptions of astronomical phenomena.

Both examples are representative of the sort of misconceptions students held, or in the case of Neo, acquired.

In the first example I show how Tlotlo had misconceptions about gravity prior to her visit, but what she experienced during the visit changed them to a more scientifically acceptable notion of gravity. Before her visit, Tlotlo knew that gravity is a force which “puts things down”, but she believed there is no gravity on the Moon or on Jupiter. Her evidence for there being no gravity on the Moon was the fact that she saw television images of Mark Shuttleworth: “he wasn’t like on land, he was floating around” (tsw02preint 154). Although Shuttleworth went to the International Space Station many students seemed to believe he went to the Moon, and used his floating as evidence that there is no gravity there. Tlotlo *did* however think there might be gravity on the Sun, using her own personal theory that “because you get heated and then you just, it grabs you, the heat” (tsw02preint 170). After her visit, Tlotlo had very different ideas about gravity. She still believed that things might float on the Moon, but having seen pictures of Neil Armstrong on the surface, she now considered that the gravity there is very low. Like many students, and as described in Section 4.2.6, Tlotlo thought people needed to wear boots on the Moon to keep them on the surface. She also now thought that the gravity on Jupiter is high, and gave a short description of how the Sun and Jupiter, with their strong gravity, fought for asteroids, one of which crashed into Jupiter. Her interpretation of an explanation at HartRAO in connection with asteroids and (probably) Comet Hale-Bopp crashing into Jupiter is likely to have been the source of this idea, although it is also possible she played with the ‘Cosmic Pinball’ exhibit in which one makes a comet crash into Jupiter (see Section 4.2.4). In her post-visit PMM she stated that “the sun and Jupiter are likely to have the same amount of gravity” (tsw02pos 9), but during the interview she elaborated on a new understanding of gravity “Well I think gravity is caused by the ... like maybe if something is big then there’s more gravity” (tsw02posint189) and decided that the Sun, as it’s bigger would have more gravity than Jupiter. Clearly, Tlotlo had a very different conception of gravity after the visit, and her understanding had changed substantially towards a scientific understanding. It is important to note that Tlotlo built on her relatively naïve prior knowledge about gravity to do this, and also that she still retained some misconceptions. She thought that boots help to hold you to the Moon’s surface in an environment of low gravity, and she did not realise that everything has gravity, however small. These misconceptions however are relatively ‘minor’ compared with the ones she

had before the visit, and it is likely that further exposure to formal or informal teaching about gravity would assist her understanding still further.

In the second example I show how Neo acquired a misconception during her visit. In Chapter 7 I described how Neo added to her knowledge of the Sun and differentiated it so that the end result was a more complex understanding of the Sun, its scale with respect to the Earth, and the notion of sunspots. During this process of addition and differentiation, Neo changed her ideas in the following ways. Prior to the visit she knew a mixture of facts about the Sun: that it is a star, but bigger, that it is bigger than the Moon and further away and that it can be ‘used’ for growing plants. She stressed the heat of the Sun (instead of its light), both for the growing of plants and the reason why stars are not visible in the day. She gave erroneous estimates of room temperature, boiling water and the Sun’s temperature, showing little understanding of the concept of temperature. After the visit she showed similar knowledge of the Sun and temperature as she had in the pre-visit interview, though she now inflated her estimate of the Sun’s surface to 5 billion (degrees). In addition, she now referred to something she was shown at HartRAO: a sunspot. Although she had some idea of the size of the sunspot she had seen – she referred to the fact that 100 Earths can fit into it – her understanding of what a sunspot consists of was somewhat flawed. She seemed to think that the spot is at the centre of the Sun, and that it is “a bit cold”. However, her limited conception is really to be expected. The sunspot was demonstrated by the HartRAO educator using the Sun telescope projecting the image on to card, and Neo would have used any prior knowledge she had about the Sun, together with what the educator was explaining, to build her own conception of the sunspot. It so happened (on the day she visited HartRAO) that this sunspot was lying in the middle of the Sun’s disc so it is natural that Neo would think it is the Sun’s middle. She would also have heard the educator saying that the spot is a cooler part of the Sun (see Chapter 4), and Neo interpreted this as being ‘a bit cold’. The other fact that Neo remembered about the Sun in her post-visit interview was that the Sun is going to expand, contract to become a dwarf, and “there will be no sun anymore”.

What Neo has constructed is a greater, but partially flawed, knowledge of the concept Sun. Although she could be said to have acquired a misconception during the visit, her knowledge has clearly increased, and it is quite possible that she will remember the idea of the sunspot for the future. Neo therefore, is an example of a student who learnt from her visit, even though her pre- and post-visit mean ‘score’ for Big Ideas hardly

changed. The implication of Neo's experience is that the visit was able to build on her prior learning. Like 12 other students in the study, she already had above-average knowledge of Big Ideas, and was able to incorporate further knowledge into her existing framework. I do not consider it of concern that she left HartRAO with a misrepresentation of sunspots as the 'cold middle of the Sun'. The fact that she has now seen and can discuss a sunspot suggests that she has the basis for further learning about them. In Roschelle's terms we can "expect learning to occur through gradual refinement and restructuring of small component[s]" (1995, p 43), and it is for this reason that follow-up by the teacher back at the school is so important (Griffin, 2004), although it was limited or non-existent in my study (Chapter 3).

The HartRAO educator provided a clear demonstration and explanation of sunspots. Some students (such as Richard and Julius) learned about sunspots without acquiring a misconception while most others (such as Douglas and Judy) never mentioned sunspots in their post-visit PMM or interview. I therefore suggest that the learning about sunspots varied across the students who visited HartRAO, and the extent of learning or acquisition of a misconception was little different to other learning environments. However, there was one incident that took place at HartRAO which appeared to *promote* the acquisition of misconceptions by students. My evidence for it is limited, but I draw attention to it here to demonstrate how an attempt to relate students' understanding to something they are familiar with may cause confusion for some students. At HartRAO during the water bottle rocket activity the educator suggested that the students experiment with different proportions of air and water in their bottles to see how high they can make the rocket go. This is a good activity to get students to make informal hypotheses and test them out. However, I observed that during the discussion at the end of the activity the educator described the water put inside the rockets as 'fuel', and although she explained why a particular proportion of water to air inside the bottle resulted in greater pressure and higher altitude reached, students were left with the impression that a similar process takes place in real rockets (e.g. notebook 1 page 49 7/6/03). Neo explained after her visit that "I've learnt that the rocket or let me say the space shuttle needs, it doesn't need more maybe like air or gas or more air or more gas in it, it just needs a little bit of gas so that the gas and the air can combine together so that it can lift off. So if it's too much gas or if there's no gas it can't go up" (swo42posint 157). Her explanation suggests that Neo actually thinks that different proportions of fuel or gas in a space shuttle are needed in the

same way that water and air are combined in the water bottle. Another student (from St Augustines School, not used in my main study) wrote in his post-visit PMM “In order for spacecraft to fly it needs approximately a quarter of fuel and the air should take the space”. Although these are only two examples, they demonstrate the danger of an analogy which is taken literally by students, resulting in them acquiring a misconception about rockets and their fuel requirements.

What does this tell us then about misconceptions in the museum environment? It suggests that with a variety of activities around a theme, conceptual change can occur as a result of a visit to a science centre. It also accepts that misconceptions can be acquired during a visit to a centre, but finds that, as Roschelle (1995) has suggested and Anderson (1999) later demonstrated, such misconceptions are a stepping stone towards more comprehensive and (ideally) scientific knowledge. As Falk and Dierking (2000) lamented, there is a dearth of research study in this area, and my findings help to add to the growing body of knowledge of how misconceptions are worked with in an informal setting.

9.6 Science Literacy

The extent to which students improved their science literacy was variable. In section 2.6 I identified Shen’s classification of science literacy (Shen, 1975) as being the most appropriate for museum learning. Evidence from my study suggests that students did ‘know more science’ after their visit, and could be said to have improved their basic knowledge of astronomy. While Rennie’s statement that deep science learning probably does not occur during a science centre visit may be true (Rennie, 2001), my study suggests that some cognitive understanding can occur for the majority of students. Some students (notably Nkulueko and Fatima) also increased their cultural science literacy, whereby they showed a greater appreciation of the achievements of science. Both the planetarium and HartRAO aligned their activities and presentations to the content of the school curriculum rather than to notions of science literacy. Measuring the achievement or otherwise of science literacy goals may therefore be more appropriate for visits by groups *other* than school students.

9.7 Role of Vocabulary

Students’ use of astronomy-related vocabulary was discussed in section 7.4. The number of words students used in their PMMs varied considerably (mean 20.3, standard deviation

7.5), and all students except Ntobeko increased their vocabulary in their post-visit PMM. There appears to be no relationship between vocabulary and knowledge of Big Ideas, except in the case of category D students, who all used a larger number of words than their peers. On this basis I suggest that counting words in PMMs is not a reliable way of assessing students' concept knowledge or understanding, as propounded by Falk (2003).

9.8 Critical Reflection of the Research Process

Carrying out research in museum environments is notoriously difficult, as any attempt to acquire empirical data tends to interfere with the learning experience of the visitor (Allen, 2002; Falk & Dierking, 2000). My strategy was to acquire pre- and post-visit data using personal meaning maps and interviews to determine whether students had constructed knowledge as a result of the visit. Similar methods have been used successfully in many studies of museum learning (e.g. Adelman *et al.*, 2000; Cox-Petersen *et al.*, 2003) but it is unclear to what extent the process of data collection has altered visitors' perceptions of the experience. While I did not encounter any difficulties in gathering my data, I need to accept that my collection of PMM data followed by one-to-one interviews with a selection of students was likely to have highlighted the importance of the visit. Six of the 34 students I interviewed (e.g. Banyana in section 5.7.1) showed that my visit had caused them to do extra preparation for the visit, which they might not have done if I had not interviewed them. Although these numbers are relatively low (18% of students) my findings may possibly overestimate the overall learning that took place in the study. Although my study did not examine teachers and their work with the classes my role could be regarded as that of a teacher, and my work with the students as preparation for and follow-up after the visit which was not done by the students' accompanying teachers.

One strand of current informal learning research stresses the importance of determining the long-term effect of museum visits (e.g. Falk & Dierking, 1997; Medved & Oatley, 2000), and my study might have benefited from follow-up data collection some months later. Unfortunately the time frame of the study precluded this possibility, but getting students to write an essay about their visit several months after the event might be an appropriate way of finding out what they remember. This could be followed by an interview to discuss what students had written, though analysis of the data collected would need to consider the further impact of the data collection methods on the 'research as intervention' compared with visits not researched.

My study did not involve a comparison between the learning taking place at the planetarium and HartRAO, but a brief comment on the two sites is pertinent here. The collective learning described in Chapter 5 show that students were able to learn about Big Ideas at both sites. Two of the portrait students who showed an increase in their Big Ideas knowledge (Fatima and Helen) visited the planetarium, again suggesting that visits to both study sites enabled learning. The one area of difference was that the planetarium did not provide activities for students to engage in, except that they were encouraged to use star charts (handed out to them) and to observe the sky on subsequent nights. Given the importance of affective learning (such as wonder and enjoyment) I have identified in this study, the planetarium might consider providing additional hands-on activities for students as part of their visit experience.

9.9 Conclusions and recommendations

A study of this kind has never been conducted before in South Africa. There has been very little research into informal learning, and none combining it with astronomy. The inferences drawn are likely to be restricted to similar contexts of school visits involving 12- to 15-year-olds, science centres themselves with similar contexts to the planetarium and HartRAO, in that didactic methods are used as part of visitors' experience.

This thesis set out to answer the following research questions:

1. To what extent do students learn in the process of a visit to a planetarium or the visitors' centre of an astronomical observatory?
2. How is the content of astronomy communicated to students?
3. What are students' individual experiences of the visit?
4. How do students construct knowledge during and after the visit?
5. How do students' interests and prior knowledge affect the learning experience of a school visit?

While my case study cannot be used to generalise to other science centres either in Southern Africa or overseas, I suggest that the points I make can be regarded as 'fuzzy generalisations' (Bassey, 1999). These are statements with some uncertainty built-in, which acknowledges the complexity of the nature of human interactions, and can lead to both limited recommendations and suggestions for further research.

Answering research questions 2 and 3, I have shown (in Chapter 4) the experience of a student visiting a science centre, that it is a unique encounter for each individual, and that some of the perceptions of school visits found in the science education literature are

confirmed, while others are challenged. For example, students regard the visit as a fun activity which will also involve learning, confirming research by Falk *et al.* (1998). However, notions of full class participation and teacher involvement in school visits appear to be even less prevalent than they are in developed countries (e.g. Griffin, 2004; Storksdieck, 2004). Chapter 5 answers research question 1: I showed that students do learn appreciably during school visits, and I described the main areas of learning in terms of Big Ideas in astronomy. Addressing research questions 4 and 5, and using a human constructivist framework for learning, I showed in Chapters 6 to 8 that each student's learning experience is unique, and that it is difficult to predict how learning will occur for any one individual. I was also able to show that incremental addition of facts was by far the commonest form of cognitive learning experienced by the students, and that more substantial knowledge restructuring also occurred, though less often. I also demonstrated that students with a greater prior knowledge of astronomy were able to show a greater degree of knowledge restructuring. I further described the importance of affective and conative aspects of learning, and that they need to be taken into account when examining how learning occurs at a science centre. The effect of student personal interest on their ability to learn at a science centre was less clear, and I suggest that future research examines how situational interest can be promoted, to improve motivation.

The importance of my study has been in a number of different areas, focusing on the students involved in school visits, and how they learn. First, I have shown that learning occurred at the study sites, and that for some students the sorts of things learnt were in line with 'academic' learning associated with the school curriculum (such as gravity and stars). Other students learnt little academic factual knowledge but still remembered numerous facts from the visit which may form the basis for future learning if properly followed up after the visit. Learning took place at the centres despite the limited involvement of teachers' preparing students for or following up on the visit.

Secondly, I have shown that all students both learnt during the visit *and* enjoyed themselves, which provides further evidence *against* the notion that planetaria and hands-on science centres are locations for mere entertainment.

Thirdly, I have shown that prior knowledge is of key importance in influencing the extent to which a student was able to restructure the knowledge they learnt. Students with extensive prior knowledge were able to show greater knowledge construction than those with limited prior knowledge. This finding adds further weight to the concept of pre-visit

preparation: if all students had been adequately prepared for their visit they would have entered the study site with greater prior knowledge which in turn would have enabled a greater degree of knowledge restructuring.

Fourthly, while I have demonstrated that for some students, misconceptions were altered by the visit, for others the visit had little or no effect. In addition, some students acquired misconceptions during the visit. However, if misconceptions are viewed as stepping stones towards scientific knowledge, then their alteration or even acquisition can assist student learning.

Fifthly, I have made some important additions to methods used in studies of learning about astronomy. The importance of using models cannot be underestimated in enabling students to discuss abstract concepts with meaning. Similarly, researchers need to pay careful attention to the use of language when discussing concepts such as orbit and spin.

Sixthly, I have demonstrated the value of Personal Meaning Mapping in research of this kind. PMMs have a distinct advantage over questionnaires and structured interviews in enabling students to identify what *they* regard as important in relation to the topic, rather than the ideas of the researcher.

Finally, I have confirmed that a human constructivist model of learning is an appropriate framework with which to view learning at a science centre. The model enables a researcher to identify the principal ways in which students learn, which can inform the development of presentations and activities at science centres. In addition, I have extended Anderson's cognitive model of HC into the affective and conative domains, highlighting the importance of these aspects of learning.

The following recommendations with respect to school visits emanate from my study:

- An astronomy-focused science centre should focus on Big Ideas (similar to the ones I have suggested) to ensure that key concepts in astronomy are covered. The number and extent of the Big Ideas would depend on the nature of the science centre and its audience.
- Currently, the science curriculum for grades 7 and 8 does not highlight the importance of all the Big Ideas I have identified for basic astronomy learning. During the next

revision of the curriculum, I recommend that gravity, size and scale, stars and the Sun, and the Solar System be given greater prominence as key concepts in basic astronomy.

- The science centre should aim to design a variety of different activities or exhibits around a limited number of Big Idea themes, so that students are exposed to related activities which help to build conceptual understanding around a Big Idea.
- Science centres should note that all students who visit are capable of learning, and plan different levels of activity which may be appreciated by students of differing ability. Presentations should consciously aim to refer to students' prior knowledge, to encourage emergent learning and knowledge restructuring.
- Science centres should provide written guidelines for teachers in advance of their visit (e.g. Braund 2004 and Appendix K).
- Centres should provide visiting students and their teachers with follow-up activities related to cognitive, affective or conative learning. The importance of such activities is to ensure that students are reminded of their visit over a period of time, so that it becomes a longer-term learning experience.
- Given than all students have idiosyncratic and individual ways of learning, centres should aim to strike a balance between didactic 'teaching' and allowing a greater degree of control over students' own movements. At both the planetarium and HartRAO the focus is on instruction, but to allow students to pursue their own interests is also important.

9.10 Future Research

My thesis has focused principally on learning by individual students visiting science centres, and forms part of the 'Personal Context' (Section 2.8.1) in Falk and Dierking's Contextual Model (Falk & Dierking, 2000). This model has only been partly investigated in empirical studies, and there is considerable further scope for research into the Sociocultural and Physical Contexts, particularly in developing countries. All three contexts interact together, and with the notion of time, and studies which examine medium- and long-term informal learning are likely to be important, if methodological issues can be addressed. Rennie and colleagues (Rennie *et al.*, 2003) provided a useful agenda for further research based on the NARST Ad Hoc Committee's policy statement on Informal Science Education. The issues include precursors to learning, the physical setting, sociocultural factors, longitudinal research, the process of learning and methods used for

capturing data. The affective domain is included in the list, and I would also expand the process of learning to embrace the conative, where the visit to the centre is a precursor for action afterwards.

While the above issues are relevant worldwide, what is particularly important in developing countries such as South Africa is rigorous research in the field. The number of science centres is increasing annually, but most of the challenges faced by the science centre community relate to visitor numbers and practitioner issues. Research is needed into how centres impact on learning at school level, and how teachers can be encouraged to become full participants in the visit experience. Research also needs to be conducted into how previously disadvantaged communities can be encouraged to visit such centres, so that the sort of family learning found to be so enriching by researchers elsewhere (e.g. Dierking & Falk, 1994) can be promoted. Finally, informal learning needs to be investigated at sites where the majority of the population reside, such as the rural areas and townships, or where they visit, such as shopping malls. In these ways the field could be expanded to address issues of importance to under-developed 'South', and not just the developed 'North'.

9.11 Endpiece

I end with three quotations on learning by the students. When asked about the purpose of the visit, one of the students in the pilot study suggested

I'm not sure because we haven't actually learnt anything yet. I still have to see about that.

In his interview he demonstrated learning about Jupiter and its Moons, the Moon phases and the concept of 'light minutes', yet he didn't feel he had learnt anything. Maybe he needed more 'overt' learning for it to count for him.

In contrast, Antonia said that the purpose was

To just learn more than we knew already ... because we learnt the stuff we knew already.

She appears to realise that the learning is more about deepening and extending her existing knowledge. For her, emergent learning appears to be important.

The last word goes to Julius who tried to explain, at some length, the importance of learning and fun:

Julius: Ja, I thought about going back there, but because I thought that if there was more time we would have learnt even more than what we've learnt and I think it didn't only benefit me, but I think many people who went they were happy to go there and they learnt more because there's some people who they don't, they aren't really interested, but because they had fun they learnt at the same time because of the fun. Now they learnt because there's fun so what I've learnt is that most people who learn they learn through fun so whatever they do should be fun so that they can learn.

Julius' comment sums up what learning at science centres *should* be during school visits, incorporating cognitive learning and affective fun. He not only learnt and had fun, but he also learnt that that's what learning should be about.

References

- Adelman, L. M., Falk, J., & James, S. (2000). Impact of National Aquarium in Baltimore on Visitors' Conservation Attitudes, Behavior and Knowledge. *Curator*, 43(1), 33-61.
- Adey, P., & Shayer, M. (1994). *Really Raising Standards*. London: Routledge.
- Adler, J., & Lerman, S. (2003). *Getting the Description Right and Making It Count: Ethical Practice in Mathematics Education Research*. In Bishop, A., Keitel, C., Kilpatrick, J. & Leung, F. (Eds.), *Second International Handbook of Mathematics Education* (pp. 441-470). Dordrecht: Kluwer Educational Publishers.
- Agan, L. (2004). Stellar Ideas: Exploring Students' Understanding of Stars. *The Astronomy Education Review*, 3(1), 77-97.
- Aikenhead, G. (1996). Science education: border crossing into the subculture of science. *Studies in Science Education*, 27(1-52).
- Aikenhead, G. (2000). *Renegotiating the culture of school science*. In Millar, R., Leach, J. & Osborne, J. (Eds.), *Improving Science Education: the contribution of research*. Buckingham: Open University Press.
- Aikenhead, G., & Jegede, O. (1999). Cross-Cultural Science Education: A Cognitive Explanation of a Cultural Phenomenon. *Journal of Research in Science Teaching*, 36(3), 269-287.
- Albanese, A., Danhoni Neves, M. C., & Vicentini, M. (1997). Models in Science and in Education: A Critical Review of Research on Students' Ideas about the Earth and its Place in the Universe. *Science and Education*, 6, 573-590.
- Allen, R. (Ed.). (2000). *New Penguin English Dictionary*. London: Penguin.
- Allen, S. (2002). *Looking for Learning in Visitor Talk: A Methodological Exploration*. In Leinhardt, G., Crowley, K. & Knutson, K. (Eds.), *Learning Conversations in Museums* (pp. 259-303). Mahwah, New Jersey: Erlbaum.
- Alsop, S. (2000). Meeting the needs of lifelong learners: recognizing a conative dimension in physics education. *Physics Education*, 35(3), 202-208.
- Alsop, S., & Watts, M. (1997). Sources from a Somerset Village: A Model for Informal Learning about Radiation and Radioactivity. *Science Education*, 81(6), 633-650.
- Alsop, S., & Watts, M. (2003). Science education and affect. *International Journal of Science Education*, 25(9), 1043-1047.
- American Association for the Advancement of Science. (1993). *Benchmarks for science literacy*. New York: Oxford University Press.
- American Association for the Advancement of Science. (2001). *Atlas of Science Literacy*. Washington DC: American Association for the Advancement of Science/ National Science Teachers Association.
- American Association for the Advancement of Science. (2005). 2061 Connections November/December 2005. Retrieved 23 March 2006, from <http://www.project2061.org/publications/2061Connections/2005/2005-11a.htm>
- Anderson, D. (1999). *The Development of Science Concepts Emergent from Science Museum and Post-Visit Activity Experiences: Students' Construction of Knowledge*. Unpublished PhD, Queensland University of Technology.
- Anderson, D., & Lucas, K. (1997). The Effectiveness of Orienting Students to the Physical Features of a Science Museum Prior to Visitation. *Research in Science Education*, 27(4), 485-495.
- Anderson, D., Lucas, K., & Ginns, I. (2003). Theoretical Perspectives on Learning in an Informal Setting. *Journal of Research in Science Teaching*, 40(2), 177-199.

- Anderson, D., Lucas, K., Ginns, I., & Dierking, L. D. (2000). Development of Knowledge about Electricity and Magnetism during a Visit to a Science Museum and Related Post-visit Activities. *Science Education*, 84(5), 658-679.
- Ansbacher, T. (1998a). John Dewey's Experience and Education: Lessons for Museums. *Curator*, 41(1), 36-49.
- Ansbacher, T. (1998b). Review of Learning in the Museum, by Geoge Hein. *Curator*, 41(4), 285-291.
- Ansbacher, T. (2002a). Misunderstandings of Meaning Making. *Exhibitionist*, 21(1), 1-4.
- Ansbacher, T. (2002b). What Are We Learning? Outcomes of the Museum Experience. *Informal Learning Review*, 53(March-April), not known.
- Atwood, R., & Atwood, V. (1996). Preservice Elementary Teachers' Conceptions of the Causes of the Seasons. *Journal of Research in Science Teaching*, 33(5), 553-563.
- Ausubel, D. (1968). *Educational psychology: A cognitive view*. New York: Holt, Rinehart and Winston.
- Ausubel, D., Novak, J., & Hanesian, H. (1978). *Educational psychology: A cognitive view* (2nd ed.). New York: Holt, Rinehart and Winston.
- Bailey, J., & Slater, T. (2003). A Review of Astronomy Education Research. *Astronomy Education Review*, 2(2).
- Bale, J. (2006). It inspired generations of children, but now the Planetarium is focusing on lesser stars. Retrieved July 12, 2006, from <http://www.timesonline.co.uk/article/0,2-2017210,00.html>
- Bar, V., Sneider, C., & Martimbeau, N. (1997). Is There Gravity in Space? *Science and Children* (April), 38-43.
- Bar, V., Zinn, B., Goldmuntz, R., & Sneider, C. (1994). Children's Concepts about Weight and Free Fall. *Science Education*, 78(2), 149-169.
- Barba, R., & Rubba, P. (1992). A Comparison of Preservice and In-Service Earth and Space Science Teachers' General Mental Abilities, Content Knowledge, and Problem-Solving Skills. *Journal of Research in Science Teaching*, 29(10), 1021-1035.
- Barnett, M., & Morran, J. (2002). Addressing children's alternative frameworks of the Moon's phases and eclipses. *International Journal of Science Education*, 24(8), 859-879.
- Bassey, M. (1999). *Case Study Research in Educational Settings*. Buckingham, UK: Open University Press.
- Baxter, J. H. (1989). Children's understanding of familiar astronomical events. *International Journal of Science Education*, 11(Special Issue), 502-513.
- Baxter, J. H. (1991). A constructivist approach to astronomy in the National Curriculum. *Physics Education*, 26, 38-45.
- Beetlestone, J. G., Johnson, C. H., Quin, M., & White, H. (1998). The Science Center Movement: contexts, practice, next challenges. *Public Understanding of Science*, 7, 5-26.
- Berg, T., & Brewer, W. (1991). Teacher Awareness of Student Alternate Conceptions about Rotational Motion and Gravity. *Journal of Research in Science Teaching*, 28(1), 3-18.
- Berk, L. (2003). *Child Development*. Boston: Allyn and Bacon.
- Bliss, J. (1995). Piaget and after: the case of learning science. *Studies in Science Education*, 25, 139-172.
- Block, E., & Rollnick, M. (2003). Words used are understandable; the way the information is phrased is impossible to understand. In Putsoa, B., Dlamini, B. & Kelly, V.

- (Eds.), Proceedings of the 11th Annual SAARMSTE conference (pp. 277-285): University of Swaziland, Mbabane.
- Boaler, J. (1998). *A Tale of Two Schools: Alternative Teaching Approaches and Situated Learning*. In Watson, A. (Ed.), *Situated Cognition in Mathematics* (pp. 83-92). Oxford: Oxford University Department of Educational Studies.
- Boisvert, D. L., & Slez, B. J. (1994). The Relationship between Visitor Characteristics and Learning-Associated Behaviors in a Science Museum Discovery Space. *Science Education*, 78(2), 137-149.
- Boone, W., & Rogan, J. (2005). Rigour in quantitative analysis: The promise of Rasch analysis techniques. *African Journal of Research in Mathematics, Science and Technology Education*, 9(1), 25-38.
- Borun, M., Massey, C., & Lutter, T. (1993). Naive Knowledge and the Design of Science Museum Exhibits. *Curator*, 36(3), 201-219.
- Braund, M. (2004). *Learning science at museums and hands-on centres*. In Braund, M. & Reiss, M. (Eds.), *Learning Science Outside the Classroom* (pp. 113-128). London: RoutledgeFalmer.
- Braund, M., & Reiss, M. (2004). *The nature of learning science outside the classroom*. In Braund, M. & Reiss, M. (Eds.), *Learning Science Outside the Classroom* (pp. 1-12). London: RoutledgeFalmer.
- Brodie, K. (2005). Textures of talking and thinking in secondary mathematics classrooms. Unpublished PhD, Stanford University.
- Brown, J. S., Collins, A., & Duguid, P. (1989). Situated Cognition and the Culture of Learning. *Educational Researcher*, 18(1), 32-42.
- Brunello, C. (1992). Entertainment and Education: Are they compatible? *The Planetarian*, 21(1), 10-14.
- Calvin, W. (1996). *How Brains Think*. London: Weidenfeld and Nicholson.
- Cameron, A. (2003). An Investigation into Collateral Learning and Cultural Border Crossing in Basic Astronomy amongst Foundation Students in a South African University. Unpublished Master of Science, University of the Witwatersrand, Johannesburg.
- Cameron, A. K., Rollnick, M., & Doidge, M. (2005). The Influence of Prior Knowledge, Culture and Religion on First Year and Foundation Students' Understanding of Basic Astronomy, 13th Annual Southern African Association for Research in Mathematics, Science and Technology Education Conference. Windhoek, Namibia.
- Candela, A. (2001). Earthly Talk. *Human Development*, 44, 119-125.
- Case, J., & Gunstone, R. (2002). Metacognitive Development as a Shift in Approach to Learning: an in-depth study. *Studies in Higher Education*, 27(4), 459-470.
- Champagne, D. W. (1975). The Ontario Science Centre in Toronto: Some impressions and some questions. *Educational Technology*, 15(8), 36-39.
- Chaplin, S. (1997). *The developing role of interactive science centres within science education*. In Thompson, D. (Ed.), *Science Education in the 21st Century* (pp. 59-76). Aldershot, UK: Arena.
- Chaplin, S., & Graham-Smith, F. (1992). *Jodrell Bank Visitor Centre*. In Durant, J. (Ed.), *Museums and the public understanding of science* (pp. 108-109). London: Science Museum.
- Chinn, C., & Brewer, W. (1993). The role of anomalous data in knowledge acquisition: A theoretical framework and implications for science instruction. *Review of Educational Research*, 63, 1-49.
- Clerk, J. (2006). Weightless Astronauts. Paper presented at the South African Association of Science and Technology Educators Conference, Durban.

- Cobern, W. W. (1991). Worldview Theory and Science Education Research: Fundamental Epistemological Structure as a Critical Factor in Science Learning and Attitude Development.
- Cobern, W. W. (1996). Worldview Theory and Conceptual Change in Science Education. *Science Education*, 80(5), 579-610.
- Cohen, L., & Manion, L. (1994). *Research methods in Education*. Beckenham: Croom Helm.
- Comins, N. (2001). *Heavenly Errors: Misconceptions About the Real Nature of the Universe*. New York: Columbia University Press.
- Coombs, P. A., & Ahmed, M. (1974). *Attacking Rural Poverty: How Non-formal Education Can help*. Baltimore: John Hopkins University Press.
- Cortazzi, M. (1993). *Narrative Analysis*. London: Falmer Press.
- Cox-Petersen, A. M., Marsh, D. D., Kisiel, J., & Melber, L. M. (2003). Investigation of Guided School Tours, Student Learning, and Science Reform Recommendations at a Museum of Natural History. *Journal of Research in Science Teaching*, 40(2), 200-218.
- Crane, V. (1994). *An Introduction to Informal Science Learning and Research*. In Crane, V., Chen, M., Bitgood, S., Thompson, D., Nicholson, H., Weiss, F., and Campbell, P. (Ed.), *Informal Science Learning: What the Research Says About Television, Science Museums, and Community-Based Projects*. Ephrata, PA: Science Press.
- Crawley, F. E., & Koballa, T. R. (1994). Attitude Research in Science Education: Contemporary Models and Methods. *Science Education*, 78(1), 35-55.
- Csikszentmihalyi, M., & Hermanson, K. (1995). *Intrinsic Motivation in Museums: Why Does One Want to Learn?* In Falk, J. H. & Dierking, L. D. (Eds.), *Public Institutions for Personal Learning: Establishing a Research Agenda* (pp. 34-37, 59-61). Washington, D.C.: American Association of Museums.
- Davidowitz, B., & Rollnick, M. (2005). Development and application of a rubric for analysis of novice students' laboratory flow diagrams. *International Journal of Science Education*, 27(1), 43-59.
- Department of Arts Culture Science and Technology. (1996). White paper on science and technology. Preparing for the 21st century. Pretoria: Government of South Africa.
- Department of Education. (2000). Draft Intervention Strategy for Science, Mathematics and Technology Education (SMTE). Pretoria: Government of South Africa.
- Department of Education. (2002). Revised National Curriculum Statement for Grades R - 9 (Schools) Natural Sciences (No. 23406). Pretoria.
- Department of Science and Technology. (2006). The Budget Vote Speech by the Minister of Science & Technology, Mr Mosibudi Mangena. Retrieved 25 June, 2006, from <http://www.dst.gov.za/media/speeches.php?id=190&print=1>
- Dewey, J. (1938). *Experience and Education*. New York: Kappa Delta Pi.
- Diakidoy, I.-A. N., & Kendeou, P. (2001). Facilitating conceptual change in astronomy: a comparison of the effectiveness of two instructional approaches. *Learning and Instruction*, 11, 1-20.
- Dierking, L. D. (2005). *Museums, Affect, and Cognition: The View for another Window*. In Alsop, S. (Ed.), *Beyond Cartesian Dualism*. Toronto: Springer.
- Dierking, L. D., Cohen Jones, M., Wadman, M., Falk, J. F., Storksdieck, M., & Ellenbogen, K. (2002). Broadening our Notions of the Impact of Free-Choice Learning Experiences. *Informal Learning Review*, 53(July/August).
- Dierking, L. D., & Falk, J. F. (1994). Family Behavior and Learning in Informal Science Settings: A Review of the Research. *Science Education*, 78(1), 57-72.

- Dierking, L. D., & Martin, L. (1997). Guest Editorial: Introduction. *Science Education*, 81(6), 629-631.
- Dodick, J., & Orion, N. (2003). Cognitive factors affecting student understanding of geological time. *Journal of Research in Science Teaching*, 40(4), 415-442.
- Dollard, J. (1935). *Criteria for the life history*. New Haven: Yale University Press.
- Dove, J. (2002). Does the man in the moon ever sleep? An analysis of student answers about simple astronomical events: a case study. *International Journal of Science Education*, 24(8), 823-834.
- Driver, R., Asoko, H., Leach, J., Mortimer, E., & Scott, P. (1994). Constructing scientific knowledge in the classroom. *Educational Researcher*, 23, 5-12.
- Duit, R., & Treagust, D. (1998). *Learning in science - from behaviourism towards social constructivism and beyond*. In Fraser, B. J., and Tobin, K.G (Ed.), *International Handbook of Science Education* (pp. 3-25). Dordrecht: Kluwer Academic Publishers.
- Dunlop, J. (2000). How Children Observe the Universe. *Publications of the Astronomical Society of Australia*, 17, 194-206.
- Durant, J. (1993). *What is scientific literacy?* In Durant, J. & Gregory, J. (Eds.), *Science and Culture in Europe* (pp. 129-138). London: Science Museum.
- Dzama, E., & Osborne, J. (1999). Poor performance among African students: an alternative explanation of the African World View thesis. *Journal of Research in Science Teaching*, 36(3), 387-403.
- Engeström, Y. (1991). Non Scoale sed vitae discimus: Toward overcoming the encapsulation of school. *Learning and Instruction*, 1, 243-259.
- Engeström, Y. (1993). *Developmental studies of work as a testbench of activity theory: The case of primary care medical practice*. In Chaiklin, S. & Lave, J. (Eds.), *Understanding practice: Perspectives on activity and context* (pp. 65-103): Cambridge University Press.
- Erickson, G. (2000). *Research programmes and the student science learning literature*. In Millar, R., Leach, J. & Osborne, J. (Eds.), *Improving Science Education: the contribution of research* (pp. 271-292). Buckingham: Open University Press.
- Exploratorium. (2006). fact sheet 2005-06. Retrieved August 4, 2006, from http://www.exploratorium.edu/about/fact_sheet.html
- Eylon, B.-S., & Linn, M. C. (1988). Learning and Instruction: an Examination of Four Research Perspectives in Science Education. *Review of Educational Research*, 58(3), 251-301.
- Falcão, D., Colinaux, C., Krapas, S., Querioz, G., Alves, F., Cazelli, S., et al. (2004). A model-based approach to science exhibition evaluation: a case study in a Brazilian astronomy museum. *International Journal of Science Education*, 26(8), 951-978.
- Falk, J., & Storksdieck, M. (2005). Using the Contextual Model of Learning to Understand Visitor Learning from a Science Center Exhibition. *Science Education*, 89(5), 744-778.
- Falk, J. H. (2001). *Free-Choice Science Learning: Framing the Discussion*. In Falk, J. H. (Ed.), *Free-Choice Science Education* (pp. 3-20). New York: Teachers College Press.
- Falk, J. H. (2003). *Personal Meaning Mapping*. In Caban, G., Scott, C., Falk, J. H. & Dierking, L. D. (Eds.), *Museums and Creativity: A study into the role of museums in design education*. Sydney: Powerhouse Publishing.
- Falk, J. H., & Dierking, L. D. (1992). *The Museum Experience*. Washington DC: Whalesback Books.

- Falk, J. H., & Dierking, L. D. (1997). School Field Trips: Assessing their Long-Term Impact. *Curator*, 40(3), 211-218.
- Falk, J. H., & Dierking, L. D. (2000). *Learning from museums: Visitor experiences and their making of meaning*. Walnut Creek, CA: Altamira Press.
- Falk, J. H., & Dierking, L. D. (2001). Learning from Science Centers: A Broader Perspective. *ASTC Dimensions*, Jan/Feb, 4-7.
- Falk, J. H., Moussouri, T., & Coulson, D. (1998). The Effect of Visitors' Agendas on Museum Learning. *Curator*, 41(2), 107-120.
- Fisher, M. S. (1997). The Effect of Humor on Learning in a Planetarium. *Science Education*, 81(6), 703-713.
- Flavell, J. (1976). *Metacognitive aspects of problem solving*. In Resnick, L. (Ed.), *The Nature of Intelligence*. New York: Lawrence Erlbaum.
- Fleer, M. (1997). A Cross-cultural Study of Rural Australian Aboriginal Children's Understanding of Night and Day. *Research in Science Education*, 27(1), 101-116.
- Gardner, H. (1993). *Multiple Intelligences: The theory in practice*. New York: Basic Books.
- Gaylard, M. (undated). History of the Science Awareness Programme at HartRAO: Hartebeesthoek Radio Astronomy Observatory.
- Gilbert, J. K. (2001). *Towards a Unified Model of Education and Entertainment in Science and Technology Centres*. In Stocklmayer, S. M., Gore, M. M. & Bryant, C. (Eds.), *Science Communication in Theory and Practice* (pp. 123-142). Dordrecht: Kluwer.
- Goldberg, S. (1995). Big Science: Atomic Bomb Research and The Beginnings of High Energy Physics. Retrieved 24 March, 2006, from <http://depts.washington.edu/hsexec/newsletter/1998/goldberg.html>
- Gorard, S. (2001). *Quantitative methods in educational research: the role of numbers made easy*. London: Continuum.
- Gorard, S., & Taylor, C. (2004). *Combining Methods in Educational and Social Research*. Buckingham: Open University Press.
- Gregory, J., & Miller, S. (1998). *Science in Public: Communication, Culture and Credibility*. Cambridge, Mass.: Perseus Publishing.
- Griffin, J. (2004). Research on Students and Museums: Looking More Closely at the Students in School Groups. *Science Education*, 88(Supplement 1), S59-S70.
- Griffin, J., & Symington, D. (1997). Moving from Task-Oriented to Learning-Oriented Strategies on School Excursions to Museums. *Science Education*, 81(6), 763-779.
- Gunstone, R. F., & White, R. T. (1981). Understanding of Gravity. *Science Education*, 65(3), 291-299.
- Hargreaves, A. (1996). The emotional practice of teaching. *Teaching and Teacher Education*, 14, 835-854.
- Hawkey, R. (2001). *Science beyond school: Representation or re-representation?* In Loveless, A. & Ellis, V. (Eds.), *ICT, Pedagogy and the Curriculum* (pp. 104-127). London and New York: Routledge/Falmer.
- Hein, G. E. (1998). *Learning in the Museum*. London: Routledge.
- Henning, E. (2004). *Finding your way in qualitative research*. Pretoria: Van Schaik.
- Hewson, P., & Hewson, M. (1992). *The status of students' conceptions*. In Druit, R., Goldberg, F. & Niedderer, H. (Eds.), *Research in physics learning: Theoretical issues and empirical studies* (pp. 176-187). Kiel, Germany: Institute for Science Education.
- Hidi, S., & Harachiewicz, J. (2000). Motivation the Academically Unmotivated: A Critical Issue for the 21st Century. *Review of Educational Research*, 70(2), 151-179.

- Hilgard, E. (1980). The trilogy of mind: Cognition, affection, and conation. *Journal of the History of the Behavioral Sciences*, 16, 107-117.
- Hlatshwayo, S., & Stanton, M. (2005). Alternative conceptions of high school science students on projectile motion. In Kasanda, C., Muhammed, L., Akpo, S. & Ngololo, E. (Eds.), *Proceedings of the 13th Annual SAARMSTE Conference*. Windhoek, Namibia: Unesco Office.
- Hofstein, A., & Rosenfeld, S. (1996). Bridging the Gap Between Formal and Informal Science Learning. *Studies in Science Education*, 28, 87-112.
- Holliday, A. (2002). *Doing and Writing Qualitative Research*. London: Sage.
- Hufnagel, B. (2002). Development of the Astronomy Diagnostic Test. *Astronomy Education Review*, 1(1), 47-51.
- Huitt, W. (1999). Conation as an important factor of mind. Retrieved 27 April, 2006, from <http://chiron.valdosta.edu/whuitt/col/regsys/conation.html>
- Jarman, R., & McAleese, L. (1996). Physics for the star-gazer: pupils' attitudes to astronomy in the Northern Ireland Science Curriculum. *Physics Education*, 223-226.
- Jarvis, T., & Pell, A. (2002). Effect of the Challenger Experience on Elementary Children's Attitudes to Science. *Journal of Research in Science Teaching*, 39(10), 979-1000.
- Jarvis, T., & Pell, A. (2005). Factors influencing elementary school children's attitudes to science before during and following a visit to the UK National Space Centre. *Journal of Research in Science Teaching*, 42(1), 53-83.
- Jegede, O. J. (1995). Collateral Learning and the Eco-Cultural Paradigm in Science and Mathematics Education in Africa. *Studies in Science Education*, 25, 97-137.
- Jegede, O. J., & Okebukola, P. A. (1991). The relationship between African traditional cosmology and students' acquisition of a science process skill. *International Journal of Science Education*, 13(1), 37-47.
- Johannesburg Planetarium. (1999). History of the Johannesburg Planetarium. Retrieved 30 August, 2005, from <http://www.wits.ac.za/planetarium/history.htm>
- Kagan, D. (1990). Ways of Evaluation Teacher Cognition: Inferences Concerning the Goldilocks Principle. *Review of Educational Research*, 60(3), 419-469.
- Kikas, E. (1998a). The Impact of Teaching on Students' Definitions and Explanations of Astronomical Phenomena. *Learning and Instruction*, 8(5), 439-454.
- Kikas, E. (1998b). Pupils' explanations of seasonal changes: age differences and the influence of teaching. *British Journal of Educational Psychology*, 68, 505-516.
- King, N. (n.d.). Template Analysis: Quality Checks. Retrieved 20 July, 2006, from http://www.hud.ac.uk/hhs/research/template_analysis/technique/qualityreflexivity.htm
- Klein, C. A. (1982). Children's Concepts of the Earth and the Sun. *Science Education*, 65(1), 95-107.
- Koballa, T. R. (n.d.). The Motivational Power of Science Discrepant Events. Retrieved 20 July, 2006, from <http://www.arches.uga.edu/~bcramond/home/DiscrepantEvents.htm>
- Koosimile, A. T. (2004). Out-of-school experiences in science classes: problems, issues and challenges in Botswana. *International Journal on Science Education*, 26(4), 483-496.
- Kubota, C., & Olstad, R. (1991). Effects of Novelty-reducing preparation on Exploratory Behavior and Cognitive Learning in a Science Museum Setting. *Journal of Research in Science Teaching*, 28(3), 225-234.

- Larkin, S. (2000). How Can We Discern Metacognition in Year One Children from Interactions between Students and Teacher, Paper presented at ESRC Teaching and Learning Research Programme Conference. Leicester, UK.
- Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge: Cambridge University Press.
- Lederman, N., Abd-El-Khalick, F., Bell, R., & Schwartz, R. (2002). Views of Nature of Science Questionnaire. *Journal Research on Science Teaching*, 39, 497-521.
- Leinhardt, G., & Gregg, M. (2002). *Burning Buses, Burning Crosses: Student Teachers See Civil Rights*. In Leinhardt, G., Crowley, K. & Knutson, K. (Eds.), *Learning Conversations in Museums* (pp. 139-166). Mahwah, New Jersey: Erlbaum.
- Lelliott, A. D., Rollnick, M., & Pendlebury, S. (2006). Gravity in the Solar System – the role of informal learning, 14th Annual Southern African Association for Research in Mathematics, Science and Technology Education Conference (pp. 78-88). Pretoria, South Africa.
- Lemmer, M., Lemmer, T. M., & Smit, J. J. A. (2003). South African students' views of the universe. *International Journal of Science Education*, 25(5), 562-582.
- Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry*. Beverly Hills: Sage.
- Loughran, J., Mulhall, P., & Berry, A. (2004). In Search of Pedagogical Content Knowledge in Science: Developing Ways of Articulating and Documenting Professional Practice. *Journal of Research in Science Teaching*, 41(4), 370-391.
- Lucas, A. M. (1983). Scientific Literacy and Informal Learning. *Studies in Science Education*, 10, 1-36.
- Lucas, A. M. (1991). 'Info-tainment' and informal sources for learning science. *International Journal of Science Education*, 13(5), 495-504.
- Lucas, K. B. (1999). When Mr Jones took Grade 5 to the Sciencecentre. Retrieved 2003/04/02, 2003
- Lucas, K. B. (2000). One Teacher's Agenda for a Class Visit to an Interactive Science Center. *Science Education*, 84, 524-544.
- Luke, J. J. (1998). Art Around the Corner: An Assessment of the Long-term Impact of an Art Museum Program on Students' Interpretations of Art. Unpublished Master of Museum Studies Thesis, University of Toronto, Toronto.
- Luke, J. J., Camp, B. D., Dierking, L. D., & Pearce, U. J. (2001). *The First Free-Choice Science Learning Conference: From Issues to Future Directions*. In Falk, J. H. (Ed.), *Free-Choice Science Education*. New York: Teachers College Press.
- Maher, F. A., & Tetreault, M. K. (1994). *The Feminist Classroom*. New York: Basic Books.
- Malcolm, C., & Alant, B. (2004). Finding Direction When the Ground Is Moving: Science Education Research in South Africa. *Studies in Science Education*, 40, 49-104.
- Mali, G. B., & Howe, A. (1979). Development of Earth and Gravity Concepts among Nepali Children. *Science Education*, 63(5), 685-691.
- Martin, L. (2001). *Free-Choice Science Learning: Future Directions for Researchers*. In Falk, J. (Ed.), *Free-Choice Science Education*. New York: Teachers College Press.
- Martin, L. (2004). An Emerging Research Framework for Studying Informal Learning and Schools. *Science Education*, 88(Supplement 1), S71-S82.
- Matthews, M. (2000). *Time for Science Education*: Kluwer Academic / Plenum Publishers.
- McClafferty, T. P. (1995). Did You Hear Granddad? Children's and adults' use and understanding of a sound exhibit at interactive science centres. *Journal of Education in Museums*, 16, 12-16.

- McClure, J. R., Sonak, B., & Suen, H. K. (1999). Concept Map Assessment of Classroom Learning: Reliability, Validity, and Logistical Practicality. *Journal of Research in Science Teaching*, 36(4), 475-492.
- McManus, P. M. (1992). Topics in museums and science education. *Studies in Science Education*, 20, 157-182.
- Medved, M., & Oatley, K. (2000). Memories and scientific literacy: remembering exhibits from a science centre. *International Journal of Science Education*, 22(10), 1117-1132.
- Miles, M. B., & Huberman, A. M. (1994). *Qualitative Data Analysis* (2nd ed.). Thousand Oaks, Ca: Sage.
- Mintzes, J. J., & Wandersee, J. H. (1998). *Reform and Innovation in Science Teaching: a Human Constructivist View*. In Mintzes, J. J., Wandersee, J. H. & Novak, J. D. (Eds.), *Teaching Science for Understanding. A Human Constructivist View*. San Diego: Academic Press.
- Mintzes, J. J., Wandersee, J. H., & Novak, J. (1997). *Meaningful Learning in Science: The Human Constructivist Perspective*. In Phye, G. D. (Ed.), *Handbook of Academic Learning* (pp. 405-447). San Diego, CA: Academic Press.
- Mischel, W. (1996). *From good intentions to willpower*. In Gollwitzer, P. & Bargh, J. (Eds.), *The Psychology of Action* (pp. 197-218). New York: Guildford Press.
- Mishler, E. G. (1990). Validation in Inquiry-Guided Research: The Role of Exemplars in Narrative Studies. *Harvard Educational Review*, 60(4), 415-442.
- Mohapatra, J. K. (1991). The interaction of cultural rituals and the concepts of science in student learning: a case study on solar eclipse. *International Journal of Science Education*, 13(4), 431-437.
- Moolla. (2003). An intervention with student teachers: pupil misconceptions in mechanics. Unpublished PhD, University of the Witwatersrand, Johannesburg.
- Morine-Dershimer, G. (1993). Tracing Conceptual Change in Preservice Teachers. *Teaching and Teacher Education*, 9(9), 15-26.
- Mosoloane, R., & Stanton, M. (2005). Learners' conceptions about astronomical concepts related to the Sun and the Earth. Paper presented at the Proceedings of the 13th Annual SAARMSTE Conference, Windhoek, Namibia.
- Novak, J. (1985). *Metalearning and Metaknowledge strategies to help students learn how to learn*. In West, L., and A. Pines (Ed.), *Cognitive structure and conceptual change*. Orlando, FL: Academic Press.
- Novak, J. (1988). Learning Science and the Science of Learning. *Studies in Science Education*, 15, 77-101.
- Novak, J., & Gowin, D. (1984). *Learning How to Learn*. New York: Cambridge University Press.
- Nussbaum, J. (1979). Childrens' Conceptions of the Earth as a Cosmic Body: A Cross Age Study. *Science Education*, 63(1), 83-93.
- Nussbaum, J., & Novak, J. (1976). An Assessment of Children's Concepts of the Earth Utilizing Structured Interviews. *Science Education*, 60(4), 535-550.
- Ogunnyi, M. B. (1996, 1998). Introduction. Paper presented at the Promoting Public Understanding of Science and Technology in Southern Africa, Cape Town.
- Ojala, J. (1992). The third planet. *International Journal of Science Education*, 14(2), 191-200.
- Opie, C. (Ed.). (2004). *Doing Educational Research: A Guide for First Time Researchers*. London: Sage Publications.

- Orion, N. (1993). A Model for the Development and Implementation of Field Trips as an Integral Part of the Science Curriculum. *School Science and Mathematics*, 93(6), 325-331.
- Osborne, J. (1996). Beyond Constructivism. *Science Education*, 80(1), 53-82.
- Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: a review of the literature and its implications. *International Journal of Science Education*, 25(9), 1049-1079.
- Palmer, D. (2001). Students' alternative conceptions and scientifically acceptable conceptions about gravity. *International Journal of Science Education*, 23(7), 691-706.
- Paris, S. G. (1999). From the Guest Editor. *Journal of Museum Education*, 23(1), 2.
- Parker, J., & Heywood, D. (1998). The earth and beyond: developing primary teachers' understanding of basic astronomical events. *International Journal of Science Education*, 20(5), 503-520.
- Parker, S. K. (1995). Lessons from Museum and Leisure Research. *Planetarian*, 24(2), 9-11.
- Parkyn, M. (1993). Scientific Imaging. *Museums Journal*, October 1993, 29-34.
- Pasachoff, J. M. (2001). What should Students Learn? *The Physics Teacher*, 39(September), 381-382.
- Pasachoff, J. M. (2002). Pasachoff's Points. *The Physics Teacher*, 40(April), 196-198.
- Pearsall, N., R., Skipper, J. E. L., & Mintzes, J. J. (1997). Knowledge Restructuring in the Life Sciences: A Longitudinal Study of Conceptual Change in Biology. *Science Education*, 81, 193-215.
- Piaget, J. (1929). *The Child's Conception of the World*. London: Routledge & Kegan Paul.
- Piaget, J. (1930). *The Child's Conception of Physical Causality*. London: Routledge & Kegan Paul.
- Polkinghorne, D. (1995). *Narrative configuration in qualitative analysis*. In Amos Hatch, J., and Wisniewski, R. (Ed.), *Life History and Narrative*. London: Falmer Press.
- Poole, M. (1995). *Beliefs and Values in Science Education*. Buckingham: Open University Press.
- Potgieter, M., Engelbrecht, J. C., & Harding, A. F. (2006). Procedural and conceptual knowledge in undergraduate mathematics and chemistry, 14th Annual Southern African Association for Research in Mathematics, Science and Technology Education Conference. Pretoria, South Africa.
- Pushkin, B. D. (1996). A comment on the need to use scientific terminology appropriately in conception studies. *Journal of Research in Science Teaching*, 33(2), 223-224.
- Rahm, J. (2004). Multiple Modes of Meaning-Making in a Science Center. *Science Education*, 88(2), 223-247.
- Ramey-Gassert, L., Walberg, H. J. I., & Walberg, H. J. (1994). Reexamining Connections: Museums as Science Learning Environments. *Science Education*, 78(4), 345-363.
- Rennie, L. J. (2001). *Communicating Science through Interactive Science Centres: A Research Perspective*. In Stocklmayer, S. M., Gore, M.M., and Bryant, C. (Ed.), *Science Communication in Theory and Practice* (pp. 107-121). Dordrecht: Kluwer.
- Rennie, L. J., Feher, E., Dierking, L. D., & Falk, J. H. (2003). Toward an Agenda for Advancing Research on Science Learning in Out-of-School Settings. *Journal of Research in Science Teaching*, 40(2), 112-120.
- Rennie, L. J., & McClafferty, T. P. (1996). Science Centres and Science Learning. *Studies in Science Education*, 27, 53-98.
- Riordan, R. (1991). Planetarium Education: A Review of the Literature. *Planetarian*, 20(3), 18-26.

- Roald, I., & Mikalsen, O. (2000). What are the Earth and heavenly bodies like? A study of objectual conceptions among Norwegian deaf and hearing pupils. *International Journal of Science Education*, 22(4), 337-355.
- Roald, I., & Mikalsen, O. (2001). Configuration and dynamics of the Earth-Sun-Moon system: an investigations into conceptions of deaf and hearing pupils. *International Journal of Science Education*, 23(4), 423-440.
- Roberts, L. C. (1997). *From Knowledge to Narrative: Educators and the Changing Museum*. Washington: Smithsonian Institution Press.
- Rollnick, M. (2000). Current Issues and Perspectives on Second Language learning of Science. *Studies in Science Education*, 35, 93-122.
- Roschelle, J. (1995). *Learning in Interactive Environments: Prior Knowledge and New Experience*. In Falk, J. H. & Dierking, L. D. (Eds.), *Public Institutions for Personal Learning: Establishing a Research Agenda*. Washington D.C.: American Association of Museums.
- Roth, W.-M. (2005). *Talking Science: Language and Learning in Science Classrooms*. Lanham: Rowman & Littlefield.
- Ruiz-Primo, M., & Shavelson, R. (1996). Problems and issues in the use of concept maps in science assessment. *Journal of Research in Science Teaching*, 33(6), 569-600.
- Rusk, J. (2003). Do Science Demonstrations in the Planetarium Enhance Learning. *Planetarian*, March 2003, 5-8.
- Ryan, G., & Weisner, T. (1997). Analyzing words in brief descriptions: Fathers and mothers describe their children. Retrieved 16 April, 2005, from www.analytictech.com/borgatti/ryantext.htm
- Sadler, P. M. (1998). Psychometric Models of Student Conceptions in Science: Reconciling Qualitative Studies and Distractor-Driven Assessment Instruments. *Journal of Research in Science Teaching*, 35(3), 265-296.
- Sadler, P. M. (2001). Choosing Between Helioseismology and Phases of the Moon. *The Physics Teacher*, 39(December), 554-555.
- Sadler, P. M. (2002). Further Discussion. *The Physics Teacher*, 40(April), 198.
- Sanders, M. (1998). No simple panaceas: A response to Fish. In Ogunnyi, M. B. (Ed.), *Promoting Public Understanding of Science in Southern Africa* (pp. 85-91). Cape Town: SSME, University of Western Cape.
- Schauble, L., Leinhardt, G., & Martin, L. (1997). A Framework of Organizing a Cumulative Research Agenda in Informal Learning Contexts. *Journal of Museum Education*, 22(2 and 3), 3-7.
- Schultz, J., Säljö, R., & Wyndhamn, J. (2001). Heavenly Talk: Discourse, Artifacts, and Children's Understanding of Elementary Astronomy. *Human Development*, 44, 103-118.
- Schur, Y. (1999). Constructivism and Mediated Learning Experience as a Basis for a Process of Conceptual Change in Students' Concepts of Earth. Unpublished Doctor of Philosophy, University of the Witwatersrand, Johannesburg.
- Setati, M. (2003). Speaking mathematically: language(s), discourse and cultural models in a multicultural mathematics classroom in South Africa, Proceedings of the 11th Annual SAARMSTE conference (pp. 605-615): University of Swaziland, Mbabane.
- Setati, M., Adler, J., Reed, Y., & Bapoo, A. (2002). *Code-switching and other language practices in mathematics, science and English language classrooms in South Africa*. In Adler, J. & Reed, Y. (Eds.), *Challenges of Teacher Development: an investigation of take-up in South Africa*. Pretoria: Van Schaik.

- Shamos, M. (1995). *The Myth of Scientific Literacy*. New Brunswick, NJ: Rutgers University Press.
- Sharma, M. D., Millar, R. M., Smith, A., & Sefton, I. M. (2004). Students' Understanding of Gravity in an Orbiting Space-Ship. *Research in Science Education*, 34(3), 267-289.
- Sharp, J. G. (1996). Children's astronomical beliefs: a preliminary study of Year 6 children in south-west England. *International Journal of Science Education*, 18(6), 685-712.
- Shen, B. (1975). *Science Literacy and the Public Understanding of Science*. In Day, S. (Ed.), *Communication of Scientific Information*. Basel: Kager.
- Shortland, M. (1987). No business like show business. *Nature*, 328, 213-214.
- Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, 15(2), 4-14.
- Silverman, L. H. (1995). Visitor Meaning-Making in Museums for a New Age. *Curator*, 38(3), 161-170.
- Sjøberg, S. (2000). The Disenchantment with Science. Retrieved 16 June, 2006, from <http://folk.uio.no/sveinsj/The%20disenchantment%20with%20scienceExp.htm>
- Slisko, J., & Dykstra, D. (1997). The Role of Scientific Terminology in Research and Teaching: Is Something Important Missing? *Journal of Research in Science Teaching*, 34(6), 655-660.
- Smith, J., diSessa, A., & Roschelle, J. (1993). Misconceptions Reconceived: A Constructivist Analysis of Knowledge in Transition. *The Journal of the Learning Sciences*, 3(2), 115-163.
- Square Kilometre Array. (nd). South Africa's Competitive Advantage. Retrieved 25 June, 2006, from <http://www.ska.ac.za/saca.html>
- Stahly, L., Krockover, G., & Shepardson, D. (1999). Third Grade Students' ideas About the Lunar Phases. *Journal of Research in Science Teaching*, 36(2), 159-177.
- Stake, R. E. (1995). *The Art of Case Study Research*: SAGE Publications.
- Statistics South Africa. (2001). Census 2001: Key Results. Retrieved July 12, 2006, from http://www.statssa.gov.za/census01/html/Key%20results_files/Key%20results.pdf
- Storksdieck, M. (2004). Testing a Model for Understanding Field Trips in Environmental Education. Unpublished Doctor of Philosophy thesis, Universitat Luneburg.
- Strike, K., & Posner, G. (1985). *A conceptual change view of learning and understanding*. In West, L., and A. Pines (Ed.), *Cognitive structure and conceptual change*. Orlando, FL: Academic Press.
- Strike, K., & Posner, G. (1992). *A revisionist theory of conceptual change*. In Duschl, R. & Hamilton (Eds.), *Philosophy of science, cognitive science, and educational theory and practice* (pp. 147-176). Albany, NY: State University of New York Press.
- Summers, M., & Mant, J. (1995). A survey of British primary school teachers' understanding of the Earth's place in the universe. *Educational Research*, 37(1), 3-19.
- Taylor, N., & Vinjevold, P. (Eds.). (1999). *Getting learning right: report of the President's Education Initiative Research Project*. Johannesburg: Joint Education Trust.Department of Education.
- Tennyson, R. D., & Rasch, M. (1988). Linking cognitive learning theory to instructional prescriptions. *Instructional Science*, 17(4), 369-385.
- Tesch, R. (1990). *Qualitative Research: Analysis Types & Software Tools*. Basingstoke, UK: Falmer Press.
- Tobin, K. (2000). *Interpretive Research in Science Education*. In Kelly, A., and Lesh, R. (Ed.), *Handbook of Research Design in Mathematics and Science Education*. Mahwah, New Jersey: Lawrence Erlbaum.

- Tobin, K., Tippins, & Gallard. (1994). *Research on Instructional Strategies for Teaching Science*. In Gabel, D. L. (Ed.), *Handbook of Research on Science Teaching and Learning*. New York: Macmillan.
- Treagust, D., & Smith, C. L. (1989). Secondary Students' Understanding of Gravity and the Motion of Planets. *School Science and Mathematics*, 89(5), 380-391.
- Trowbridge, J. E., & Wandersee, J. H. (1998). *Theory-Drive Graphic Organizers*. In Mintzes, J. J., Wandersee, J. H. & Novak, J. D. (Eds.), *Teaching Science for Understanding. A Human Constructivist View* (pp. 109-131). San Diego: Academic Press.
- Trumper, R. (2001a). A cross-age study of junior high school students' conceptions of basic astronomy concepts. *International Journal of Science Education*, 23(11), 1111-1123.
- Trumper, R. (2001b). A Cross-age study of Senior High School Students' Conceptions of Basic Astronomy Concepts. *Research in Science & Technological Education*, 19(1), 97-109.
- Trundle, K., Atwood, R., & Christopher, J. (2002). Preservice Elementary Teachers' Conceptions of Moon Phases before and after Instruction. *Journal of Research in Science Teaching*, 39(7), 633-658.
- Tyson, M., Venville, G., Harrison, J., & Treagust, D. (1997). A multidimensional framework for interpreting conceptual change events in the classroom. *Science Education*, 81, 387-404.
- University of Huddersfield. (2006). Template Analysis. Retrieved 15 July, 2006, from http://www.hud.ac.uk/hhs/research/template_analysis/technique/qualityreflexivity.htm
- Urke, T. (1993). Research on the Effects of Teaching Astronomy with a Planetarium. *Planetarian*, 22(4), 19-20.
- Uzzel, D. (1993). *Contrasting psychological perspectives on exhibition evaluation*. In Bicknell, S. & Farmelo, G. (Eds.), *Museum visitor studies in the 90s* (pp. 125-129). London: Science Museum.
- van der Riet, M., Dison, A., & Quinn, L. (1998). Conceptual development through process-writing in a Psychology II course. *South African Journal of Higher Education*, 12(1), 221-226.
- Vosniadou, S. (1991). Designing curricula for conceptual restructuring: Lessons from the study of knowledge acquisition in astronomy. *Journal of Curriculum Studies*, 23(3), 219-237.
- Vosniadou, S., & Brewer, W. F. (1992). Mental Models of the Earth: A Study of Conceptual Change in Childhood. *Cognitive Psychology*, 24, 535-585.
- Vosniadou, S., & Brewer, W. F. (1994). Mental Models of the Day/Night Cycle. *Cognitive Science*, 18, 123-183.
- Vosniadou, S., Skopeliti, I., & Ikospenkati, K. (2005). Reconsidering the role of artifacts in reasoning: Children's understanding of the globe as a model of the earth. *Learning and Instruction*, 15, 333-351.
- Wall, C. (1973). A Review of Research Related to Astronomy Education. *School Science and Mathematics*, 73(8), 653-669.
- Watts, D. M. (1982). Gravity -- don't take it for granted! *Physics Education*, 17(3), 116-121.
- Weinburgh, M. (1995). Gender Differences in Student Attitudes towards Science. A Meta-Analysis of the Literature from 1970 to 1991. *Journal of Research in Science Teaching*, 32, 387-398.

- Wellington, J. (1990). Formal and informal learning in science: the role of the interactive science centres. *Physics Education*, 25, 247-252.
- White, R. (1997). Trends in Research in Science Education. *Research in Science Education*, 27(2), 215-221.
- Wolcott, H. (1988). *Adequate School and Inadequate Education: The Life History of a Sneaky Kid*. In Jaeger, R. (Ed.), *Complementary Methods for Research in Education*. Washington DC: American Educational Research Association.
- Yin, R. K. (1994). *Designing Single- and Multiple-Case Studies*. In Bennett, N., Glatter, R., and Levacic (Ed.), *Improving Educational Management* (pp. 135-155). London: Open University and Paul Chapman Publishing.
- Zeilik, M. (1994). *Astronomy: The Evolving Universe*. New York: John Wiley.
- Zeller, N. (1995a). *Narrative Rationality in Educational Research*. In McEwan, H. & Egan, K. (Eds.), *Narrative in Teaching, Learning, and Research*. New York: Teachers College Press.
- Zeller, N. (1995b). *Narrative strategies for case reports*. In Amos Hatch, J. & Wisniewski, R. (Eds.), *Life History and Narrative*. London: Falmer Press.

Appendix A

Original questionnaire administered as a pilot study

Survey

We would like to find out your ideas about things in space. This is not a test, and won't be used at school in any way.

1. What is the solar system?

2. The sun is a star.

- a. What is it made of?

- b. What makes the sun shine?

- c. Why does the sun look different to the stars you see at night?

3. Name the four inner planets of the solar system

4. Why don't the planets orbiting (going around) the sun fly off into space?

5. What makes the moon shine at night (and sometimes during the day)?

6. Draw a picture of the Earth and the Sun to show why day-time and night-time happen. Include these labels: Earth, Sun, day-time, night-time.

Thank You

Appendix B

Condensed versions of Pre Visit Interview Schedules (white space removed)

HartRAO Pre-Visit Student Interview (PVSI) Code:

Introduction

1. *Introducing myself*

I am Tony Lelliott, a student in the School of Education, University of the Witwatersrand, doing research at the Johannesburg Planetarium and the Hartebeeshoek Radio Astronomy Observatory in Gauteng, South Africa.

2. *Purpose, Context, and Intended Use of the Interview*

The purpose of this interview is to find out about your proposed visit to the Johannesburg Planetarium or the Hartebeeshoek Radio Astronomy Observatory . I intend to use the information you provide to get an overall picture of what happens during your visit and what you experience.

3. *Assuring Confidentiality*

I assure you of complete confidentiality of any information you share with me, and the use of pseudonyms instead of actual names in the transcript and the report. No one except my supervisor and myself will have access to the videos.

4. *Permission to Tape*

I would like to videotape the conversation for recollection of our discussion. Will you give me the permission to videotape this conversation? [if the answer is yes, I set the tape on; if the answer is no, I take notes during the interview].

5. *Any Questions*

Before we start, first, do you have any questions about the purpose of the interview, confidentiality, tape recording, or any other thing you would like to ask me?

Section A. Demographic information.

1. Fictitious name: _____
2. Age: _____
3. Sex (Male/Female): _____
4. Your parent/guardians names _____
5. Place of Origin (Farm/Township/Town/City/Other): _____
6. Name of School you are at _____
7. Grade _____
8. Your home phone no. _____
9. What language(s) do you mainly speak at home? _____

Section B. The Proposed Visit. (HartRAO)

1. Where are you going on the forthcoming visit?
2. What subject and topic area is the visit related to?
3. What do you think is the purpose of the visit?
4. What preparation have you been doing for the visit? Probe for organisational preparation; tasks/worksheets, learning preparation in class on topic; preparation for the nature of the venue; etc.
5. Are you looking forward to the visit? Why/not?

Section C. Knowledge (relevant for HartRAO trip)

1. How is the sun similar or different to stars that we see at night?
2. What is the temperature today (approx.)? What temperature does water boil at? How hot do you think the sun is? What else can you tell me about the sun? What can we use the sun for?
3. Why does the sun move across the sky every day? Use model if you like.
4. The sun and the moon look the same size in our sky. Are they? Why do you say that? [Which is really bigger?] Why do they look the same size?
5. Stars at night look like pinpricks of light. Why? What are they?
6. What does the word 'satellite' mean to you? Probe: if DSTV, where is signal from? What is the shape of the dish? Why is it this shape? Is the word satellite used in any other way/meaning? [What about satellite dish]
7. What does the moon look like if you see it every night over the course of a month? Why does the moon look different on different nights throughout the month?
8. What is gravity? What does it do? What would gravity be like on the moon? On Jupiter? Why the difference? So what is the pull of gravity related to? Does the earth's' gravity have any effect on the moon? What? What about the moon's grav. effect on the earth?
9. Have you heard any planet or space-related things on TV, in magazines or in the news at all recently?

Section D. Attitude to Science/Astronomy

1. Do you like school? Probe why/not.
2. What are your 2 **favourite** subjects at school? Why?
3. What are your 2 **least favourite** subjects at school? Why?
4. What do you do in your spare time? What TV programmes do you like? Do you read much? Tell me any books you have read recently.
5. So far at school, have you ever covered things like the sun, the moon, planets, space stars etc? In which subject did you cover them?
6. Do you find anything to do with space, planets and stars interesting? If so, what? why? If not, why not?
7. If **you** were a teacher teaching about space, planets and stars, what would **you** do with your students (in your own grade)?
8. Have scientists found life anywhere other than earth? Do you think there is life anywhere else in the universe? Do you believe in aliens? Probe why. Have aliens ever visited earth?
9. Do you believe in the horoscope in magazines etc? [astrology]. Probe.

10. Are you religious? What is god's relationship to the universe?

Planetarium Pre-Visit Student Interview (PVSI)

Sections A and B are same as the HartRAO PVSI

Section C. Knowledge (relevant for planetarium trip)

1. Do you know the names of any stars? Can you see any planets in the night sky? What do they look like?
2. What is the solar system? What ["things"] does it consist of? What shape is it? How do you know?
3. [Tell me anything you know about the sun] – if not covered in PMM interview.
4. Why does the sun move across the sky every day?
5. The sun and the moon look the same size in our sky. Are they? Why do you say that? [Which is really bigger?] Why do they look the same size?
6. Stars at night look like pinpricks of light. Why? What are they? [why are they there?]
7. In the fastest space ship we could build, how long would it take to reach the closest star outside our solar system? Guess?
8. Why does the moon look different on different nights (and days) throughout the month?
9. have you heard any planet or space-related things in the news at all recently?

Section D. Attitude to Science/Astronomy

1. Do you like school? Probe why/not.
2. What are your 2 **favourite** subjects at school? Why?
3. What are your 2 **least favourite** subjects at school? Why?
4. What do you do in your spare time? What TV programmes do you like? Do you read much? Tell me any books you have read recently.
5. So far in your schooling, have you ever covered things like the sun, the moon, planets, space stars etc? In which subject did you cover them?
6. Do you find anything to do with space, planets and stars interesting? If so, what? why? If not, why not?
7. If **you** were a teacher teaching about space, planets and stars, what would **you** do with your students (in your own grade)?
8. Do you believe in aliens? Probe why. Have aliens ever visited earth? Have scientists found life anywhere other than earth?
9. Do you believe in the horoscope in magazines etc? [astrology]. Probe.
10. Are you religious? What is god's relationship to the universe?

Appendix C

Condensed versions of Post Visit Interview Schedules (white space removed)

HartRAO Post-Visit Student Interview Questions (PoVSI)

Code:

Introduction

1. *Introducing myself (reminder)*

As you know, I am Tony Lelliott, a Doctor of Philosophy student in the School of Education, University of the Witwatersrand, doing research at the Johannesburg Planetarium and the Hartebeeshoek Radio Astronomy Observatory in Gauteng, South Africa.

2. *Purpose, Context, and Intended Use of the Interview*

Thank you for allowing me to observe your class trip to the Johannesburg Planetarium (pltm) or the Hartebeeshoek Radio Astronomy Observatory (hartrao). The purpose of this interview is to find out how your visit to the pltm or hartrao went. I intend to use the information you provide to get an overall picture of how the visit takes place, and what the students learn. I will be asking some similar questions to the ones I asked before the trip, but also some new questions.

3. *Assuring Confidentiality*

I assure you of complete confidentiality of any information you share with me, and the use of pseudonyms instead of actual names in the transcript and the report. No one except my supervisor and myself will have access to the videos.

4. *Permission to Tape*

I would like to videotape the conversation for recollection of our discussion. Will you give me the permission to tape this conversation? [if the answer is yes, I set the tape on; if the answer is no, I take notes during the interview].

5. *Any Questions*

Before we start, first, do you have any questions about the purpose of the interview, confidentiality, tape recording, or any other thing you would like to ask me?

Fictitious name of student: _____

Grade(s)/Class(es) taken on trip: _____

PoVSI HartRAO

Section B. The Recent Visit. [Answers will be noted by the interviewer on a separate sheet]

6. Where did you go on your [recent] science [or HSS] visit? When did you go?
7. What learning area and/or topic was the visit related to?
8. What do you think was the purpose of the visit?
9. Did you do any work on topic of the visit? Probe for what was done; tasks/worksheets, any classwork or homework on topic; essay written; etc.

Section C. Follow-up of questionnaire

10. How is the sun similar or different to stars that we see at night?
11. What is the temperature today (approx.)? What temperature does water boil at? How hot do you think the sun is? What else can you tell me about the sun? What can we use the sun for?
12. Why does the sun move across the sky every day? Use model if you like.
13. The sun and the moon look the same size in our sky. Are they? Why do you say that? [Which is really bigger?] Why do they look the same size?
14. Stars at night look like pinpricks of light. Why? What are they?
15. What does the word 'satellite' mean to you? Probe: if DSTV, where is signal from? What is the shape of the dish? Why is it this shape? Is the word satellite used in any other way/meaning? [What about satellite dish]
16. What does the moon look like if you see it every day over the course of a week? Why does the moon look different on different nights throughout the month?
17. What is gravity? What does it do? What would gravity be like on the moon? {Probe further if they think there is no gravity on moon] On Jupiter? Why the difference? So what is the pull of gravity related to? Does the earth's' gravity have any effect on the moon? What? What about the moon's grav. effect on the earth?
18. Have scientists found life anywhere other than earth? Do you think there is life anywhere else in the universe? Do you believe in aliens? Probe why. Have aliens ever visited earth?
19. Since the visit, have you heard any planet or space-related things on TV, in magazines or in the news?

Section D. Attitude to Science/Astronomy

11. Now you've been to the HartRAO, have your ideas about space, planets and stars changed at all? What?
12. What things did you most enjoy about the visit? Can be anything.
13. What did you enjoy least? Is there anything you disliked about the visit?
14. Have you told anyone about the visit? Who? What did you tell them?
15. If your school arranges a visit to Hartebeeshoek Radio Astronomy Observatory, would want to you go (again)?
16. The Hartebeeshoek Radio Astronomy Observatory run public visits. Would you want to visit again together with your family?
17. What sort of job do you want to do when you leave school?
18. Other than today and when you told xx [#D4 above], have you thought about the trip since? Tell me what.

Planetarium Post-Visit Student Interview (PoVSI)

Sections A and B are same as the HartRAO PoVSI

Section C. Follow-up of questionnaire

1. Do you know the names of any stars? Can you see any planets in the night sky? What do they look like?
2. What is the solar system? What ["things"] does it consist of? What shape is it? How do you know?

3. [Tell me anything you know about the sun] – if not covered in PMM interview.
4. Why does the sun move across the sky every day? Use model if you like.
5. The sun and the moon look the same size in our sky. Are they? Why do you say that? [Which is really bigger?] Why do they look the same size?
6. Stars at night look like pinpricks of light. Why? What are they?
7. In the fastest space ship we could build, how long would it take to reach the closest star outside our solar system? Guess?
8. Why does the moon look different on different nights (and days) throughout the month?
9. Have you heard any planet or space-related things in the news at all recently?

Section D. Attitude to Science/Astronomy

1. Now you've been to the planetarium, have your ideas about space, planets and stars changed at all? What?
2. What things did you most enjoy about the visit? Can be anything.
3. What did you dislike about the visit?
4. Have you told anyone about the visit? Who? What did you tell them?
5. If your school arranges a visit to Planetarium/Hartebeeshoek Radio Astronomy Observatory, would want to you go (again)?
6. The Planetarium/Hartebeeshoek Radio Astronomy Observatory run public visits. Would you want to visit again together with your family?
7. What sort of job do you want to do when you leave school?
8. Other than today, have you thought about the trip since? Tell me what.

Appendix D Ethics sheets and forms

Information Sheet

Research Study on Learning in Astronomy

My name is Tony Lelliott. I'm a member of staff in the School of Education at the University of the Witwatersrand and also a Doctor of Philosophy student at the same institution.

I am carrying out a study of informal learning at the Johannesburg Planetarium and the Visitor's Centre of the Hartebeeshoek Radio Astronomy Observatory, mainly looking at how school students and teachers learn about astronomy and science as a result of a school visit to the site. My research will benefit not only the two institutions where it is taking place, but also the South African educational system in improving the learning and teaching of science.

I selected your school as representative of many of the schools in South Africa. I would like to interview you as a [student]/[teacher] who is going to visit one of the above places, as well as observe the class when you actually visit the planetarium or observatory. In addition, I'd like to check what you might learn by using a questionnaire that asks about particular astronomical phenomena. After your return to school, I'd like to interview you again about your experiences of the visit, and possibly follow this up with a final questionnaire some weeks later. I have selected you because your school class is intending to conduct a school visit to Johannesburg Planetarium or Hartebeeshoek Radio Astronomy Observatory in the near future, and because your school is representative of the bulk of schools in South Africa.

Each part of the research will take about 40 minutes to complete, that is the interview before the visit; the questionnaire during the visit, the post-visit interview and the post-visit questionnaire. In addition, I'd like to conduct a follow up interview with you several weeks or months after the visit.

If you agree to take part in my study, I'd like to make it clear that your participation is entirely voluntary, no harm will come to you, and all information will be treated with confidentiality and anonymity. If you do choose to participate, you may decline to answer any questions, and you may withdraw from the study at any time. I hope to publish the results of my study in academic journals. In order to protect confidentiality, all names I use will be fictitious.

I will provide you with a summary of my research results on completion if you would like me to.

Thank You.

Informed Consent Form

Research Project: Learning about Astronomy

I, _____ consent to participate in this study conducted by Mr. A. Lelliott for his research on learning at an observatory and a planetarium.

I realise that no harm will come to me, and that the study is being conducted for educational purposes.

I participate voluntarily and understand that I may withdraw from the study at any time.

I further consent to being video and/or audio recorded as part of the study.

I also understand I have the right to review the questionnaires I complete and the transcripts made of our conversations before these are used for analysis if I so choose.

I can delete or amend any material or retract or revise any of my remarks. Everything

I say will be kept confidential by the interviewer. I will only be identified by a pseudonym in the transcript. In addition, any persons I refer to in the interview will be kept confidential.

Verbatim quotes from me may be used in the research report, but they will be reported so that my identity is anonymous. Any specific individuals or courses I refer to will be given pseudonyms. I understand that the results of the study may be published, but my identity will be anonymous.

Name _____

Signature _____

Date _____

Informed Consent Form – Parent/Guardian

Research Project: Learning about Astronomy

I, _____, parent/guardian of my ward
_____ consent to her/him participating in the study
conducted by Mr. A. Lelliott for his research on learning at an observatory and a
planetarium.

I realise that no harm will come to my ward, and that the study is being conducted for
educational purposes.

I allow my ward to participate voluntarily and understand that s/he may withdraw
from the study at any time. I further consent to my ward being video and audio
recorded as part of the study.

Everything my ward says will be kept confidential by the interviewer. My ward will
only be identified by a pseudonym in the transcript. In addition, any persons my ward
refers to in the interview will be kept confidential.

Verbatim quotes from my ward may be used in the research report, but they will be
reported so that her/his identity is anonymous. Any specific individuals or courses my
ward refers to will be given pseudonyms. I understand that the results of the study
may be published, but my ward's identity will be anonymous.

Name _____

Signature _____

Date _____

Appendix F

Student	Gravity		Star concept		Sun concept		SS		Size/Scale		Sun movement		Moon phases		Parabolic/Satellite Dish		Mean score		Difference in mean score
	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post	ave pre	ave post	
scf06	2	n/a	2	2	1	3	2	2	2	3	1	1	2.5	2	n/a	n/a	1.8	2.2	0.4
scf08	n/a	n/a	2	2	3	3	3	3	3	3	3	3	2	2	n/a	n/a	2.7	2.7	0.0
scf10	n/a	n/a	2	2	3	3	2	2	2	2.5	2	3	2.5	2.5	n/a	n/a	2.3	2.5	0.3
Helen	2	3	2	2	2	2	2	2	3	3	1	3	3	3	n/a	n/a	2.1	2.6	0.5
scf12	n/a	n/a	2	2	2	3	2	2	2	3	2	3	2	2	n/a	n/a	2.1	2.5	0.4
Fatima	n/a	n/a	2	2	2	3	2	2	1	2	1	2	1	1	n/a	n/a	1.5	2.0	0.5
scf17	n/a	n/a	2	2	2	2	1	2	2	3	1	1	1	1	n/a	n/a	1.5	1.8	0.3
scf19	n/a	n/a	3	3	3	3	3	3	3	3	2	2	2	2	n/a	n/a	2.7	2.7	0.0
swo05	2	2	1	2	2	3	n/a	n/a	2	3	3	3	3	1	1.5	2	2.1	2.3	0.2
swo06	1	2	1	1	1	2	n/a	n/a	2	2	2	2	1	1	2	1	1.4	1.6	0.1
swo07	1	2.5	1	1	2	2	n/a	n/a	2	2	3	3	3	2.5	1.5	2	1.9	2.1	0.2
swo14	1	2	1	2	2	2	n/a	n/a	2	2	1	1	1	1	1	1.5	1.3	1.6	0.4
swo20	2	3	2	2	1	2	n/a	n/a	2	3	3	3	2	2.5	2	2	2.0	2.5	0.5
swo22	1	2	1	1	1	1	n/a	n/a	1	2	2	3	1	n/a	2	2	1.3	1.8	0.5
Nonkul	0	1	1	1	1	1	n/a	n/a	1	1	1	1	1	n/a	2	2	1.0	1.2	0.2
swo29	1	2	2	2	2	2	n/a	n/a	2	3	3	2	1	n/a	2.5	3	2.1	2.3	0.3
swo36	1	2	2	2	2	3	n/a	n/a	2	2	3	2	2.5	n/a	2	2.5	2.0	2.3	0.3
Neo	1	1	2	2	2	3	n/a	n/a	3	3	3	3	2.5	n/a	1.5	2	2.1	2.3	0.2
swo53	1	1.5	1	2	1	2	n/a	n/a	2	2	3	1	2	n/a	1	1.5	1.5	1.7	0.2
swo59	2	2.5	1	2	2	2	n/a	n/a	1	2	3	3	1	n/a	1	3	1.7	2.4	0.8
swo69	2	3	1	1	3	3	n/a	n/a	2	2	3	3	1	n/a	2	2.5	2.2	2.4	0.3
Brenda	1	2	1	2	2	3	n/a	n/a	2	3	3	3	1	n/a	2.5	3	1.9	2.7	0.8
tsw02	1	3	1	1	2	2	n/a	n/a	2	2	1	3	1	1	1.5	2	1.4	2.0	0.6
Botho	1	2	2	3	2	2	n/a	n/a	2	2	2	2	1	1	1	1	1.6	1.9	0.3
tsw08	2	2	1	1	2	2	n/a	n/a	2	2	1	1	1	1	1.5	2	1.5	1.6	0.1

Appendices

Student	Gravity		Star concept		Sun concept		SS		Size/Scale		Sun movement		Moon phases		Parabolic/Satellite Dish		Mean score		Difference in mean score
	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post	ave pre	ave post	
tsw15	1	2	1	1	1	2	n/a	n/a	2	3	3	3	2	2.5	2	3	1.7	2.4	0.6
vho02	2	2.5	2	2	3	3	n/a	n/a	3	3	3	3	3	n/a	2	2.5	2.5	2.7	0.2
vho06	1	1.5	1	2	2	3	n/a	n/a	2	3	2	2	2	n/a	2	3	1.7	2.4	0.8
vho09	1	1	2	2	1	1	n/a	n/a	1	1	1	1	1	n/a	1	1	1.2	1.2	0.0
vho10	2	2	2	2	2	3	n/a	n/a	2	2.5	3	3	1	n/a	3	3	2.3	2.6	0.3
vho11	1	1	1	1	3	3	n/a	n/a	2	2	2	2	1	1	1	2	1.6	1.7	0.1
vho12	3	3	2	2	3	3	n/a	n/a	3	3	3	2	1	n/a	1.5	2.5	2.6	2.6	0.0
vho13	2	2	2	2	2	2	n/a	n/a	2	2	2	3	1	n/a	2	2	2.0	2.2	0.2
John	3	3	3	3	3	3	n/a	n/a	3	3	2	3	3	n/a	3	3	2.8	3.0	0.2
Ave	1.5	2.1	1.6	1.8	2.0	2.4	2.1	2.3	2.0	2.4	2.2	2.3	1.7	1.7	1.7	2.2	1.8	2.1	0.3

Appendix G

Original categorisation scheme

Pre-visit category	Post-visit learning		
	1	2	3
Low	swo07 ✓ swo26 ✓ Nkululeko* vho09 ✓ vho11 ✓ tsw04 ✓ tsw08 ✓	scf17 – Kefilwe ✓ swo06 – Zanele ✓ swo14 can't code swo22 ✓ swo59 ✓ swo70 ✓ tsw02 ✓	swo53 ✓ vho06 ✓ scf15 – Fatima ✓ *
Medium	swo42 – Neo ✓ * vho13 ✓ These 2 very similar: neither learnt much, despite good pre- knowledge.	scf06 ✓ swo29 ✓ swo36 ✓ tsw15 vho10	scf11 – Helen ✓ * scf12 swo05 swo20
High	scf08 scf10 scf19 swo69 vho02 vho12 vho16 – John ✓ *		

□

✓ - means that the PDs have been recoded in December 2005- early 2006.

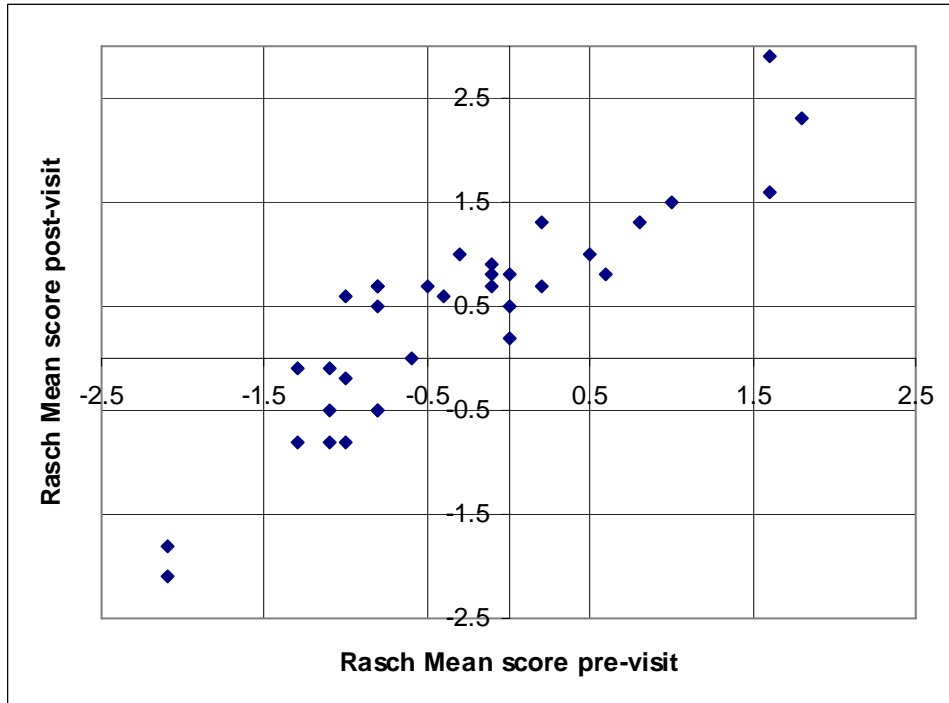
* means that a portrait has been 'completed' (early 2006) incl HC & ILF discussion.

The 5 most improved according to the Revised Classification are:

scf15 (Fatma), swo05, swo59, tsw15 and vho06.

Appendix H

Scattergram of students' pre- and post-visit mean scores recalculated using the Rasch technique.



Appendix I

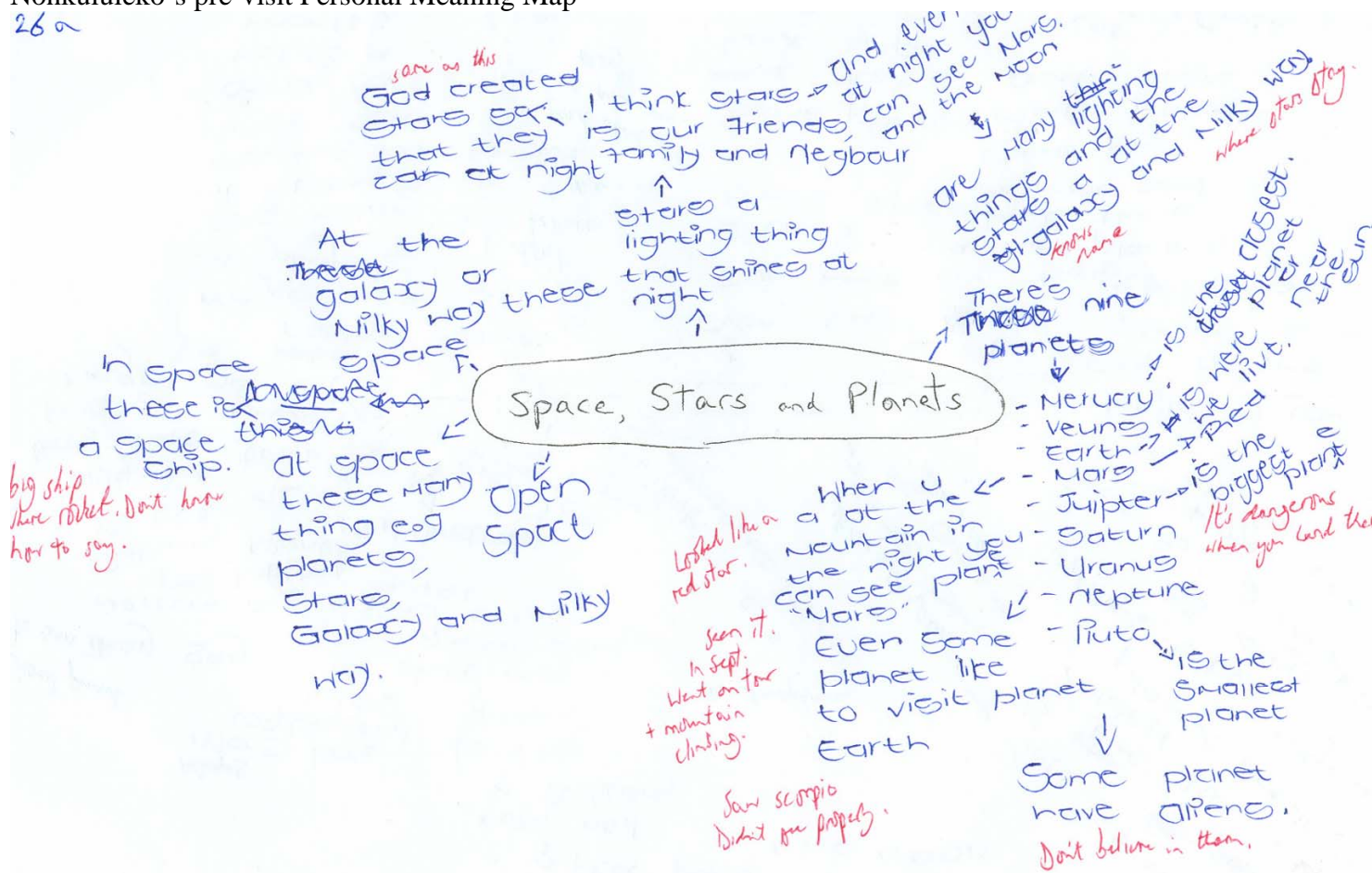
Astronomy-related Vocabulary used by students

Student code	Student name	Number of words used in pre-visit PMMs	Additional number of words used in post-visit PMMs
scf06	Sibongile	29	6
scf08	Susan	24	11
scf10	Lara	14	15
scf11	Helen	16	9
scf12	Sarah	19	2
scf15	Fatima	26	7
scf17	Kitso	13	3
scf19	Antonia	28	8
swo05	Sipho	12	7
swo06	Zanele	17	1
swo07	Bhekiwe	22	1
swo14	Mpho	13	10
swo20	Banyana	20	10
swo22	Ntobeko	21	0
swo26	Nkululeko	18	7
swo29	Douglas	8	6
swo36	Judy	23	3
swo42	Neo	7	11
swo53	Batsile	10	5
swo59	Thapiso	13	2
swo69	Phillip	23	4
swo70	Brenda	19	9
tsw02	Tlotlo	17	11
tsw04	Botho	11	9
tsw08	Fane	17	11
tsw15	Nnaniki	26	12
vho02	Paul	30	4
vho06	Vicky	27	2
vho09	Theresa	22	8
vho10	Lynn	23	8
vho11	Cathy	19	1
vho12	Richard	37	10
vho13	Ross	31	4
vho16	John	36	14
Mean		20.32353	6.794118
SD		7.530627	4.043546

Appendix J: Personal Meaning Maps

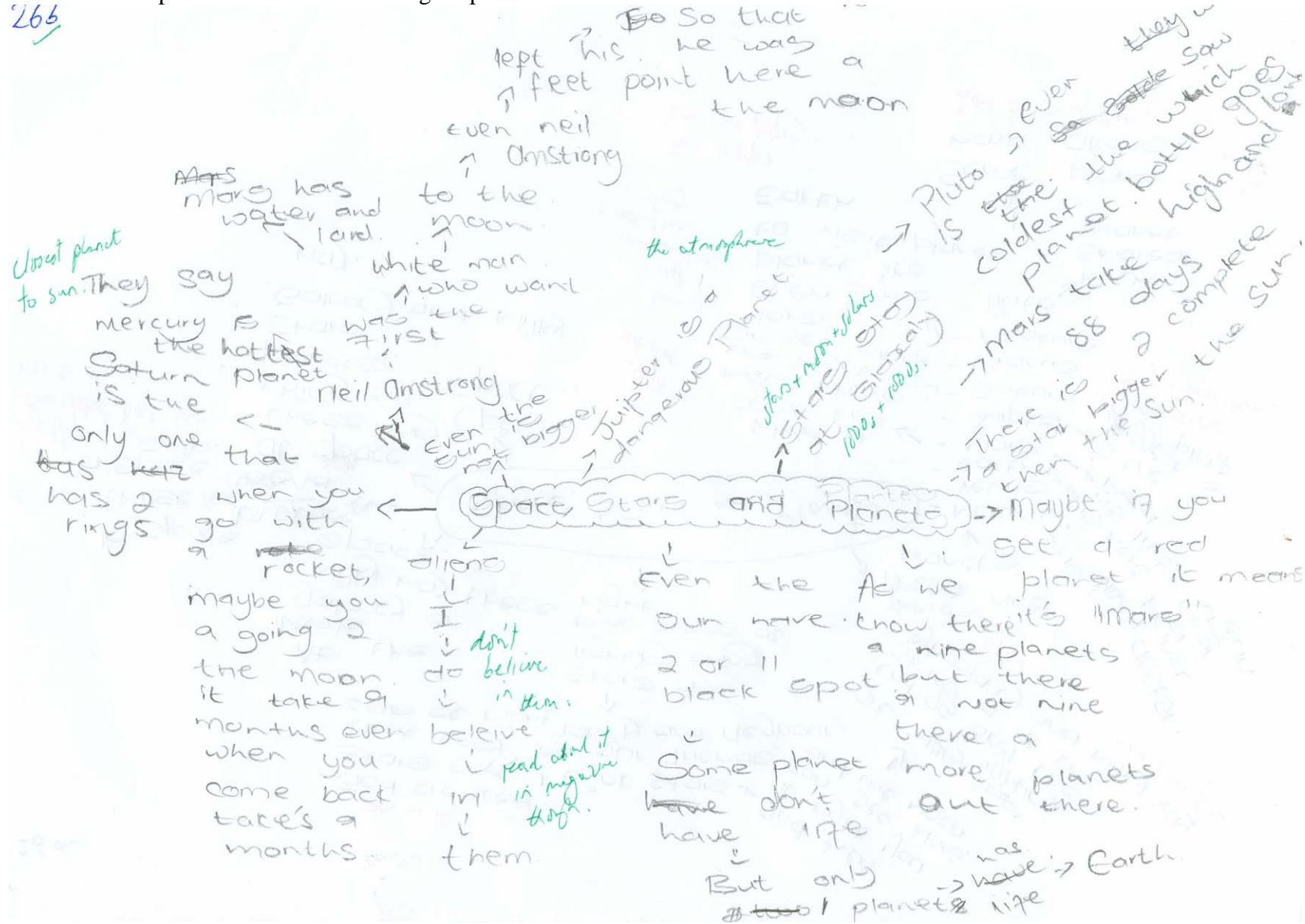
Nonkululeko's pre-visit Personal Meaning Map

26 a



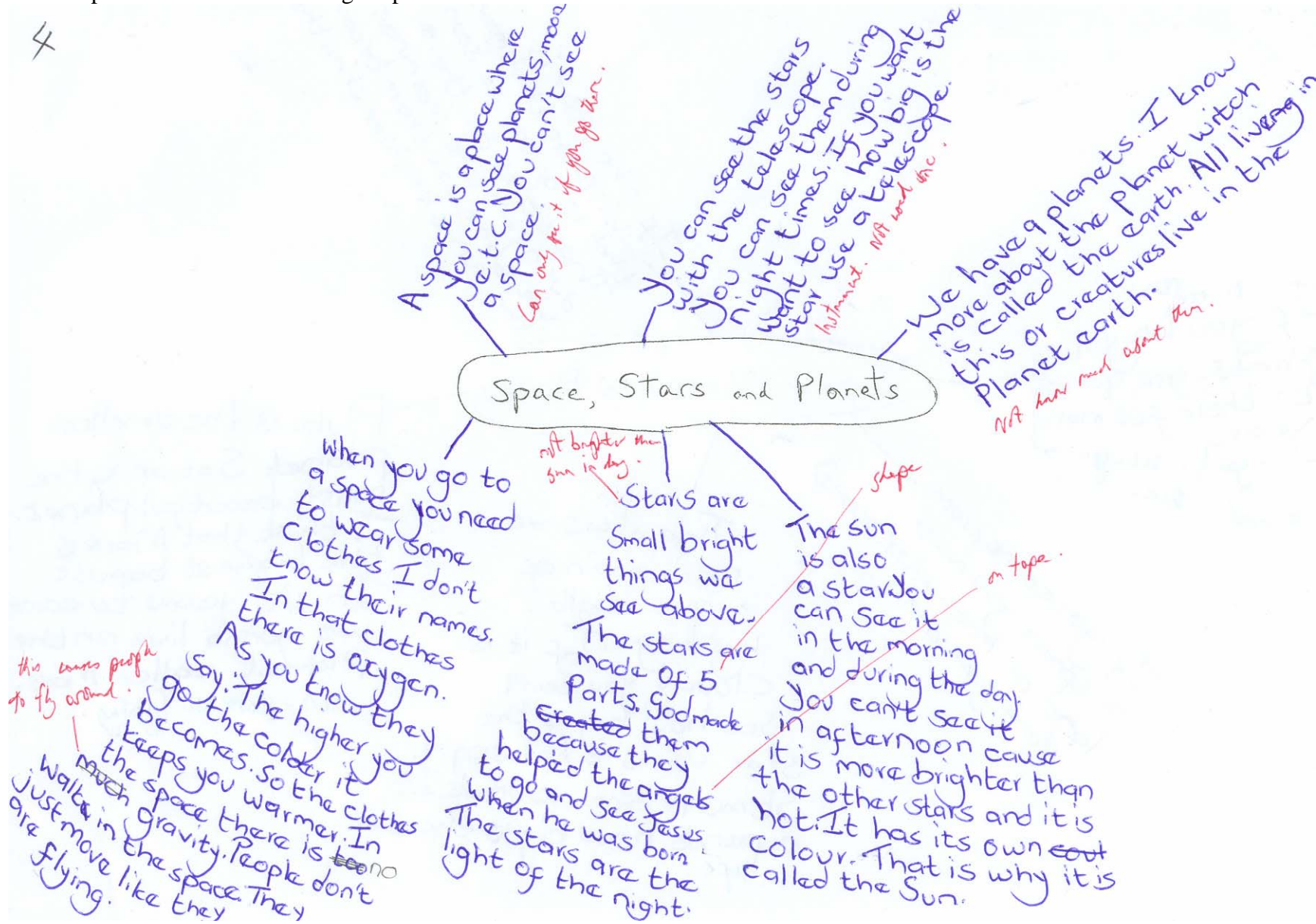
Nonkululeko's post-visit Personal Meaning Map

266

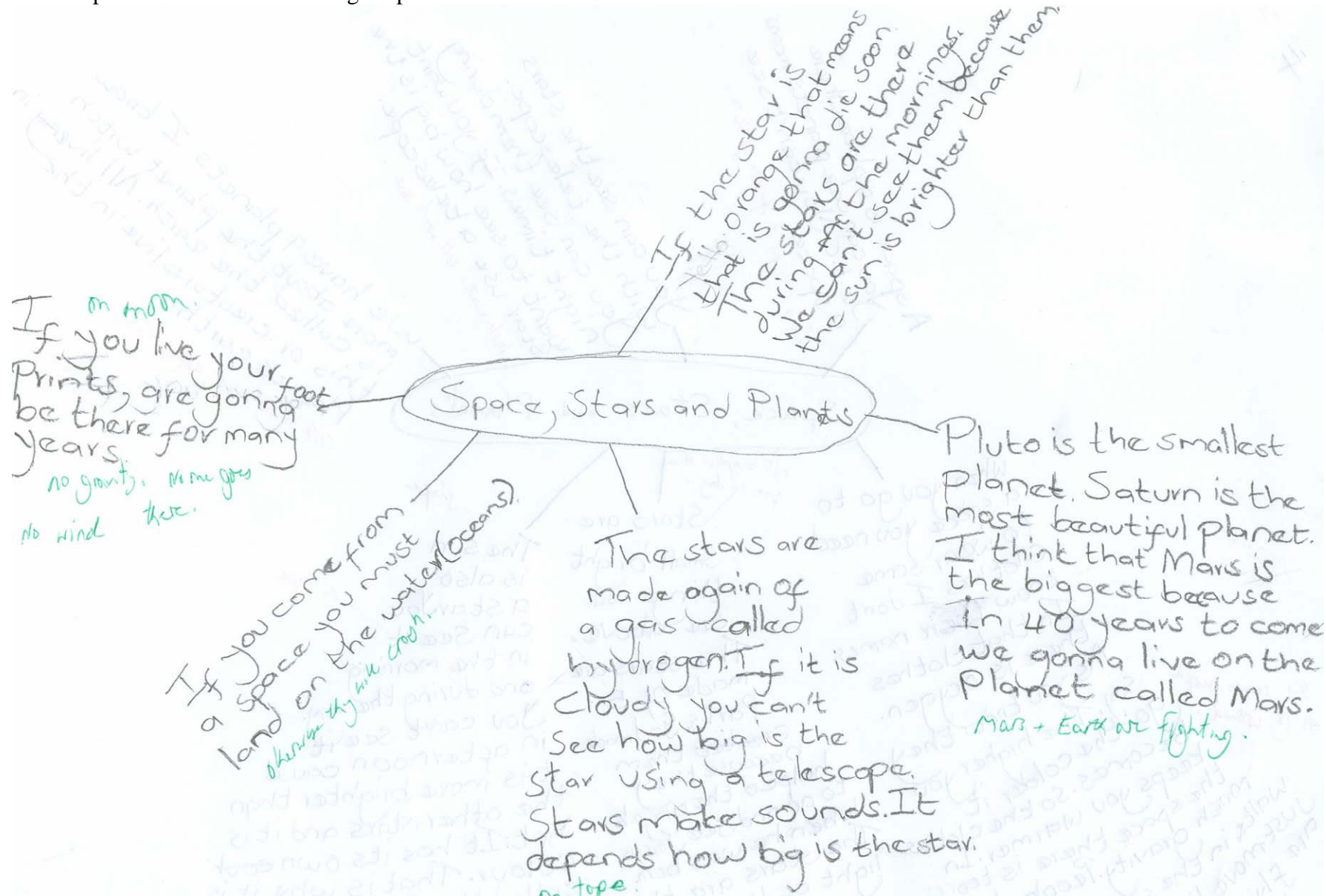


Botho's pre-visit Personal Meaning Map

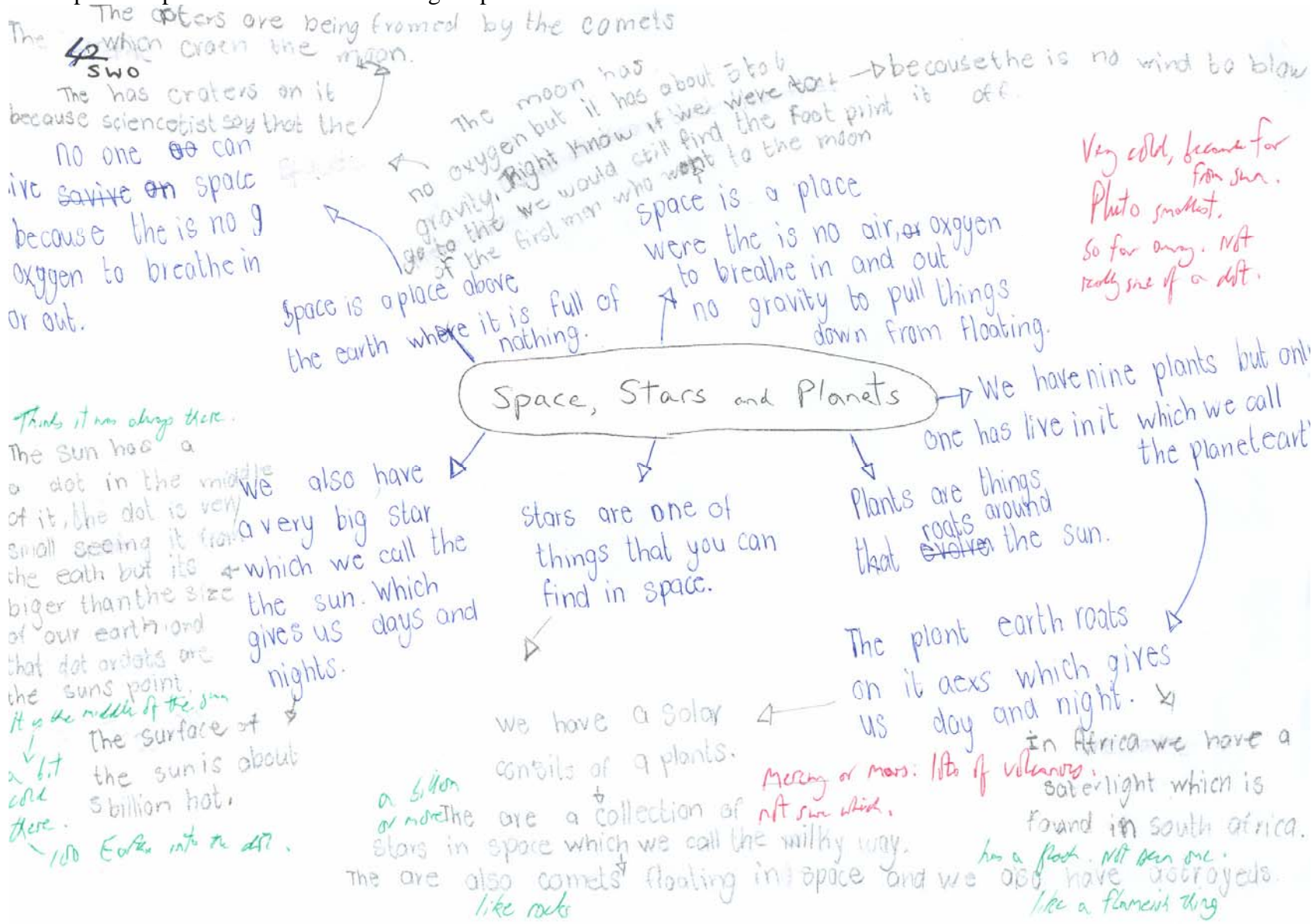
4



Botho's post-visit Personal Meaning Map

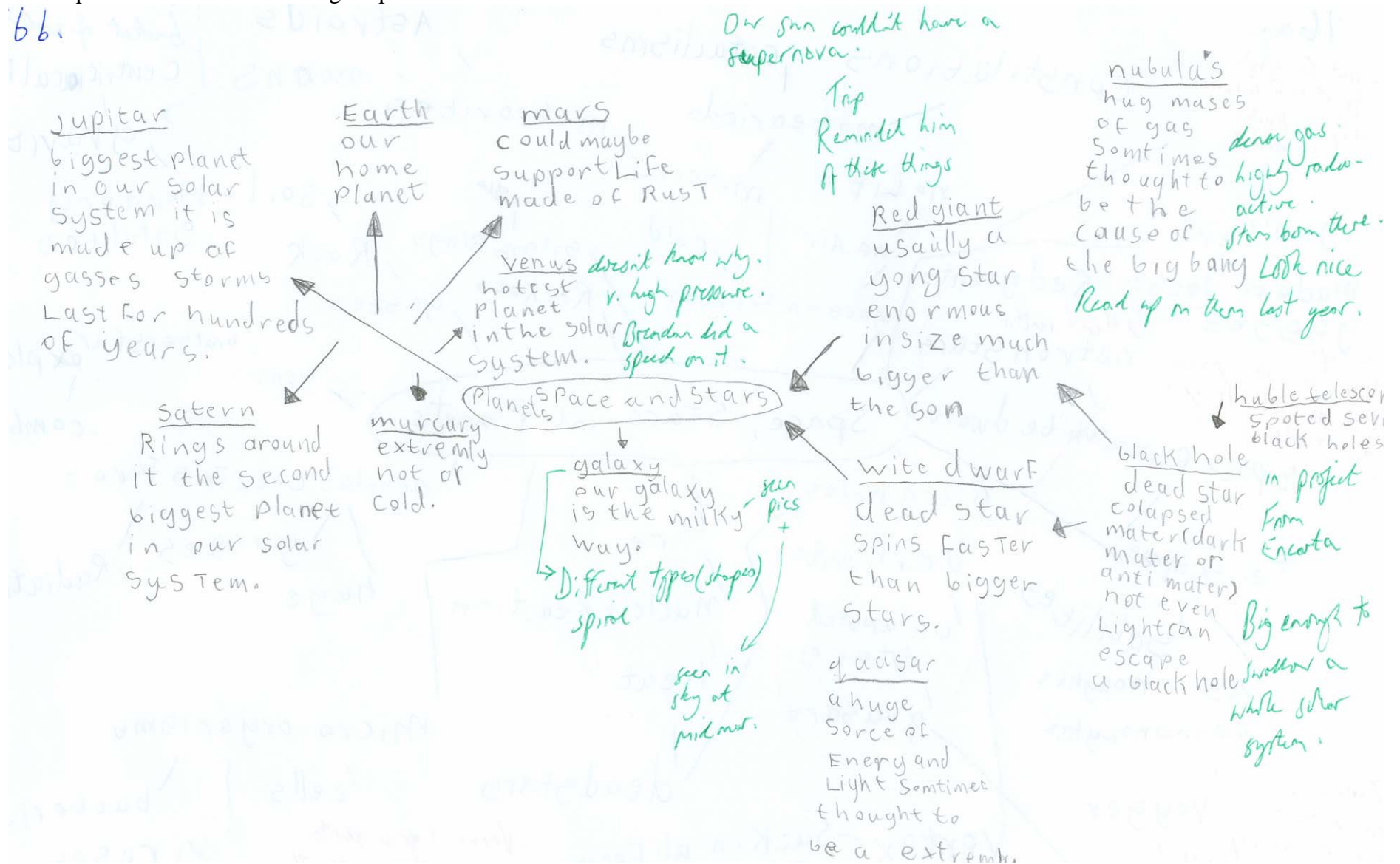


Neo's pre- and post-visit Personal Meaning Map



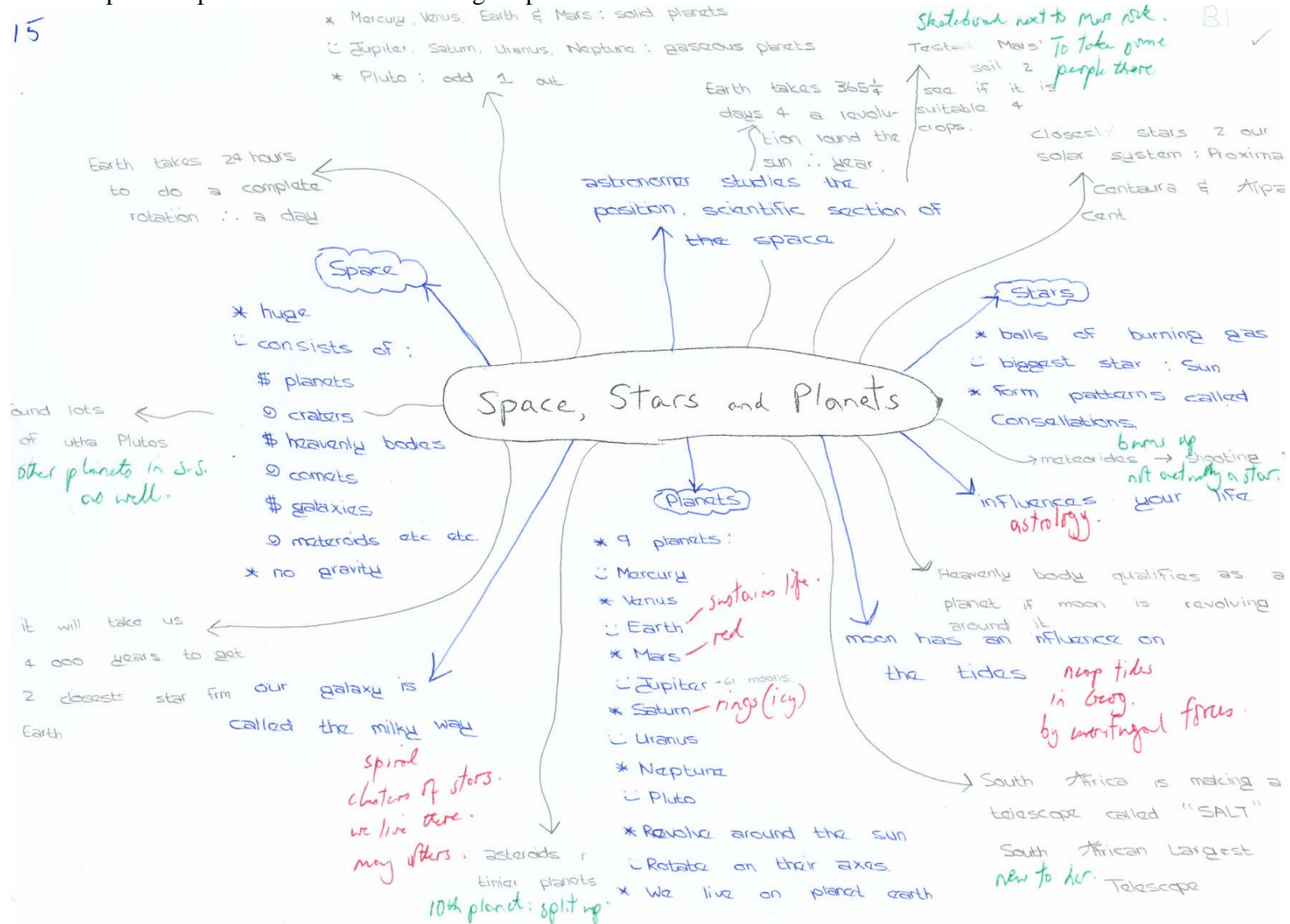
John's post-visit Personal Meaning Map

66.

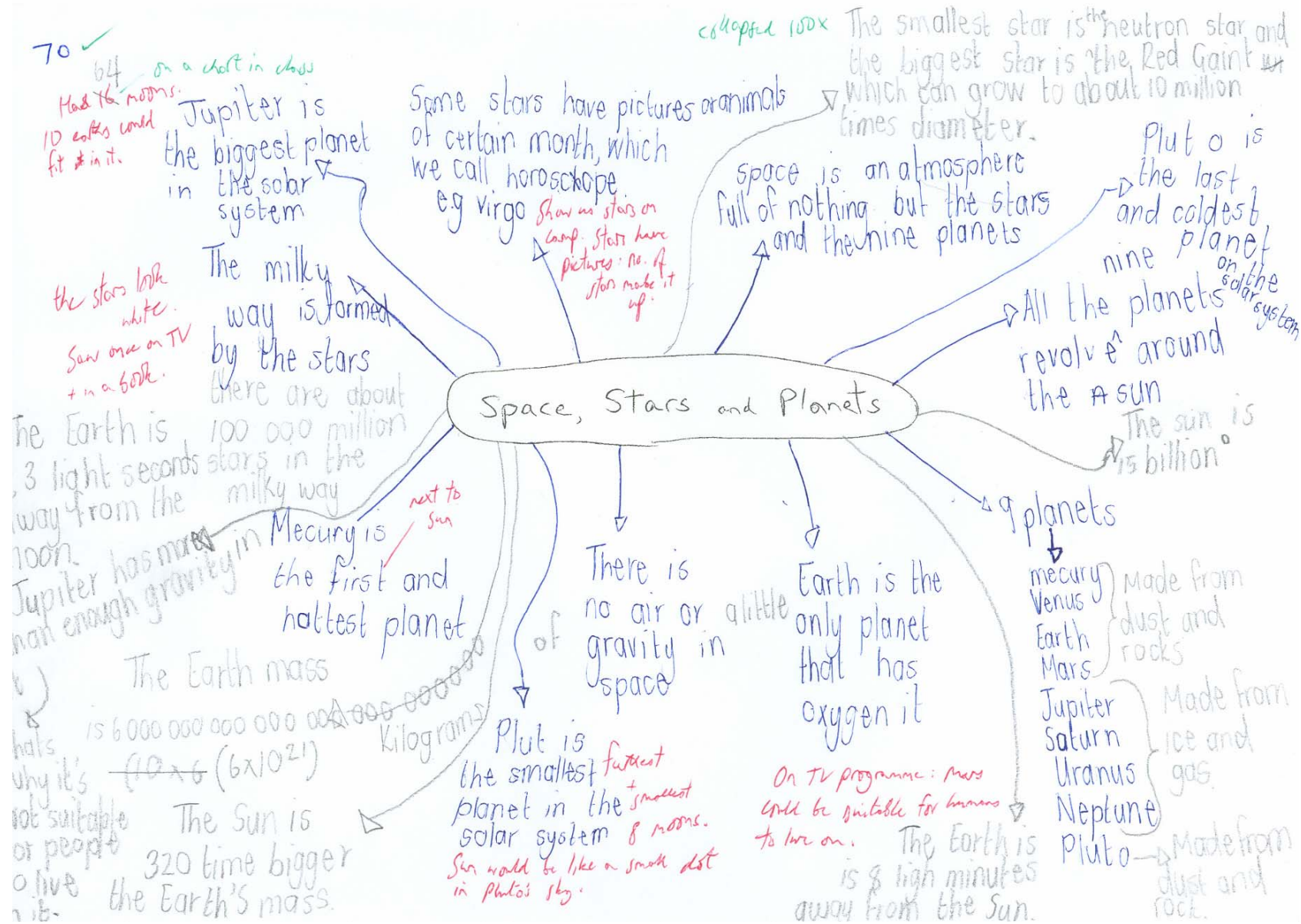


Fatima's pre- and post-visit Personal Meaning Map

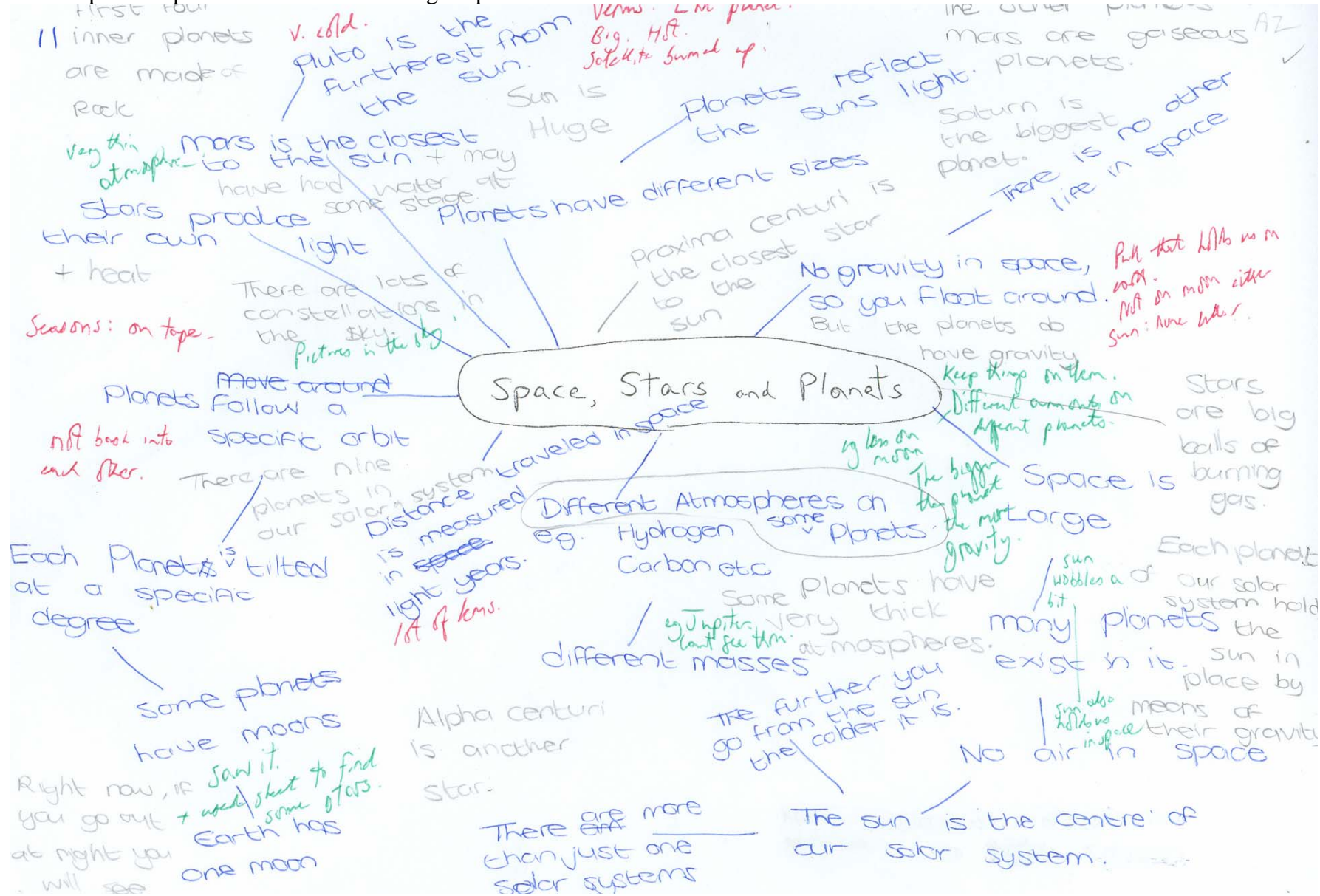
15



Brenda's pre- and post-visit Personal Meaning Map



Helen's pre- and post-visit Personal Meaning Map



Appendix K

Getting the most from your visit to a museum or hands-on centre

Before you go:

- Think about the purpose of your visit and its position in your scheme of work. Is the visit to give general experience and stimulation as an introduction to the topic? Is it to support specific learning of certain concepts? Is it to consolidate teaching that has already taken place?
- Visit the museum, or if you can't, visit its website or talk with someone who has been before.
- Plan for what scientific concepts and skills should be met before the visit and what should be followed-up back at school.
- Decide what part of the exhibition or what exhibits will form the focus for learning and/or whether your pupils need to follow a set route or sequence.
- Find out what facilities and services the museum offers, e.g. whether the museum has 'explainers' to assist pupils, a classroom where work can be followed-up or workshop activities led by the museum's education service. Decide how you will use these services.
- Find out what additional adult support is available and can be provided for the visit, e.g. parents, student teachers, etc.
- Decide how adults might be informed and supported so that they can offer help to pupils at the museum, e.g. devise prompt sheets or use ones provided by the museum.

At the museum:

- Provide some time and space for pupils to orientate themselves and 'play'. This allows the class to have some free exploration time and to dissipate some of their initial 'energy'.
- Tell the class what you expect them to do. It is usually better for pupils to work in pairs or small groups so that social interaction at exhibits can occur.
- You may want to offer some limited guidance or prompts, e.g. by way of a 'trail card'. Record experiences, e.g. by taking digital photographs or making a video.

Following your visit:

- Ask pupils to tell you what they remembered most from their visit. What were they impressed by? What new things did they learn?
- Allow pupils to develop their learning by broadcasting their experiences to others. You could ask them to do this by preparing and sharing posters and displays or by giving a presentation.
- Use activities and practical tasks that enhance and develop the learning experiences at the museum. Avoid trying to replicate what they did at the museum.
- Refer back to experiences at the museum, not only in the topic but in future lessons as well. This helps pupils to value the experience and to consolidate learning by integrating gains from the informal situation in the museum with the more formal learning in school.

From: Braund, M. (2004). Learning science at museums and hands-on centres. In Braund, M. & Reiss, M. (Eds.), Learning Science Outside the Classroom (pp. 113-128). London: RoutledgeFalmer.