

ABSTRACT

Studies in astronomy education have shown that socio-cultural factors combine with everyday human experience to create learning difficulties that are unique to this field. The history of astronomy also shows a complex link between science and religion. The foundations of modern astronomy lie in religious beliefs and practices, but over time, in the West, as science grew ever more powerful in explaining the apparently mechanistic processes of nature, the beliefs and understanding associated with scientific explanations came into conflict with those of the Christian church. In Africa, Western religious and scientific beliefs were brought by the missionaries, and imposed onto already existing beliefs systems. From colonial times to the present, Western knowledge has been privileged over local knowledge in African formal schooling. Little recognition has been given to the learning difficulties that may be caused in situations where the knowledge system taught at school is different to that imbibed through home and culture.

The difficulties of epistemic access have been highlighted through the development of socio-cultural constructivist theories of learning. This study, which is based on the socio-cultural constructivist theories of cultural border crossing and collateral learning, represents an investigation of the learning difficulties experienced by South African first year university students who study a compulsory course in basic astronomy called 'The Earth in Space'. The sample was thus a convenience sample, made up of 191 students who took the course between 2000 and 2004.

The investigation was carried out using a pre-instruction questionnaire to record the pre-course knowledge of the students. The questions that were asked focused on knowledge related to some of the key concepts in basic astronomy, such as an understanding of the nature of stars, the rotation and revolution of the earth and the phases of the moon. These questions had the dual purpose of benchmarking South African students' knowledge of the scientific explanations for these phenomena against similar international studies, as well as establishing the prevalence of cultural or traditional ideas held by these students. After the course had been completed, a post instruction questionnaire was used to establish students' views on the difficulties they had experienced in learning in the course. This was followed up by semi-structured interviews with 25 of the students.

The data obtained from the questionnaires were analysed using two methods: the first used a deductive coding system where the students' responses were allocated to chosen categories, i.e. whether they conformed to the explanations of Western Modern Science or to cultural knowledge and beliefs, or both. The second method used a computer software programme, Atlas.ti, where each statement made by the student was recorded and coded, leading to an inductive, fine-grained analysis of their responses.

The results from the pre-instruction questionnaire indicated that South African students display similar poor levels of knowledge in this field, to students from other Western and non-Western countries. The explanation for this lies in the fact that understanding the scientific explanations requires the ability to think abstractly, and to be able to construct complex mental models, in situations where the processes involved run counter to normal daily experience. However, the explanations given by the South African students also indicated that there were epistemological and ontological issues, related to conflicting beliefs in terms of culture and religion, which exacerbated the barriers to border crossing

in this field. However, the data indicated that students did not find it as difficult to cross the barriers created by cultural or traditional beliefs as those caused by fundamentalist Christian beliefs. The biggest obstacle to learning related to conflict between creationist and scientific accounts of the formation of the Earth and Universe. While this is not unusual, as shown by studies carried out in the United States, where religious students are also affected by the apparent conflict between Christianity and science, the most significant finding of this study related to the existence and extent of this conflict in Black African students.

In post-1994 South Africa, the revision of the national education system has resulted in a science curriculum that recognizes 'other ways of knowing'. These refer specifically, however, to Indigenous Knowledge Systems (IKS) rather than religious beliefs. The curriculum does not acknowledge that African ontology is religious. It also does not recognize the duality of this ontology in terms of African Traditional Religion and Christianity, which is the stated religion of the majority of Black South Africans. The findings of this study indicate that because of the nature of African philosophy, religious ways of knowing need to be explicitly acknowledged as one of the 'other ways of knowing'. Such acknowledgement by science teachers and lecturers would help to prevent these different knowledge systems from being discarded or compartmentalized, which was found to lead either to the promotion of scientism, or to the preclusion of meaningful engagement with science.

DECLARATION

I declare this thesis my own, unaided work. It is being submitted for the Degree of Doctor of Philosophy in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or Examination in any other University.

.....

..... day of 2007

DEDICATION

Breaking the silence
Of an ancient pond,
A frog jumped into the water -
A deep resonance.

Basho Matsuo
(in Rhor, 2004, 53)

This work is dedicated to the
students who broke their silence
and shared their experiences with me.
May the ripples they created
be helpful to others involved in
teaching and learning.

I also dedicate this work to
my husband Roger,
and our daughters
Kathleen, Megan, Hayley and Rachel
who shared the journey with me

ACKNOWLEDGEMENTS

I thank my supervisors:

Professor Marissa Rollnick, for providing me with the opportunity to embark, at this stage of my life, on studying for a higher degree. Her support and insightful comments and guidance have been invaluable. I especially thank her for giving me the freedom to pursue an investigation which took us all into uncharted territory;

Ms Meg Doidge for introducing me to the impact of culture on learning in science, and in so doing opened the way to pull together and understand parts of my own history. I also especially thank her for her encouragement and support.

I am also grateful to:

The Centre for Learning and Teaching Development at the University of the Witwatersrand for granting me a six month 'Time-Out' sabbatical. Professor Colin Wright, former Dean of the Faculty of Science for granting an additional six month sabbatical for me to complete my thesis.

Professors Ogunniyi, Okere and Mbiti for their interest, suggestions and encouragement;

Professor Pamela George, visiting Fulbright Senior Fellow, who read the manuscript and offered useful advice and encouragement.

Mrs Tracey Butchart, for her careful proofreading of the manuscript.

Colleagues: Dr Tony Lelliott: for his patient and helpful assistance with Atlas.ti; Dr Teresa Dirsuweit: for directing me to some useful readings; Ms Mary Evans and Dr Moyra Keane for their support and encouragement.

The students who participated in the study, especially those who volunteered to be interviewed and who introduced me to a new way of understanding.

I would especially like to thank my family:

Roger, my husband, for his interest and support through many hours of discussion, and for his wisdom, insight and patience - thank you. My children, Kathleen, Megan, Hayley and Rachel, for allowing me the space to be a student too; for often shopping and cooking for the family and assisting me with their computer skills, as did Stuart Jackson. I also thank my mother, Kathleen, who has always inspired me by her love of learning and my sister, Jane, for her encouragement. And finally, I thank God for providing and directing the opportunity to continue to learn.

CONTENTS

	Page
Abstract	i
Declaration	iii
Dedication	iv
Acknowledgements	v
Table of Contents	vi
List of Figures	vii
List of Tables	viii
List of Appendices	x
List of Acronyms	xi
Outline of thesis	1
Chapter 1: Introduction	2
1.1 Background	3
1.2 The Research Problem	7
1.3 Aim of the Study	10
1.4 The Research Questions	10
1.5 Rationale	10
1.6 Limitations	12
1.7 Structure of the Thesis	13
Chapter 2: Literature Review and Theoretical Framework	14
2.1 Introduction	16
2.2 Constructivism	19
2.3 Astronomy Education	24
2.4 Religion and Science	30
2.5 African Religion and Philosophy	43
2.6 The South African curriculum and the recognition of IKS	52
2.7 Collateral Learning and Cultural Border Crossing	57
2.8 Summary of the literature review	71
2.9 The Theoretical Framework for the study	73
2.10 Conclusion to Chapter 2	75
Chapter 3: Positionality Statement	77
Chapter 4: Research Methodology	84
4.1 Background	84
4.2 The Pilot Study	92
4.3 The Pre-instruction Questionnaire	96
4.4 The Post-instruction Questionnaire	108
4.5 The Interviews	114
4.6 Conclusion to Chapter 4	119
Chapter 5: Results and Analysis	121
5.1 The Pre-instruction Questionnaire: Prior Knowledge	121
5.2 The Post-instruction Questionnaire: Reflections on Learning	159
5.3 The Interviews: Vignettes of Border Crossing	211
5.4 Conclusion to Chapter 5	225
Chapter 6: Discussion and Conclusion	228
6.1 Astronomy Education and the prior knowledge of the students	230
6.2 Cultural and religious barriers to learning	236
6.3 Methodological findings, limitations and recommendations for further research	249

6.4 Conclusion	253
References	257

LIST OF FIGURES

Figure	Subject	Page
Fig. 1	Diagram to show cause of day and night (04.COS.4.PRE)	135
Fig. 2	Diagram to show cause of day and night (04.MS.42.PRE)	136
Fig. 3	Diagram to show cause of day and night (04.MS.38.PRE)	137
Fig. 4	Diagram to show cause of day and night (04.COS.28.PRE)	137
Fig. 5	Diagram to show the cause of seasons (04.COS.7.PRE)	142
Fig. 6	Pie chart showing relative frequency (as a percentage) of the categories created from code statements in response to the question "What did you find hard to understand?"	169
Fig. 7	Pie chart showing relative frequency (as a percentage) of the categories created from code statements in response to the question "What did you find hard to believe?"	174
Fig. 8	Pie chart showing relative frequency (as a percentage) of the categories created from code statements in response to the question "Did any of your knowledge change as a result of the course?"	195
Fig. 9	Pie chart showing relative frequency (as a percentage) of the categories created from code statements in response to the question "Does WMS give the true explanation for natural phenomena?"	197
Fig. 10	Pie chart showing relative frequency (as a percentage) of the categories created from code statements in response to the question "Are there other valid explanations for natural phenomena?"	198
Fig. 11	Pie chart showing relative frequency (as a percentage) of the categories created from code statements in response to the question "What did you learn?"	200
Fig. 12	Pie chart showing relative frequency (as a percentage) of the categories from the question "Who most influences the way you think?"	205
Fig. 13	Pie chart showing relative frequency (as a percentage) of the categories in response to the question "What will you teach your children?"	209

LIST OF TABLES

Table	Subject	Page
Table 2.1	Spectrum of relationships between science and religious beliefs (adapted from Barrett, 2000, 133)	38
Table 2.2	A summary of links between collateral learning and Barbour's typology	69
Table 2.3	Categories of students according to their ability to 'cross cultural borders' into the culture of science.	71
Table 2.4	Synthesis of the concepts of cultural border crossing and collateral learning	73
Table 2.5	An African Typology of student learning in basic astronomy (adapted from Aikenhead, Jegede and Barbour's Typologies)	74
Table 4.1	Summary of the sample groups and numbers of participants for each data collection strategy: questionnaires and interviews	88
Table 4.2	Summary of research methodology: Pre-instruction questionnaire	91
Table 4.3	Summary of research methodology: Post-instruction questionnaire	92
Table 4.4	Coding system for answers to Questions 1 to 6 in the pre-instruction Questionnaire (Phase 1).	98
Table 4.5	Example: Method 1: Frequency of occurrence of single and multiple worldview concepts	102
Table 4.6	Categorization of the students' responses to the pre-instruction questionnaire	103
Table 4.7	Example: Method 2: Prior Knowledge. "Why is it generally colder in winter than it is in summer?"	105
Table 4.8	Coding system for sources of information	108
Table 5.1	"What is a star?" : Method 1	124
Table 5.2	"What is a star?" Method 2	125
Table 5.3	"What happens to the stars during the day?" : Method 1	129
Table 5.4	"What happens to the stars during the day?" Method 2	130
Table 5.5	"What causes day and night?" Method 1	133
Table 5.6	"What causes day and night?" Method 2	134
Table 5.7	"Why is it generally colder in winter than it is in summer?": Method 1	140
Table 5.8	"Why is it generally colder in winter than it is in summer?": Method 2	141
Table 5.9	"Why does the moon appear to change its shape during the course of a month? Method 1	144
Table 5.10	"Why does the moon appear to change its shape during the course of a month? Method 2	145
Table 5.11	"What is the universe?" Method 1	149
Table 5.12	"What is the universe?" Method 2	150
Table 5.13	Overview of worldview profiles held by students	152

Table 5.14	Overview of numbers of students to mention IKS and/or religion (from within the Alternative Beliefs (AB) worldview group)	153
Table 5.15	Sources of information	157
Table 5.16	Pre and post-instruction questionnaires: results of the content questions	161
Table 5.17	What did you find hard to understand?	164
Table 5.18	Categories and code statements for Question 1: "What did you find hard to understand?"	168
Table 5.19	What did you find hard to believe?	170
Table 5.20	Categories and code statements for Question 2: "What did you find hard to believe?"	174
Table 5.21	Collateral learning using Barbour's Typology	170
Table 5.22	Cultural border crossing in relation to religion, IKS and cognitive conflict	182
Table 5.23	Types of students (Costa's categories) in relation to cultural border crossing	184
Table 5.24	Barbour's Typology and Border Crossing	187
Table 5.25	Barbour's Typology related to the type of student (Costa's categories)	189
Table 5.26	Border Crossing and Types of students	191
Table 5.27	"Was any knowledge changed or replaced?" Analysis of code statements	195
Table 5.28	"Does WMS give the true explanation for natural phenomena?" Analysis of code statements	197
Table 5.29	"Are there other valid explanations for natural phenomena?" Analysis of code statements	198
Table 5.30	"What did you learn?" Analysis of code statements	200
Table 5.31	"Who was your primary care-giver?"	202
Table 5.32	Relationship between the type of school attended and types of border crossing	203
Table 5.33	Influential people	205
Table 5.34	Importance of traditional customs	206
Table 5.36	"What will you teach your children?"	207
Table 5.37	"What will you teach your children?" Analysis using code statements	209
Table 5.38	Composition of the interview sample	212

LIST OF APPENDICES

Appendix	Subject	Page
1	Eclipse story	275
2	Flow Chart: Methodology: pre-instruction questionnaire	276
3	Flow Chart: Methodology: post-instruction questionnaire	277
4	Copies of pre- and post-instruction questionnaires	278
	4.1 2001 Pre-instruction Questionnaire (pilot study)	279
	4.2 2002 Pre-instruction Questionnaire (College of Science and Geography groups)	284
	4.3 2004 Pre-instruction Questionnaire (College of Science, Geography and Geology mainstream groups)	289
	4.4 2001 Post-instruction Questionnaire (pilot study)	293
	4.5.1 2002 Post-instruction Questionnaire (Geography group)	295
	4.5.2 2002 Post-instruction Questionnaire (College of Science group)	297
	4.6 2004 Post-instruction Questionnaire (College of Science, Geography and Geology mainstream groups)	299
5	Notes: explanation to students	306
6	Coding in Atlas.ti Method 1 (worldview): examples	307
7	Coding in Atlas ti Method 2 (code statements): examples	313
8	Network views : examples	322
9	Breakdown of results: different sample groups	324
10	Ethics clearance	327
11	Interview schedule	328
12	Breakdown of responses by students: IKS and religion	330
13	Table: frequency of reference by sample groups to "What did you find hard to understand?"	332
14	Table: frequency of reference by sample groups to "what did you find hard to believe?"	333
15	Glossary of terms and glossary of astronomical concepts	334

LIST OF ACRONYMS

AB	Alternative Beliefs
ANT	Actor Network Theory
ATR	African Traditional Religion
COS	College of Science
CDE	Centre for Development and Enterprise
CNE	Christian National Education
ESL	English Second Language
G	Geography Preliminary and Geography Foundation
HPS	History and Philosophy of Science
IKS	Indigenous Knowledge Systems
MS	Mainstream Geology course
NOS	Nature of Science
OBE	Outcomes Based Education
PD	Primary Document
RNCS	Revised National Curriculum Statement
SAARMSTE	Southern African Association for Research in Mathematics, Science and Technology Education
SAASTE	South African Association for Science and Technology Educators
WMS	Western Modern Science