Research proposal for the degree of Doctor of Philosophy

Learning about Astronomy: a case study exploring how children and teachers experience sites of informal learning in South Africa

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Introduction

I always dreamed about space, it is the ultimate frontier for technology and exploration – Mark Shuttleworth, International Space Station, 4 May 2002

We are such insignificant creatures on a minor planet of a very average star in the outer suburbs of one of a hundred thousand million galaxies – Stephen Hawking, BBC broadcast, 1989.

Space…..is big. Really big. You just won’t believe how vastly hugely mindbogglingly big it is. I mean you may think it’s a long way down the road to the chemist, but that’s just peanuts to space – Douglas Adams, The Hitch Hiker’s Guide to the Galaxy, 1978.

Background

Astronomy is often regarded as the ‘oldest science’ (Zeilik 1988), yet as a discipline it has developed into a very specialised scientific field with relatively few employment opportunities. In many developed countries, astronomy is a popular hobby among peoples of medium to high socio-economic status, yet as a career it holds relatively few opportunities. This is principally because the discipline of astronomy, like other areas of science such as ecology and genetics has made such rapid progress over the past century that a considerable gap has developed between the amateur and the professional. In order to become a professional astronomer, a school student must concentrate on science and mathematics and enter a physics, applied mathematics or astronomy course at university. Post-graduate work in astronomy is also required in order to enter the field as a professional. Since much astronomy is pure research funded directly by governments, job opportunities are relatively few. A similar situation prevails in the area of space science, with only highly developed economies able to afford such programmes, which are again funded almost exclusively by governments.

Astronomy and space science are, however, regarded as being areas of popular science which are a motivating factor to draw school students and the general public into learning more about science (Percy 1999, 2002, Rijsdijk 2000, Whitelock and Flanagan, 1998). The various waves of science popularisation since the Sputnik era have all aimed to bring about a greater public engagement with science. Politically, the notion of promoting scientific literacy is very appealing. The usual argument promulgated by government and the press is that in order to promote economic development, a country requires larger numbers of scientists, technologists and engineers. The only way to produce the professionals needed is to encourage greater numbers of school and tertiary students to enrol for science, mathematics and
(possibly) technology (Ogunnyi, 1998, 1999). Scientific literacy is therefore equated with encouraging the take-up of science-related courses at educational institutions. On a wider scale, Popli (1999) summarises the ‘usual reasons’ for advancing scientific literacy, which include:

- science has become an essential part of human heritage;
- knowledge and outlook of science are useful in practical ways in everyday life;
- awareness of science and technology is important in individual, social and political decisions

Sjoberg (1997) however, counters these arguments, suggesting that there is no conclusive evidence for a direct relationship between a nation’s level of scientific understanding and its economy. He points out that although it has the largest economy in the world, the USA does not usually score very highly in comparisons of general levels of scientific literacy between countries. Others such as Cromer (1993) question whether scientific knowledge gained at school is really of value in everyday life. He contends that scientific thinking is so different to ‘common sense’ thinking that educators have underestimated the difficulties in putting across scientific concepts to learners.

The fact remains however, that given the shortage of skilled scientists and technologists, countries such as South Africa are likely to benefit considerably if larger numbers are attracted to the sciences during their school years. According to a recent study (Department of Arts, Culture, Science and Technology in Department of Education, 2000), the number of engineers and technologists produced per capita in South Africa compares unfavourably with that of other developing countries. This is due mainly to insufficient and declining numbers of school leavers with mathematics and natural sciences as subjects (Ogunnyi, 1999).

**Rationale**

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 of phenomena 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 made. 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?”

Although many children’s natural interest in space and the stars has been identified as a way of encouraging them into the sciences, scholars have noted that achievement in science at secondary school level in many countries is not as high as education authorities, employers and institutions would like. 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. However, Erickson (2000) notes that “A theory of learning [is] not in itself a sufficient foundation to develop curricular and instructional programmes”.

As I show in the literature review below, most research in astronomy education has involved students’ conceptions and misconceptions. The aim of the empirical study described in this proposal is to understand how children and their teachers learn, not in the classroom, but in the informal settings of a planetarium and the visitors’ centre of an observatory. The research falls under the general framework of learning at museums and science centres, which has 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. This may not be as true in South Africa as it is in the USA. However, the kind of informal learning that takes place in a planetarium, museum or science centre is still important to study precisely because it can provide important motivation for students and can engage them in the kind of ‘big questions’ in science referred to above.
Purpose of Research

This study aims to investigate informal learning of students and teachers at the Johannesburg Planetarium and the visitors’ centre of the Hartebeeshoek Radio Astronomy Observatory (HartRAO), both situated in Gauteng Province, South Africa.

The concept of informal learning is a contentious construct (see below), but one that on a superficial level describes the sort of learning that takes place when people visit a museum, a science centre or in the case of the proposed study, a planetarium or visitors’ centre of a scientific institution. The study aims to work with both teachers and students to find out the extent to which learning does occur during the preparation for a visit, the visit itself, and the follow-up at school after the visit. The study will include an examination of the students’ attitudes towards science in the light of the experience of visiting the centre.

Finally, the proposed study will relate the findings to the place of astronomy in the school curriculum. In the pre-1995 school curriculum, the study of astronomy was mainly covered under the subject of geography. However, under Curriculum 2005, the current curriculum for grades 1 to 9, astronomy is placed within the Natural Sciences.

Literature Review

In common with other sciences, there is a significant disjuncture between the content of astronomy – which is reported in international scholarly astronomy journals, proceedings of conferences and books, as well as increasingly over the Internet – and issues of astronomy education, which are found in popular science and science education journals. There are one or two exceptions however, notably the Publications of the Astronomical Society of Australia which devoted a special issue (August 2000) to ‘Astronomy Education for the Next Millennium’, and a new journal ‘Astronomy Education Review’ which is published only on the Internet. Research into ‘informal’ learning, which takes place in museums, planetaria and science centres, is found both in science education journals and museum journals. This literature review gives a brief overview of science education research, followed by an examination of the astronomy education literature and a summary of the extensive research carried out on science learning at museums and similar institutions. The PhD thesis will provide a fuller review, including an analysis of policy statements of the South African
government regarding the Public Understanding of Science and natural science within the school curriculum.

**Research in Science Education**

For at least the first half of the 20th century, science teaching and learning theories associated with science education were predominantly positivist and behaviourist in nature (Poole 1995, Duit and Treagust 1998)

Over the past 15 years, there have been various attempts to analyse research in science education since the 1950s, and to place the theoretical orientations into a framework. Eylon and Linn (1988) identified four research stances: concept learning, developmental, differential and problem-solving perspectives. In a lengthy analysis, they place each of the major research orientations into one of the four perspectives, and comment on the latter’s effectiveness in learning and instruction. The concept learning perspective comprises the conception/misconception and conceptual change research of the constructivist school, which even in 1988 had already carried out numerous research studies (eg. Nussbaum and Novak 1976, Driver and Easley 1978, Erickson 1979). Eylon and Linn note that several approaches to instruction have been tried to change learners’ conceptions, and that “integrated in-depth coverage of science topics to help students achieve coherent understanding” is of value (Eylon and Linn 1988, p. 263). The developmental perspective has been 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. Eylon and Linn cite several studies which indicate that the purely Piagetian view of instruction has been relatively unsuccessful in improving learning, and the developmental perspective has evolved to incorporate the work of psychologists such as Vygotsky and his notion of the zone of proximal development. The differential perspective has examined the relationship between instruction and learners’ individual differences in ability and aptitude, and how they can explain conceptual change. However, Eylon and Linn suggest that “The lack of success of efforts to explain scientific proficiency in terms of general aptitudes suggest that this is the wrong grain size for analysis” (Eylon and Linn 1988, p. 263). Finally the problem-solving perspective covers research into the science problem-solving processes employed by learners. Although regarded by the reviewers as an promising area, the number of teaching-related studies are relatively few, and further research is regarded as being necessary. Eylon and Linn conclude by recommending
that science education research lacks coherence and “would benefit from a larger number of multidisciplinary and multiple-perspective investigations” (Eylon and Linn 1988, p. 291). 10 years after this study, Duit and Treagust report that there has been “an encouraging tendency towards an ‘inclusive’ view of science learning which brings together approaches of different theoretical orientations” (Duit and Treagust 1998 p. 8). These authors conclude that conceptual change strategies based on social constructivist views of learning are an important way forward, and may help in providing an inclusive framework for future research.

Erickson (2000) provides a different analysis from either of the above reviews. Using Lakatos’ analysis of scientific progress, he identifies three ‘research programmes’ within science research over the past 25 years, and analyses each from the point of view of its ‘hard core’ commitments (its unquestioned assumptions which remain more-or-less unchallenged), its ‘protective belt’ (the part of the programme being changed as a result of credible research) and its ‘heuristic methods’ (the new research approaches derived from the programme). Erickson’s analysis is less fine-grained that those of Eylon and Linn (1988) and Duit and Treagust (1998) described above, and – principally on the basis of the theoretical core commitments – he identifies three research programmes: the Piagetian programme, the constructivist programme and the phenomenological programme. The Piagetian programme and the constructivist programme both encompass the research covered by the two previous reviewers. 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 studies since the 1980s. In contrast the constructivist research programme has become dominant in the student science learning literature (see Table 1).

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After White (1997): a compilation of terms used in ERIC summaries.
The phenomenological research programme identified by Erickson was only cursorily referred to by Duit and Treagust, and had not been sufficiently developed at the time of the Eylon and Linn review. Erickson regards the phenomenographical approach of Ference Marton as a promising methodology, which provides a more holistic position that that adopted by either of the other two programmes. Phenomenography is based on the postulation that there are a limited number of qualitatively different ways in which a phenomenon can be experienced, and that it is possible for a researcher to determine the variation in these conceptions in a group of individuals (Marton and Booth 1997). Once the variation has been established it can be analysed to determine hierarchical relationships within the set. Such relationships can be used to both enrich our knowledge of how people perceive the world and to improve pedagogy in the subject area being investigated. Unlike cognitivist or constructivist approaches to learning, phenomenography does not take a dualistic view of the world. In a dualistic view, the learner builds up or constructs her own internal conception of an external world. However, in a non-dualistic stance, as expressed by Ramsden et al. (1993)

….there are not two worlds (an objective outside world and an internally-constructed subjective world). There is only one world to which we have access – the world-as-experienced.

From a phenomenographical stance, “a way of experiencing something …. is an internal relationship between the experiencer and the experienced” (Marton and Booth 1997, p. 113, my emphasis). Learning is seen by phenomenographers as experiencing a phenomenon in a different way, and subsequently coming to view the world in a different way.

The conceptual framework of phenomenography has been subject to critiques by a number of scholars, including Hasselgran and Beach (1996), Ashworth and Lucas (1998) and Richardson (1999). Hasselgran and Beach question the “unproblematic acceptance” by phenomenographers that data they collect really are the descriptions of the internal relation between the persons and the phenomena they are experiencing. Further, they argue that the findings of phenomenographical research “may be [merely] the reflections of the researchers’ own ideas”, and that “these possibilities have not really been penetrated in phenomenography” (Hasselgran and Beach 1996, p.3).
Richardson questions the innovation claimed by phenomenography in its analytic procedures. Richardson maintains that phenomenographic methodology and analysis combines elements of grounded theory as well as protocol and discourse analysis. Further he argues that the subjective nature of the claims made by phenomenographers would be more valid if they interpreted their findings from a constructivist viewpoint. However, from the position taken by Marton himself in which he criticises situated cognition as a “denial of pedagogy” (Marton and Booth 1997, p.201), it seems very unlikely that this suggestion would be incorporated into phenomenography.

An examination of any of the major science education journals demonstrates that the current predominant paradigm within science education is that of constructivism, which as a method on which to base pedagogy has few major rivals, except perhaps the history and philosophy of science school (Matthews 2000).

Recent developments within the social constructivist paradigm are the notions of situated cognition (Lave and Wenger, 1991), border crossing (Aikenhead 1996, 2000, Aikenhead and Jegede, 1999) and worldview theory (Cobern 1996). Situated learning or cognition 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. Aikenhead and his collaborators take a different approach: 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, with the result for the students in the latter category that they avoid assimilation into the ‘school science’ subculture, and either fail or pass science courses without true comprehension of the science involved. Cobern (1996) suggests that concepts covered in the science classroom will only be assimilated into a learner’s belief system if it corresponds with his or her worldview. Dzama and Osborne (1999), Cleghorn and Rollnick (2002) and others have recently critiqued the ‘world view’ hypothesis, and this is clearly an area for further research.
Research in Astronomy Education

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 he refers to previous psychologists’ work on similar conceptions. 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 (see below in the literature review) has shown that children’s conceptions are dependent not only on age (i.e. mental development), but also on context and content. And Piaget himself made no claims in using his research to assist in student learning.

After Piaget classic studies (Piaget 1929, 1930), Nussbaum and Novak (1976) and Nussbaum (1979) provide the first modern accounts of American and Israeli students’ conceptions of the earth and gravity. Using clinical interview techniques, they identified five ‘notions’ or constructs held by the children of how they conceptualised the earth ‘as a cosmic body’. These ranged from construct 1 (in which the Earth is flat, and continues infinitely sideways and downwards) through to construct 5 in which the accepted scientific conception is held. These studies provided a baseline against which several subsequent studies compared themselves, the first one being that of Mali and Howe (1979). This is a replication of the Nussbaum and Novak study and is an enquiry of urban and rural pupils in Nepal. It confirms the results of the previous studies, with some variations due to context, such as the notion of the flat earth, which is held to higher age than the study of American children. These early studies use a conceptual framework based on the work of Piaget, and relate their findings to his stage model of development, and the cognitive mental structures developed in the mind of the individual. Although the study reported by Klein (1982) followed closely after the initial pioneering work of the above researchers, she does not work from a Piagetian perspective, but is more interested in to what extent astronomy concepts are cross-cultural. She provides an account of a cross-cultural study of Mexican- and Anglo-American children’s understanding of simple
astronomical concepts. Klein selected the children carefully so that socio-economic status did not influence the results. She found that the majority of children did not demonstrate an understanding of most of the concepts being investigated, and that the Mexican-American children showed less understanding than their Anglo-American counterparts. Although she produces some conclusions and recommendations, she does not relate her findings to theory.

As in most of science education, by the end of the 1980s constructivism becomes the major conceptual framework on which studies in astronomy education are based. Baxter (1989) examines misconceptions in a number of areas of astronomy in British children aged between 9 and 16 years. He identifies ‘phases’ of conceptual representation which are paralleled with historical views of the solar system. He suggests that the historical parallels can be used as a teaching device, and that knowledge of the children’s conceptual change can assist in the design of teaching materials. Ideas of using the history of science to assist in science teaching have been promoted by many other scholars, for example Matthews (2000) and Säljö (1988). Baxter (1991) gives examples from constructivist theory of how 7-year-old children’s alternative conceptions of the causes of the seasons (the distance of the earth from the sun) were directly challenged by the scientific conception, and how the children dealt with such challenges. The author further relates this process of conceptual change (or lack of it) to the difficulties scientists experience when faced with a new theory.

Another investigation carried out on astronomy misconceptions at this time is one by Finegold and Pundak (1991) who survey high school students in Israel. They present the results of a multiple-choice questionnaire administered to high school students in Israel. Although of interest to the teachers and school, the paper does not discuss any educational implications, and the rather idiosyncratic nature of the questions does not add to the literature in the field.

The work of Stella Vosniadou and her associates provides a somewhat different theoretical orientation in the field in the early 1990s. Vosniadou (1991) presents a discussion of previous studies she has engaged in, and develops the concept of ‘mental models’ as cognitive constructs people hold about astronomical phenomena. She discusses detailed implications for curricula and comments on how poor school textbooks contribute to misconceptions held by school students and teachers. She further recommends that ‘entrenched beliefs’ of students need to be ‘removed’ before
misconceptions can be replaced by scientific conceptions, and that teachers should concentrate on identifying the entrenched beliefs as they are a major constraint to developing scientific mental models. Although her work is located within the overall constructivist framework, Vosniadou and her colleagues (Vosniadou and Brewer 1992, 1994,) have developed a specifically cognitivist view of mental models which later researchers in astronomy education have replicated or adapted. One example is Sharp (1996), who examines a wide range of astronomical conceptions of 10- to 11-year-olds in Britain. Drawing on Vosniadou’s studies he classifies the children’s conceptions into ‘intuitive’, ‘scientific’ and ‘synthetic’ categories and confirms and extends previous research. The author recommends that strategies based on constructivist models of learning and conceptual change be extended and exploited to their full potential. Two recent papers by Roald and Mikalsen (2000, 2001) present the results of a study of deaf and hearing pupils’ conceptions of astronomical conceptions in Norway. Using instruments developed by Vosniadou and Brewer, the researchers interview pupils from 9 to 17 years of age and present the range of conceptions elicited. They conclude that most students hold ‘synthetic’ conceptions and that while there is little difference between young deaf and hearing students, these differences increase with age. The authors highlight some interesting methodological issues around translating some of the concepts (e.g. ‘the earth’) into sign language. A recent study by Diakidoy and Kendeou (2001) in Cyprus uses Vosniadou’s instruments as a basis for determining students’ prior conceptions, and then assesses two contrasting instructional styles, one traditional and the other that took student preconceptions into account. Results indicate that the latter method “had a strong positive effect on [student] learning and understanding. However, an analysis of the sort of questions asked in the pre- and post-test casts doubt on the learning gains claimed. For example, Question 1: “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”. And Question 5: “What is under the earth?” (a) soil; (b) water; (c) sky”. These questions could be regarded as having very ambiguous answers, which I consider invalidates the assertions of an improvement in learning.

Two studies have examined indigenous knowledge (Jegede and Okebula 1991, Mohapatra 1991) in relation to astronomical and everyday phenomena. However, the
traditional cosmological systems are not described, and the studies are conducted mainly from the point of view of scientific misconceptions.

By the late 1990s, with the astronomy education field having now produced some substantial studies, Albanese, Neves and Vicentini (1997) carried out a critical review of several internationally published research papers on the Earth and its place in the universe over the period 1976 to 1994. 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 his colleagues are particularly harsh in their criticism, a similar argument could be put forward for much of the constructivist alternative conception research in astronomy education. Out of the 20 papers on children’s alternative conceptions cited in the literature review in this PhD proposal, only six theorise how the understanding of the alternative conceptions can be used to promote improved learning.

Six recent publications (Dunlop 2000, Fleer 1997, Kikas 1998a, 1998b and Trumper 2001a, 2001b) provide interesting studies in four different cultures (New Zealand, Australia, Estonia and Israel respectively, but do not add significantly to the literature.

Several papers in the astronomy education field examine trainee and practising primary teachers’ conceptions. All the studies indicate that most teachers in training hold misconceptions similar to those of the students they are intending to teach. In the first of these studies, Ojala (1992) presents the conceptions of the causes of the seasons and variations in temperature change among Finnish primary teacher trainees. In a study using an essay to explain their understanding, only 5 of 87 respondents gave the scientific conception, and the author lists the misconceptions prevalent among the other students. The misconceptions are attributed partly to ambiguous diagrams in textbooks, and the author recommends their replacement. A similar study was conducted by Summers and Mant (1995), who present the results of a multiple-choice test covering a number of areas of astronomy administered to 120 primary
teachers in the UK. They report that results are ‘not encouraging’, but the authors, using a constructivist paradigm, examine a number of implications for teaching and for the training of teachers. Atwood and Atwood (1996) examine American pre-service teachers’ conceptions of the causes of the seasons, and determine that only 1 out of 49 teachers holds a ‘scientific conception’, while roughly 40 provide ‘alternative conceptions’. The authors highlight the most commonly held alternative conceptions. The paper concludes that this information should be useful for instructional designers in teacher preparation programmes, and advocates instruction which targets the alternative conceptions, to replace them with scientific conceptions.

Two recent 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 the others reviewed is the implications the authors identify for the key features of the learning process and the trainees’ Pedagogical Content Knowledge (PCK). The other key paper is by Trundle, Atwood and Christopher (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 authors recommend use of a particular instructional sequence for teaching the moon phases.

Finally, only one paper looks at students’ attitudes to astronomy. Jarman and McAleese (1996) present evidence that astronomy topics (‘the earth in space’) are of considerable interest to Northern Ireland 15-year-old children, outscoring biology, physics and chemistry in attitude surveys of around 3000 students.

Table 2 shows the principle concepts examined by the authors referred to above.
Table 2

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TT = teacher training students
* gravity was not covered in this study

**Research into Informal Science Learning**

A simple definition of informal science learning is that it consists of out-of school learning in free-choice environments (Rennie, Feher, Dierking and Falk 2003). Its characteristics have been identified as being non-sequential, self-pacing, non-assessed, and often involving groups (Dierking and Martin 1997, Griffin and Symington 1997). Most of the modern research on informal science learning has been carried out in museum environments, with a lesser amount at science centres.

Relatively few studies have been executed at either planetaria or observatory visitors’ centres, where Dierking and Martin’s (1997) and Griffin and Symington’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, this research proposal contends that learning at planetaria and visitors’ centres can indeed be classified as informal, on the basis that it is out-of-school, and, in at least part of the programme does have some aspects of free choice, and of being unstructured, self-paced, exploratory and non-sequential.
Although studies into how visitors experience museums were first published in the early 20th century, modern research in this area dates back to the 1960s, when Frank Oppenheimer first conceptualised the Exploratorium in San Francisco as an interactive centre for science learning (Hein 1998). Research during the 1970s and 1980s was predominantly influenced by the behavioural paradigm, and most studies were experimental and quantitative in nature (Rennie and McClafferty 1996). The nature of learning in informal environments has been identified as both being difficult to define and to measure (Hein, 1998). Even by the beginning of the 1990s, Feher (1990, p. 35) stated that “the study of learning in science museums is a field in its infancy”.

Over the past decade, researchers into museum and interactive exhibits have taken a number of pedagogical positions. Semper (cited in Rennie and McClafferty, 1996) identified four perspectives: visitors’ curiosity and intrinsic motivation, multiple modes of intelligence, play and exploration in the learning process, and the background knowledge and understanding visitors bring to their visit. Perry (cited in Rennie and McLafferty, 1996) developed a set of criteria for why an exhibit is successful in attracting visitors and providing a learning experience, namely: curiosity, confidence, challenge, control, play and communication. In turn, researchers have tried to identify frameworks to describe and understand the complete visit experience. Falk and Dierking (1992) conceptualised the Interactive Experience Model, comprising interaction between the physical, social and personal contexts, which they further developed as the Contextual Model of Learning (Falk and Dierking 2000), identifying eight key factors within the same three contextual domains. Griffin and Symington (cited in Cox-Peterson et. al. 2003) distinguished specific qualities of museum visitors that would result in optimal learning. All the positions are shown for comparison in Table 3.
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<td>Visitors’ curiosity and intrinsic motivation.</td>
<td>Visitors have to enjoy themselves and to learn something</td>
<td>Visitors have to enjoy themselves and to learn something</td>
<td>Personal context</td>
<td>Taking responsibility for learning</td>
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<td>Multiple modes of intelligence.</td>
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<td>Motivation and expectations</td>
<td>Active involvement in learning.</td>
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<td>Play and exploration in the learning process.</td>
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<td>Prior knowledge, interests and beliefs</td>
<td>Purposeful manipulating of objects.</td>
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<td>Background knowledge and understanding of visitors</td>
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<td>Choice and control</td>
<td>Making links between exhibits and ideas.</td>
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<td>Sociocultural context</td>
<td>Sharing learning with peers and experts.</td>
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<td>Within-group sociocultural mediation</td>
<td>Showing confidence in learning.</td>
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<td>Mediation facilitated by others</td>
<td>Responding to new information or evidence.</td>
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<td>Physical context</td>
<td>Advance organisers and orientation</td>
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<td>Exhibit design</td>
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<td>Reinforcing events and experiences outside museum</td>
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Despite the pedagogical positions described above, and proponents of a constructivist view of learning in museums (Hein 1998), a recent paper by Anderson, Lucas and Ginns (2003) criticises the field of informal learning for lacking a theory base, and proposes that the human constructivist view of learning is the most appropriate theoretical framework for guiding and analysing research in informal settings. While Anderson and collaborators are making a useful proposal, it is not as original as they make out. Hein (1998), not quoted in the Anderson et. al. (2003) paper, spends his final chapter giving a rationale for ‘The Constructivist Museum’.

According to Joannides (2003), very little research has been conducted in South Africa in museum environments or in the relationship between formal and informal learning. Joannides cites seven studies, all of which are unpublished reports and dissertations, and she highlights the fact that language difficulties in museums have been identified as a major problem in South Africa, as well as the cultural differences between museum staff and learners. Fish (1998) provides a rationale for the popularisation of science and technology in South Africa that includes the promotion of interactive science centres. Sanders (1998) critiques Fish’s proposals and recommends that such centres be investigated to determine whether they ‘work’ before considering them further. My proposed study aims to do just that: examine the learning associated with sites of informal learning.

Research at planetaria

In contrast to substantial volume of museum and visitor studies, there is a very limited literature available on research into learning at planetaria. 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 most research in science education, research into the effectiveness of the planetarium as a teaching tool was mainly quantitative during the 1960s and 1970s. Riordan provides examples of studies, principally from the USA, which show that in comparison with the use of a classroom chalkboard and celestial globe, the planetarium is not a more effective teaching device. 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. In common with museum research,
some attention in the 1970s was given to the “mystique effect” of the planetarium, and the need for students to undergo an orientation session in order to improve learning. However, 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.

Other studies from the last decade include Urke (1993), who provides a summary of a study of primary school children; Brunello (1992) who examines the relationship between entertainment and education in the planetarium; and Parker (1995) who relates lessons from current museum research to the planetarium. Baxter and Preece (2000) made a comparison of dome and computer planetaria used in teaching and found no statistically significant differences, although there was some indication that female students gained most from the planetaria sessions.

A recent study examined the effect of humour on learning in a planetarium (Fisher, 1997). Humorous and non-humorous versions of a taped script were presented to nearly 500 adults, who were subsequently tested for their short-term retention of concepts presented. The results indicate that those who saw the humorous show scored lower on the test, suggesting that they retained fewer concepts than those who saw the non-humorous show. However, this research was limited to a particular style of humour (fast-paced, integrated and concept humour) and the results are in need of replication and variation.

The ever-increasing literature on science museums, visitors, exhibits, and interactive science centres is likely to increase still further over the next decade. The USA’s National Association for Research in Science Teaching (NARST) formed an Ad Hoc Committee on Informal Science Education in 1999, and it produced a policy statement which is likely to guide further research, at least in the developed world (see Rennie, et.al., 2003). The challenge for countries such as South Africa is for the informal science community to be informed by such research and to extend and relate it to the Southern African context.
Research Questions

Research questions addressed in the study are as follows:

1. What do students and their teachers learn in the process of a visit to a planetarium and the visitors’ centre of an astronomical observatory?
   a. How is the content of astronomy conveyed to students?
   b. What is the range of learning experiences that students gain from the visit, and how do attitudes towards science change?
   c. How do students’ interests, prior knowledge and beliefs affect the learning experience of a school visit?

2. How does the content and pedagogy of the visit relate to the current South African school curriculum?

3. What implications do answers to questions 1 and 2 have for learning in the curriculum and learning at centres where science is promoted?

Theoretical Framework

The proposed study will be informed by the notion of informal learning, the precise nature of which is a subject of debate (See literature review above, and Falk and Dierking 2000, Hein 1998, Anderson et. al. 2003). Further, consideration will be given to the four major theoretical positions on learning within museum environments, as shown in Table 3. Many research studies in science centres and museums have been conducted without any explicit reference to theory (e.g. Greenfield 1995, Griffin and Symington 1997, Orion and Hofstein 1994). Indeed, in a survey of 17 research papers concerned with learning in museums and science centres, 8 did not present a theoretical framework. However, more recently, scholars such as Griffin and Symington (1997) Anderson, Lucas, Ginns and Dierking (2000), Cox-Peterson, Marsh, Kiesiel and Melber (2003) and Lucas (2000) have used a social constructivist view of learning as a theoretical framework in which to base their research. The proposed study will use social constructivism as a theoretical construct in which to embed the research, and examine whether ‘situated cognition’ (Lave and Wenger, 1991) or ‘border crossing’ (Aikenhead 1996, 2000, Aikenhead and Jegede, 1999) are more appropriate theories to explain how people learn at sites of ‘informal learning’. However, the study will include a modest realist stance (Osborne 1996). From this viewpoint, the considerable advantages of a constructivist theoretical framework are acknowledged, especially 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.

I considered using phenomenography as theoretical basis for the research study. However, most phenomenographic studies concentrate on producing an outcome space: a concise range of qualitatively different ways in which a group of individuals experiences a phenomenon. It would therefore not be an appropriate framework to use in answering the research questions posed in this study.

**Research Design**

*Methodology*

As the literature review demonstrates, scholars in the field of both astronomy education and informal learning have used a number of types of research design. Although experimental designs based in a behavioural paradigm were common in the 1970s to the early 1990s, there has been a shift to qualitative, more interpretive methods over the past ten years (Rennie and McClafferty 1996). This has mirrored a similar trend elsewhere in science education, where a consideration of the social context of learning has increased in prominence.

The research questions above are examining learning within a social context, so the proposed empirical study will use an ethnographic case study research design (Cohen and Manion, 1985, Stake, 2000). The study will consider second language issues and cultural sensitivity as part of the methodology. Unlike an experimental design in which a number of variables are identified and measured, a case study will allow detailed observation of a relatively small number of individuals, in which a rich description of their experiences can be captured (Cohen and Manion 1985). As a collective case study (Stake, 2000) the proposed research will be able to provide a more detailed understanding, and hopefully better theorising about the issues involved in informal science education in South Africa.

*Sample*

Using contacts within teacher education and the informal learning sector, I will identify 20 to 30 schools planning to visit the Johannesburg Planetarium and/or HartRAO. These schools should use English as their language of learning and teaching. I will then select a smaller number (5 to 10) of grade 6 to 10 classes as
objects of study. Grades 6 and 7 are the last two years of primary school, while grades 8 to 10 are the first three years of secondary school. Currently, Curriculum 2005, the South African policy on curriculum from grades one to nine, guides all these grades in public schools. Although grade 10 falls outside Curriculum 2005 it is considered to be of relevance to the study as a bridge between the General Education and Further Education bands of the South African school curriculum. In selection of the sample, preference will be to public schools, as they form the bulk of the schools in South Africa, and any findings from the study are most valuable if relevant to them. Classes from grades 11 and 12 will not be included in the study, as these grade levels do not form part of Curriculum 2005, and are mainly concerned with the preparation of students for the Matriculation examination which forms the school exit point.

Data Collection

I will carry out data collection in accordance with the items shown below. In using several different data sources, I hope to be able to examine the case studies from several different viewpoints (a form of triangulation). For each type of collection method, its relationship to the research questions listed above is shown in square brackets. Where necessary during interviews and observations, I will be accompanied by assistants who can code data and assist as an interpreter for students whose main language is not English.

A. Semi-structured interviews with teachers prior to the visit to the study sites to establish the purposes of the visit and what preparation (if any) they are doing with their students. [1c]

B. Semi-structured interviews with a selection of students to determine their perception of the purpose of the visit and what preparation they have received for the visit. [1c]

C. Observation of classes during visit, using a prepared instrument, to establish study site educator, teacher and student behaviour. Field notes also to be taken on group dynamics with respect to ethnicity, gender, age and language. [1a, 2]. See Appendix 2.

D. Open-ended questionnaire and tasks for students on learning related to activities presented during visit. [1b, 2]. See Appendix 2.
E. Semi-structured interviews with teachers after the visit to establish the extent of intended and perceived follow-up in class. [1c, 3]. See Appendix 2

F. Semi-structured interviews with students after the visit to establish the extent of actual follow-up in class and attitudes towards visit. These interviews would be in the form of focus groups in order to provide a “comfortable, supportive and conversational atmosphere for the students, and remove any feeling that they [are] being examined” (Griffin and Symington, 1997 p.767) [1b, 1c, 3]

G. Several weeks later: Questionnaire, tasks and semi-structured interviews with students on learning related to activities presented during visit. [1b, 3]

H. Review of Natural Science and learning areas related to astronomy within Curriculum 2005 [2]

Justification for data collection procedures proposed to be used:

Semi-structured interviews will provide extensive opportunities for obtaining personal information, which can be probed to acquire greater detail (Cohen and Manion 1985). Although information could alternatively be acquired by the use of a questionnaire, the prospects of obtaining rich descriptions of preparation and purposes of visits to the study sites is less likely. However, questionnaires will be used to obtain background information on study participants, and in collecting data on student learning during and after the visits. Both interviews and questionnaires will be piloted prior to using them in the main study.

Observation is a key part of case study research (Cohen and Manion 1985), and in the proposed study will be required to identify how the students, teachers and study site educators behave and interact during the visits. Such interaction will provide data relating to any learning that takes place during the visits.

All interview data will be audio-recorded and transcribed.

Validity and Reliability

Validity refers to the research carried out being credible and trustworthy. Many forms of validity are used in quantitative research and are based on behaviourist and positivist assumptions. In this ethnographic study, I intend to use respondent
validation, in which the subjects of research, and possibly other independent readers will be able to comment on the analysis I construct.

Reliability usually refers to the replicability of the results of the research undertaken. In a qualitative study such as the one proposed, it is unlikely that, given the subjective nature of the study, very similar or identical results would be obtained by a second researcher. However, Sandberg (1997) suggests that interpretative awareness can be used as a form of reliability, in which the researcher acknowledges and deals with the subjectivity throughout the whole research process. Such awareness will need to demonstrate how the interpretation processes are controlled and checked.

Analysis

Analysis of the data will be on-going throughout the study, and will consist of examination of the interview transcripts, observation instruments and questionnaire results of student learning using open coding procedures (Strauss and Corbin, 1990). While most analysis will be interpretational, frequencies and percentages will be calculated where appropriate.

Limitations

This study is limited to two sites in Gauteng, South Africa. Although the research will be unable to claim generalisability, it is expected to contribute substantially to the body of knowledge (see below)

Ethical Issues

This proposal will be sent to the University Ethics Committee together with draft instruments intended to be used in the study. All participants will be voluntary and they (or their parents/guardians where relevant) will sign informed consent waivers.

Contribution to knowledge & importance of empirical study

Most research in informal science education has been carried out in North America, Europe and Australasia in communities where Western view of science predominates. Very little research of this sort has been carried out in South Africa, and this study will provide data on South African students from various ethnic and SES backgrounds. The findings are likely to be useful for many centres of informal learning such as museums, science centres and planetaria. As this forms baseline data
for the two study sites under investigation, the study will provide useful comparative data for future researchers.

Answers to research question 2 will assist educators and curriculum developers to consider the social and cultural issues and needs of students from diverse backgrounds, and how they relate to school visits to science centres and similar institutions.

Answers to research question 1 will assist science educators to develop effective interventions in astronomy as a motivating factor to interest students in science and to improve pedagogy in informal situations.

**Proposed Chapters in Thesis**

The following chapters are proposed for the final thesis:

1. **Introduction**: this chapter will give background information on science literacy, science education and informal learning, with special reference to southern Africa. The chapter will also examine the research purpose, the research approach, key assumptions and limitations, and the contributions to be made by the research.

2. **Review of the Literature**: this chapter will provide a complete survey of prior research conducted in the areas relevant to the thesis, namely informal science learning in relation to science literacy.

3. **Research Methodology**: this chapter will provide a complete description of the theoretical framework and research methodology used in the study.

4. **Research Results**: this chapter will give a complete description of the research findings in relation to the conceptual framework adopted.

5. **Analysis**: this chapter will provide a full analysis of the results given in chapter 4, and relate them to the conceptual framework of the study.

6. **Implications and conclusions**: this chapter will examine the analysed results from chapters 4 and 5, and identify implications for informal science learning, both internationally and in southern Africa.
Time Frame

It is envisaged that the literature review, review of curriculum documents and the bulk of the data collection will be carried out during 2003 (see Appendix 1).

Jan-June 2004  Finalise any data collection not completed in 2003, continue data analysis.
June-Dec 2004  Writing up thesis
Jan-April 2005 Complete writing up thesis and submit.
References


Appendix 2

Sample Observation Protocol for students, teachers and study site educators (after Cox-Petersen et.al. 2003)

1. Record student, teacher and study site educator behaviour (using codes, see below) every 5 minutes or when an activity changes.
2. Record anecdotal notes beside each code including specific questions or comments asked by student, teacher or study site educator, and specific on-task or off-task behaviours.
3. Record the number of students that relate to each data code.
4. As you observe, note indicators of ethnicity (connections to culture, stereotypic or non-stereotypic behaviour or comments made during the visit); gender (appropriateness of comments, attention given to all students); age (discussion and activities are age-appropriate); language (level of English used, connections to students’ home languages)

Example of questions and tasks for data collection D – learning related to activities presented during visit

At Radio Astronomy Observatory Visitors’ Centre

Students will be asked to make annotated drawings of the causes of day and night. These will be supplemented during interviews by students demonstrating the causes of day and night using models.

Students will be asked: What is the sun? What are sunspots? How can the sun be used to show the time of day (demonstration)? Relevance of demonstration showing the speed of a spinning star.

Students will be asked to show distances between sun and planets in the solar system using a scale model.

Students will be asked to demonstrate the phases of the moon using models.

At Planetarium

Students will be asked: What does the planetarium dome represent? What is the sun? Why does it look different to the stars you see at night? What is the solar system? What makes the moon shine at night (and sometimes during the day)?

Students will be asked to show distances between sun, planets in the solar system and other stars using a scale model.

Students will be asked to show how an eclipse of the sun and moon occur.

Sample Teacher Interview Questions (after Cox-Petersen et.al. 2003)

1. Why did you choose to visit this planetarium/visitors’ centre?
2. Was it possible to prepare your students for the visit? Explain how.
3. Explain how the content of the tour relates to your curriculum.
4. On a scale of 1 to 10, how would you rate today’s visit? (10 represents the most valuable)
5. What did you like most and least about the visit?
6. What can the centre change to make your visit more relevant to your students?
7. Do you plan to follow up this visit with class activities once you return to school? If so, what types of activities will your students be doing?