EXAMINING STUDENT UNDERSTANDING OF THE SCIENCE OF A SOCIETAL ISSUE IN BOTSWANA: EFFECTS OF ULTRAVIOLET RADIATION ON THE HUMAN SKIN

DISSERTATION

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By

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Science has had such an impact on our way of life that it has been at the centre of discussion for all issues of health, education, development, and the safe stewardship of the Earth’s resources. Science has advanced so quickly in the last 50 years that the amount of knowledge generated by scientists is overwhelming. Science teachers who have persistently introduced children to science from a very young age, have been charged with a daunting task of presenting science knowledge to students in ways that not only make it easy to understand, but also make it relevant to them. The methods of how best they should go about this task have been debated from time immemorial.

Due to the many concerns and demands placed on science teachers and science education programs in general, there have been a number of efforts to reform and redefine the science curriculum. Science education reform efforts in the US and elsewhere have examined all possible nucleotides in the building up of the reform DNA molecule.

Many studies have measured people’s level of understanding on given issues that affect their communities, but little attention has been given to conceptions and level of scientific literacy among students in developing countries.
This study assessed Botswana school children’s knowledge about ultraviolet radiation (UVR) and its effects on human health using a scientific literacy lens. Results show that students do not know as much as one would expect them to know, from public school through the first year in college. Exploratory factor analysis identified four indicators of knowledge about UVR. These are: (a) diseases related to UVR, (b) items that can be used for protections against UVR, (c) misconceptions held about UVR, and (d) general issues surrounding UVR. MANOVA analysis showed that whereas there are no differences in general based on school location, certain groups of students performed differently depending on the school type, type of science pursued at school and or the gender of the student.
To my wife, Keitumetse Shanah-Suping
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CHAPTER 1

INTRODUCTION AND BACKGROUND

Science has had such an impact on our way of life that it has been at the center of discussion for all issues of health, education, development, technology and the safe stewardship of earth’s resources. When new waves of terrorism break out, society looks to the nation’s scientists and technology experts to come up with new ways of detecting and averting acts of terrorism. The newly formed United States Department of Homeland Security has offered scholarships in science and technology in an attempt to encourage development of scientific technologies that will detect and mitigate the use of weapons of mass destruction.

The severe acute respiratory syndrome (SARS) scare could have been a major epidemic fueled by the advancement of technologies that enable people to travel around the globe in a matter of hours, risking spreading the disease, had scientific knowledge on disease control not increased. It took only a matter of weeks to identify the virus as well as modes of transfer of the disease from one individual to the other.
This was made possible by technologically advanced ways in which medical practitioners could share findings quickly, effectively, and accurately. Science played a key role in all of these advances.

Science has advanced so quickly in the last 50 years that the amount of knowledge generated by scientists is overwhelming. Science teachers, at all educational levels have been charged with a daunting task of teasing apart this vast amounts of knowledge and presenting it to students in ways that not only make science easy to understand, but also make it relevant to them. The methods of how best science teachers should go about this task have been debated almost from time immemorial.

No one seems satisfied with what and how this should be done. Quality versus quantity (Kennedy, 1997); methods of science versus products of science; knowledge about the Earth versus appreciation of the Earth’s beauty; are some of the issues raised by these debates. Parents have certain expectations and ways in which they demand that their children be taught. Legislature gives baseline understanding of what learning science should entail. Colleges raise high school graduation standards and increasingly require specific courses to have been taken by the time students reach college (Advisory Committee to the National Science Foundation, 1996). Industry puts different and contrasting demands on the graduates of the same school systems (The Secretary’s Commission on Achieving Necessary Skills (SCANS), 1992). Teachers are trying their level best with very little appreciation from all quarters.

As a result of the many concerns and demands placed on science teachers and science education in general, there have been a number of efforts to reform and redefine the science curriculum. As is the case with everything else, the reasons for science
education reform have evolved with time. This evolution has occurred in the United States (US) more than anywhere else in the world. For example, the importance and place of science in school curricula was realized immediately after World War II. It was argued that no other field of study had the same potential of improving the health, prosperity, and security of the US than science (Baker & Piburn, 1997). The National Science Foundation, one of the key organizations spearheading the advancement of science in the US, was founded out of this realization. Then the Soviet Union launched the Sputnik and set the world powers on a race of technological advancement (Hassard, 1992).

About the same time as Sputnik, elsewhere, the British were more concerned with methods of science teaching. According to Jenkins (1991), it was argued that the nature of science should be included in the school science curriculum with the hope that it would offer humanizing effects in the otherwise dehumanizing study of science.

Parents are still not happy, and industry keeps raising the bar in terms of what they expect graduates of school systems to be able to do. Many students at all grade levels are still failing proficiency examinations. Colleges demand that students graduating from high schools should have certain competencies for admission (Shulman, 1987). “Our children are falling behind; they are simply not ‘world-class learners’ when it comes to mathematics and science” (National Commission on Mathematics and Science Teaching for the 21st Century, 2000, p. 4). This has pushed the reform efforts to the edge. Many factors that were thought to contribute to student success have been studied and none of them seem to be the answer to the multimillion-dollar question of student performance.
Among the efforts considered for improving science teaching at the K-12 levels in the US are K-12 syllabus reform, writing of better teaching materials, new forms of assessment, teacher education reform in the form of teacher change, and more recently the link between teacher education and science content professors versus science education professors (Adams & Tillotson, 1995; Hewson, Tabachnick, Zeichner, & Lemberger, 1999; Nelson, 1997).

Science teachers typically take their science content courses from the College of Arts and Sciences and their methods courses from the College of Education. There is need therefore to take the reform efforts a step further and look at how teachers themselves are taught the subject matter they are trained to teach. This leads us directly to the College of Arts and Sciences professors. There seems to be problems with the way students (teachers to be) conceive of their teaching subjects because “content specialists from the colleges outside the College of Education lack an appreciable understanding of cognition, metacognition, learning processes, misconceptions reasoning structures and fallacies, cognitive, moral, social, and emotional growth and development” (Zeidler, 2002, p.33).

Key to the debate on education reform is the argument that science teachers do not seem to conceptually benefit from the content courses offered by the College of Arts and Sciences due to the nature of instruction they are exposed to (Hewson et al, 1999). What secondary teachers seem to graduate with is the superficial factual knowledge of their content areas, but their conceptual understanding is not any better than their counterparts’ at elementary schools (Hewson et al.). This is a disheartening finding because the secondary education students usually take a lot more science content courses
compared to their elementary counterparts, and one would expect them to have a better conceptual ecology.

As a result of the ill-prepared teachers, the so much desired scientific literacy in school graduates is not realized. This becomes an amplified problem for developing countries like Botswana. As a developing country, Botswana finds herself at crossroads in terms of meeting the demands for the nation to develop and at the same time keeping its identity as a nation. The 1997 long term vision for Botswana, Vision 2016, as is commonly known bears testimony to this dilemma. Creating an educated, informed, prosperous, productive, innovative, compassionate, just, caring, safe, secure, open, democratic, accountable, moral, tolerant, united, and proud nation (Presidential Task Group for the long Term Vision for Botswana, 1996, 1997) that the vision calls for speaks directly about a well formulated science education policy in a nation that will ensure that the nationals are scientifically literate. Yet such a policy is not explicitly addressed or at least outlined for future adoption.

Statement of the Problem

The US has a long history of science education reform. The technological, scientific, and economic advancements found in the US attest to the impact that the science education reform efforts have had on the lives of ordinary Americans (Suping, 1997). Developing countries like Botswana do not have to try and re-invent the wheel, but can learn a lot from what a developed country like the US has had to go through to be where it is now. This is not to suggest that the educational system in the US should be copied as is and applied in Botswana, but necessary adaptations can be made to make it
applicable to the conditions in Botswana. This is more relevant in science than in any
other subject because of the universal nature of science and the natural laws that govern
it. Adaptation is particularly applicable in Botswana because of the small and centralized
educational system; change can be effected without the difficulties experienced by large
nations with decentralized educational systems like the US.

Vision 2016 has become a centerpiece for all aspects of development as far as
Botswana is concerned, and yet there does not seem to be a clearly developed long-term
strategy about what the role of science and technology will be in achieving these goals.
For example, the framework for the vision recognizes what it calls the “rapid
international developments in science and technology that are re-shaping the societies of
the world” (Presidential Task Group for the long Term Vision for Botswana, 1996, p. 32),
but does not seem to see the link these advances have to what goes on in a high school
science classrooms. The vision calls for the setting up of a science and technology
council that should promote innovation and invention in Botswana, and nothing about the
monitoring of the kinds of science curricula that are needed in high schools and colleges,
to give a foundation for and sustain such innovations.

In contrast, educational reform in the US has long recognized the link between
what goes on in the world of work and what students are exposed to in schools (Zeidler,
2002). The current push is to improve classroom teaching at all levels so as to improve
production in industry. Conceptually sound teaching in high school science classrooms
can be realized by producing conceptually sound science teachers at college. This has
implications for the type of teaching that goes on in college undergraduate science
classrooms (Berenson, & Stiff, 1990/1991; Van Sickle & Kubinec, 2000; Woods, 1998),
because that is where attitudes to science and technology as well as decisions about becoming scientists or science teachers are made.

There is need therefore to look into how the Botswana student population fares in issues that they should be familiar with because they are everyday occurrences for them. For example, Botswana is a very hot, dry and almost desert like country with very high ultraviolet radiation (UVR) indices in summer months. One would expect students therefore to be well aware of the consequences of overexposure to such conditions as UVR and its effects on the human skin. The science curricula should pay special attention to environmental issues like those associated with UVR and make it a concern for all students to be aware of possible effects that can arise from overexposure to it.

Analysis of a study like one envisioned in the preceding paragraph should give direction about the kind of changes to the science curricula that should be undertaken to produce the educated and informed citizenry that Vision 2016 calls for. Students should not just be educated for the sake of education, but should be able to function and adapt in a world that is rapidly changing. Lederman (quoted in Marshall, Scheppler, & Palmisano, 2003) succinctly phrased this realization:

The purpose of schools (my opinion) is to produce graduates who can manage and thrive in the world into which they emerge. But that world is changing (it is not the world of the teachers, parents, school officials, even of president Clinton...). They must of course manage their own lives but also play a role in deciding how the city, the state and the nation will use the potential of the awesome new technologies: for the benefit of humanity or for greed and fear. p. 110

Botswana’s emerging economy places her in a better position for adaptation and change. What better way to bring about change than to cultivate it from a nation’s school system? It may be easier to change the current school going nationals than it would be to
try to change those who have been doing things the same way for a long time and may not see a reason to change anything at all.

It is felt that the Botswana science curriculum needs so be considered in light of the role that the national science curriculum should play in making the nationals develop a scientific habit of mind. Rather than just teach science for the sake of teaching it, efforts should be made to ascertain that the new topics or concept infused into the curriculum are such that they directly and immediately benefit students’ health and way of life. The science taught in school should be such that it enables students to live up to their full potential and survive in their locale.

**Purpose of the Study**

The purpose of this study was to glean direction from the history of science education reform in the US and consider how an emphasis on science literacy and societal issues might provide directions for seeking improvement on the Botswana school system science curricula (Nebres, 1999). Specifically, student knowledge of UVR and its effects on human health was examined as a possible example of the effectiveness of Botswana science education programs in addressing issues that affect students and the general public directly. There are many other issues that could have been chosen for this purpose, it was however felt that due to the recent AIDS/HIV prevalence in the country, and the link between UVR overexposure and human immune system suppression, the UVR issue was a more relevant and urgent issue to examine.

Findings from the UVR study would then be used to inform considerations of how UVR and other societal issues can be infused into the curriculum to better benefit
students. Vision 2016’s recommendation that developing countries need to look within their own resources and cultures to find the sources of innovation (Presidential Task Group for the long Term Vision for Botswana, 1996) was questioned. No stone should be left unturned in every country’s attempt to establish itself as a scientifically and technologically advanced nation.

The case of UVR and its effects on human health was considered at as an example of a possible initiative to improve science curricula so as to make it more relevant and beneficial to students and society at large. The Botswana climate conditions warrant such a study because of the high ultraviolet radiation indices that prevail almost year round (Luhanga, 1994; Luhanga, & Nijegorodov, 1997). Despite the fact that about 99% of the population in Botswana is black and not prone to skin cancers due to UVR, the other adverse effects of UVR on the black skin cannot be ignored. The Botswana science education curricula needs to address this and other issues that directly impact on the health of its nationals. The high incidence of HIV-AIDS in Botswana is not coincidental given the documented suppression of the human immune system by UVR (Luhanga, 1994; Rhodes, 1995).

Topics dealing with HIV-AIDS were infused into the curriculum because it was felt that it impacted negatively on the nation’s efforts to develop its manpower needs by crippling the most productive in society – the youth (Presidential Task Group for the long Term Vision for Botswana, 1997). The cosmetically unsightly consequences of exposure to excessive doses of UVR warrant the same urgency. This is an even more urgent issue as far as youth are concerned because their appearance carries more weight about their self-image.
It would seem that if nothing were done about the UVR phenomenon in Botswana, the country’s efforts to combat the HIV-AIDS pandemic would be fruitless. Getting rid of an unwanted tree by plucking off the fruits and leaving the tree intact does not seem to be the wisest thing to do. Perhaps the key to uprooting the HIV-AIDS scourge may be in strengthening the immune system of the nation by providing information and knowledge, starting with the best methods of avoiding UVR exposure from a very early age.

**Rationale and Significance**

Science education reform efforts the world over, and the US in particular, have looked at all possible nucleotides in the building up of the reform DNA molecule. Students’ attitudes, both student and teacher performance, cognitive development, science content relevance, appropriateness and depth, teacher pedagogical content knowledge (PCK), pedagogical knowledge (PK) and subject matter knowledge (SMK) (Zeidler, 2002), collaborative efforts between arts and sciences and education professors in the teaching of undergraduate science (Brush, 2002; Project SUSTAIN, 2000; Van Sickle & Kubinec, 2002; Zeidler, 2002), are a few of the many nucleotides considered. Collaborative efforts between science and science education faculty members have been described as prone to discord, feuds, contempt (for lack of better words) and many times failure (Zeidler, 2002). Despite these difficulties, it seems that the world is increasingly been driven by scientific and technological developments by the day now than ever before in the short history of mankind. Graduates, at all school levels, more than ever, have to have what has commonly come to be called scientific literacy (Jenkins,
Science for all Americans (Jenkins, 1999) has perhaps evolved into science for the
global citizen.

The AAAS’s (1990) realization that the understanding of science should make the
general public acquire a “scientific habit of mind” is an imperative that should be
extended to the general global citizenry. This will, at the very least, teach people to value
the environment, plants and animals, and more especially human life. The
interdependence between humans and their environment is so delicate that any mistake
on environmental impact may take forever to correct the damage that may result, yet
many so called literate people do not seem to realize the importance of this aspect of
science. The more people become aware of this delicate interconnection, the more I think,
they will become sensitive to how important it is for us to be better stewards of planet
earth.

That science education in general does not seem to reach students in making them
science literate is a reality that we have lived with for sometime now. The cause of this
dire failure is a debatable issue. The AAAS (1990) observed that:

The present science textbooks and methods of instruction, far from helping, often
actually impede progress towards science literacy. They emphasize the learning
of answers more than the exploration of questions, memory at the expense of
critical thought, bits and pieces of information instead of understanding in
context, recitation over argument, reading in lieu of doing. (p. xvi)

A lot has been done in an attempt to address such issues in developed countries,
yet there are still a lot of people who are science illiterate. Roth (2003) observed that as a
science educator and a research scientist, it becomes very difficult to decide whether to
be for or against the proliferation of scientific ideas given how deadly the same ideas can
be if they fall on wrong hands. He sights the mishap of September 11, 2001 in the US.
Roth makes it clear that the sheer magnitude of human life lost in the tragedy attest to the deadly ways in which technology through science has advanced.

The significance of this study lies in the realization that whereas developed countries have achieved a lot in terms of formulating policies that address the way science teaching is handled at all educational levels, it is not particularly so with developing countries. Students in these developing countries are still taught science as rhetoric of conclusions; as a result, their science classroom experiences are very boring, irrelevant, and uninspiring. Because of these experiences, students do not attach contexts to what they are taught in their science lessons. They do not see any relevance between what they are taught and everyday life experiences and consequently if given an opportunity to do so, will fail dismally to make a link between what they were taught in class and what they are being asked to apply it to.

Whereas the purpose and importance of science teaching cannot be disputed, there is need to examine whether what is covered by science curricula in any given country prepares students and ultimately the citizenry enough to know the central tenets of health issues. Does the amount of size one does at school influence the conceptions and or misconceptions that they might have regarding health issues that are typical of their locale? In the case of Botswana for example, are Batswana students and the population in general aware of the consequences of over exposure to UVR, which is an environmental health issue for them?
Theoretical Framework

The science that is taught in any school system should be such that it equips students with the necessary skills to live fulfilled lives. Thus, change should occur because what is known about science has changed. This calls for a change in what is taught. But the means by which the new knowledge is generated also changes. The students do not live in the same conditions as the students of 50 years back. Change should thus also occur because the people being taught are different and perceive things differently than those of 50 years ago. Not only do they perceive things differently, they do not have the same patience that generations before them had. They want microwave results. This calls for a change in the methods of teaching science to incorporate new developments and technologies as they take place.

Science education reform is perhaps also complicated by the fact that producing science teachers requires the participation of two equally important camps (college of education and college of arts and sciences). Zeidler (2002) has convincingly argued that the difference in the way teaching is carried out in the two camps is deeply rooted in the way the camps were conceived of in the past. The failure in the marriage between the two camps, according to Zeidler, is rooted in the different ontological, epistemological, or methodological commitments. The content colleges are informed by philosophies and social behaviorists like Herbart, Wundt, and Thorndike whilst methods colleges on the opposite experientialist end of the spectrum are informed by such philosophers and theorists as Rousseau, Froebel, Dewey, Ausubel, and Piaget. Figure 2.2 depicts the differences in conceptions of teaching and learning between the science (social behaviorists) and education (experientialists) faculty in general.
It must be borne in mind that this depiction is a very generalized one. Individual faculty members may differ in the different colleges. For example, it may be possible to find faculty members in the college of arts and science that teach using methods that can be classified as experientialist in nature. A detailed discussion of these conceptions of learning and teaching is given in chapter two.

Research Questions

There have been many studies that measured people’s level of understanding on given issues that affected their communities, students’ understanding of newspaper articles and other studies (Miller, 1998; Norris & Phillips, 2003; Roth, 2003). What have not been explored though are what developing countries’ conceptions and level of scientific literacy may be like. What is the impact, for example, of developed countries giving genetically altered food products to developing countries? When leaders in these hungry developing countries refuse to accept these food products, do they do so because of political reasons or because of lack of scientific understanding of what genetically altered means?

Can the developed countries give out food products that they know have harmful side effects? Does the fact that no harmful side effects are known at the moment mean that there are none or just that they have not been discovered yet? What are the long-term effects of using such food products? How long is long in this context? These and many other questions need to be addressed in a scientifically meaningful way so that all are brought to the same understanding.
Reform, it has been suggested, should not just be about changing the curriculum for the sake of change. The changes that are effected should be such that they benefit both the students as individuals and society at large. In this regard, the effects of the UVR on human health cannot be ignored. The study in this paper seeks to determine, using scientific literacy lens, students’ knowledge about the effect of UVR on human health and to determine how informed they are in general on the topic. This study also seeks to determine when in their educational level the Botswana students are informed enough about the effects of UVR on the human skin. Students’ ability to respond to free response questions on UVR will also be determined with the assumption that this ability will inform us of their level of understanding of the phenomenon under study.

Specifically, this study will seek to determine whether what is taught in the Botswana school system provides enough knowledge base for students to be informed about UVR and its effects on the human skin when over exposed to it. It will also be determined if the amount and type of science that one does has an influence on the conceptions and misconceptions that one has. In an attempt to answer these general questions, the following specific questions will be examined in detail.

1. Are Botswana students at all educational levels:
   a) aware of the effects of UVR on the human skin?
   b) aware of simple procedures for protection against UVR?
   c) able to answer simple questions related to UVR when given in a context they have not before seen in class?
2. Are there differences in knowledge about UVR and its effects on the human skin by school type (junior high, senior, and college), school location (urban vs. semi-urban)?

3. Students at the senior school and college levels do different types of science depending on depth of coverage. Do these students differ based on the type of science they students do or did?

4. Are there any differences in knowledge about UVR by gender?

It is hypothesized that students throughout the Botswana educational levels are not aware of the effects of the sun’s UVR and cannot answer simple questions relating to this concept when presented in a format that they were not taught in class. The scenario used in the study places a situation in context that the students would not likely have been taught in their formal schooling. The idea is to get them to think in a scientific context and test their understanding and application of concepts learned in their formal education. Can they apply their science knowledge and give scientifically accepted answers to everyday phenomena? This puts Lederman’s notion of the need to be science literate for a democratic society to survive, to the test (Marshall, Scheppler, & Palmisano, 2003).

Limitations to the Study

This study was limited by the fact that students report on the questionnaire what they want to report and no follow-ups were made on the answers that they provided. It would have been useful to pick a couple of the students and follow-up with the answers that they provided in the questionnaire with an attempt to find out what their thinking was as they were answering the questions.
Students at all educational levels in the Botswana education system had not specifically covered the topic on UVR in their classes. Reference to UVR was only at the senior school level when students were to learn about the electromagnetic spectrum. This may have thrown off some of the students and rather than exert themselves in answering the questions, especially the open ended ones, they may have had some feelings of despair and given up too quickly. This was evidenced by the many instances where students did not answer parts of the open-ended section of the questionnaire.

Another possibility could be that the students were not used to answering questions that require them to apply their science knowledge, but were only used to questions that cover materials that were discussed in class. The fact that they had not discussed ultraviolet radiation as it relates to the human skin in the way it came across in the study could suggest to them that they had not covered the topic in class and fail to make the connection with the other concepts they learned.

The design of the study was such that only students retained by the school system were included in the study. This is especially relevant since although there is a near 100% progression from primary to junior school, there is only about 50% progression from junior to senior school level in the country and only about 14.5% of the students who make it to senior secondary education make it to post secondary level education. Of these students who make it to post secondary education from secondary education only 7.4% of them make it to four-year bachelors degree-granting institutions. It would have been interesting to compare students who did not make it to senior school and college level with those that made it. But such a comparison would have had budgetary implications
for the study because it would not have been as easy to find such students in one place, as it was to find those that went on in the educational system.

**Definition of Terms**

In this study, the following phrases and words were used as described below, unless where stated otherwise.

*Reform* is used in an all encompassing sense to refer to curriculum change, better practices in teacher preparation, professional development initiatives for science teachers, research informed practices, and all such activities that are aimed at improving science education in a school system.

*College professor* and *college faculty* shall be used interchangeably and shall refer to a person who teaches at college level.

*College of arts and sciences* refers to the college where the science departments are housed in a university.

*Science faculty* or *college science faculty* shall refer to a college professor who teaches a science content class.

*Education faculty* or *science education faculty* shall refer to a faculty trained in science education pedagogy. They can be either from the colleges of education or arts and sciences.

*Urban school* shall mean a school that is located in a city as opposed to one that is in a rural area or within the vicinity of the city.

*Peri-urban (semi-urban)* school is located within reach from the city and such that the students in such a school may have a lot of influence from the city.
*College student* or *college science student* refers to an undergraduate student taking a science course at a college level, particularly at the freshmen or sophomore levels, unless where specifically specified.

*High school* and *senior school* shall mean the same thing and may be used interchangeably.

*Scientific literacy* or *science literacy* shall mean a student’s ability to read/or listen to, comprehend, and make sound decisions regarding a scientific topic.
Introduction

To better situate this study, a quick look at the history of science education reform in the US will help. I start the review of the history from the 50s because of the observation that major strides in scientific discoveries and developments were made mainly from around that time period. This does not in any way imply that there were no attempts to improve the science curricula prior to this time period, but perhaps reform as we know it today was initiated in the time period just after the second World War which places us in the same time frame.

The history can benefit other countries of the world especially the developing world because according to Suping (1997), the US has been a role model for most of the developing world in the way that reform efforts have been conducted. This is succinctly captured by his observation that “The United States of America has advanced both scientifically and technologically as a nation. These advances can be accounted
for using the educational system of the nation, for without education, development is stunted” (p. 7). It is no wonder that when trouble arises the nation turns to its schools for answers. The scholarships in science and technology offered by the US Department of Homeland Security attest to this realization (US Department of Homeland Security website, visited November 2003).

**Historical Account of Science Education Reform in the US**

*The Space War (late 50s)*

Baker and Piburn (1997) argued that major reform efforts in the US started immediately after World War II. They stated that “we had a totally new impression of the importance of science” and consequently a paper published by the President’s National Research Board in 1947 “argued that no other field than science had the potential for improving the health, prosperity, and security of the United States or ensuring its place as a nation in the modern world” (p. 5) (See also DeBoer, 2000). Today, 60 years later, these words are a fulfilled prophecy. The US is still a world power and technologically at the cutting edge. The US is a prosperous nation and despite attacks by terrorists, its security has not been compromised. In fact, the attacks made security a priority, and because of the technological advancements, all is in place to secure the nation.

The National Science Foundations (NSF), according to Baker and Piburn (1997) was founded as a result of the recommendations made in 1945 in an attempt to improve the state of science in the nation, though Hassard (1992) argued that its main thrust was at colleges and universities at the time. According to Hassard, there had been other reports
like the Science Education in American Schools of 1947 by the National Society for the Study of Education. This study recommended that (a) science education should begin early in the experience of a child, (b) all education in science at elementary and secondary level should be general, and (c) competence in the use of the scientific method of problem solving and attitudes should be key in development of objectives in science teaching.

Things changed in October 17, 1957, when the “Soviet launch of Sputnik into orbit about the Earth was a shot that had reverberating effects on American Science and Mathematics Education like no other even in the century” (Hassard, 1992, p. 108). Case (1988), Hassard (1992), and Killian (1997) argue that the launching of Sputnik led to the development of crash programs to reform science education. Curriculum materials were developed and adopted throughout the educational system, elementary through high school.

At the elementary level, there were programs like Elementary Science Study (ESS), Science Curriculum Improvement Study (SCIS), and Science-A Process Approach (SAPA). At the junior high level, there were Earth Science Curriculum Project (ESCP), Individualized Science Instruction System (ISIS), Interaction Science Curriculum Project (ISCP), Intermediate Science Curriculum Project (ISCS), and Introductory Physical Science (IPS). At the high school level were the famous Biological Science Curriculum Study (BSCS), Chemical Bond Approach (CBA), Chemical Education Materials Study (CHEM Study), Harvard Project Physics (HPP), and Physical Science Study Committee (PSSC). (See Case, 1988 and Baker & Piburn, 1997 for a description of these programs).
It is interesting to note that at this time in the science education reform DNA formulation, it was believed that the decline in performance in the American schools was as a result of poor curriculum materials. It was believed that better curricula would produce better performing students, and restore the nation’s competitive edge irrespective of the teachers using the materials.

There is More to a Course of Study (the 70s)

The US won the space war by sending a satellite into orbit and being the first nation to put man, in the person of Neil Armstrong, on the surface of the moon (Baker & Piburn, 1997). The most logical question was, what is next?

And so the 1970s brought another crisis, as Haney (1992) would have us believe. There were a number of concerns raised especially by individual citizens. There was according to Hassard (1992), a call to back-to-basics movement. There was a need to meet secondary needs as the nation had secured its place as a super power. *Man: A Course of Study* (MACOS) was one of the curriculum packages that were developed for the time. According to Hassard, this course of study was met with a lot of resistance especially from fundamentalist Christian groups “on the grounds of its abhorrent, repugnant, vulgar, morally sick content” (p. 110) and others on the grounds that MACOS emphasized cultural relativism as opposed to skills and facts (p. 110). BSCS textbooks were accused of emphasizing Darwin’s evolution theory. These arguments started the race for textbook censorship and the influence that politics and society have on what goes on in science classrooms.
The Economic War (the 80s)

The 1983 Nation at Risk publication was an attempt by the US to beat another country. Such reform initiatives never have far reaching results because once the purpose is achieved, an end has been reached and naturally, there would be no reason to push forth. The report lamented “Our once unchallenged preeminence in commerce, industry, science, and technological innovations is being overtaken by competitors throughout the world” and that this was due to “a rising tide of mediocrity that threatens our very future as a nation and a people” (National Commission on Excellence in Education, 1983, p. 1).

The report recommended that:

The teaching of science in high school should provide graduates with an introduction to: (a) the concepts, laws, and processes of the physical and biological sciences; (b) the methods of scientific inquiry and reasoning; (c) the application of scientific knowledge to everyday life; and (d) the social and environmental implications of scientific and environmental and technological development. (p. 25)

Another report in 1983 was *Educating Americans for the 21st Century* issued by the National Science Board. According to Hassard (1992), the report’s main goal was:

The improvement and support of elementary and secondary school systems throughout America so that by the year 1995, they will provide all the nation’s youth with a level of education in mathematics, science, and technology, as measured by achievement scores and participation levels, that is not only the highest quality attained anywhere in the world but also reflects the particular needs of the nation. (p. 114)

It is interesting to note that up until this time, most reform efforts were aimed at competing with and beating other nations of the world. We already have alluded to the fact that such a motive does not have long lasting results. The objectives are just short termed and once they are achieved, there is not much motivation to continue.
The American Association for the Advancement of Science (AAAS) initiated in 1985 a long-term project aimed at producing school graduates who were science literate. This project, supported by the NSF, aimed at improving science education in America without competing with another nation of the world (AAAS, 1996). The project had multifaceted objectives to be achieved by the year 2061 (Haney, 1990; Hassard, 1992; Martin, Sexton, Wagner, & Gerlovich, 1997) and calls for (AAAS, 1993):

- A reduction in the amount of material to ensure scientific literacy
- Elimination of rigid subject-matter boundaries and attention to connections between science, mathematics, and technology
- Social aspect of science with some interdependence on human thought
- Fostering of scientific ways of thinking consistent with the spirit and character of scientific inquiry and
- A more student centered teaching, giving students a chance to practice the methods of science.

Because the project was a long-term initiative, it consisted of three phases that were expected to span a decade (AAAS, 1990). Phase I of the project attempted to “establish a conceptual base for reform by defining the knowledge, skills, and attitudes all students should acquire as a consequence of their total school experience” (p. 220). Phase II aimed at developing blueprints for reform with the ultimate aim of producing “a variety of curriculum models that school districts and states can use as they undertake to reform the teaching of science, mathematics, and technology” (p. 220). Phase III of the project has the mandate of turning the Phase II blueprints into educational practice.

These objectives seem achievable, but there is more that needs to be done to arrive at what they demand of high school graduates. In justifying the long lasting reform of education rather than the past quick fixes that always failed, the AAAS underscored the fact that change is a slow process. It is particularly so when the enterprise to change is
as enormous as the American education system which is not only large but also
decentralized. It takes time, a long time, for the wave of change to ripple through the
structures that be.

The years of experience for most professionals have reinforced views that “tend to
change slowly when it comes to attitudes, beliefs, and ways of doing things” (AAAS,
1990, p. 211). The key to true school reform, the AAAS observes, is reforming teacher
education. Young teaching professionals can bring values, attitudes, knowledge, and
skills that were not necessarily learned through the vicious circle of “teachers teach the
way they were taught”, but learned through the new reformed methods of teaching that
promote conceptual understanding. It is these graduates at whatever level, that will not
only be personally fulfilled, responsible, open, decent and able to live harmoniously with
fellow citizens, but recognize the global nature of the problems that humans face in this
time and age (AAAS, 1990).

Technology, much as it has immensely improved our lives, has also brought with
it challenges that are very difficult to deal with. A person sick with a contagious disease
such as the severe acute respiratory syndrome (SARS) at one corner of the earth travels
through the entire globe in a couple of days, infecting other people along the way. This
makes it difficult to contain diseases. These new challenges demand an informed
citizenry that is capable of protecting itself in more scientifically sound ways from such
plagues.

*Project Synthesis* was a project supported by the NSF in 1981. According to Kyle,
Jr. (1991), *Project Synthesis* study recommended the emphasis on (a) decision making
and problem solving skills in school children, (b) human biology and the effect of human activities on the living world as well as our dependence and responsibility for safe keeping of the environment, and lastly (c) the relationship of science and technology and their roles in modern life.

The effects of such objectives can be seen in such new developments in science curricula as earth system education where the main emphasis is on the interdependence of the sciences. There has also recently been a move toward the integration of the sciences. The argument leveled by proponents of such curricula is that scientific problems never pose themselves to students, let alone in everyday life, as compartments that we have divided the study of nature into (American Geophysical Union, 1996). The application of science to solve problems requires that problem solvers go across disciplinary boundaries of physics, chemistry, biology, or any science for that matter.

The National Science Teachers Association (NSTA) carried out a project called Scope, Sequence and Coordination (SS&C) with an emphasis at grades 7 through 12 (NSTA, 1992). Key to the SS&C guiding principles is the belief that all students can understand science provided the content is sequenced “from concrete experiences and descriptive expressions to abstract symbolism and quantitative expression, revisiting concepts, principles, and theories as successively higher levels of abstraction and coordinating learning in the four science subjects so as to interrelate basic concepts and principles” (Lawrenz & Huffman, 1997, p.12). This is key to science instruction as a teacher who holds such a philosophy will go a long way to assuring the success of all students in his/her classroom.
Lawrenz and Huffman (1997) carried out a study that compared classes at the 9th and 10th grades that used the SS&C strategy with those that did not. Their results showed that on average, for all the four questions that guided their study, the SS&C students performed better than their counterparts.

*The Quiet Crisis (1990s)*

A lot of the projects initiated in the 80s transcended decades and thus overlapped into the 90s. The AAAS’s project 2061 is a typical example. The Federal Coordinating Council for Science, Engineering, and Technology’s (FCCSET) Committee on Education and Human Resources (CEHR) hereafter referred to as FCCSET-CEHR, characterized this period as the quiet crisis because despite the proliferation of reform mandates, there still was no evident change. Change takes a long time to occur and results take even a longer time to manifest. There were still declining student performances in science relative to international peers, scientifically illiterate Americans, declining enrollments in scientific and technological courses, and under-representation of women, minorities and persons with disabilities in science careers (FCCSET-CEHR, 1991).

This period is characterized by the Federal government’s leading role in committing funds to educational reform in science out of its own initiative. It saw reinforcements of past reform efforts such as in the establishment of the national goals for the improvement of education in 1991 by the FCCSET-CEHR. It was clear to government that the American child was losing against children from other nations such as Japan. Something had to be done, and done soon. The fourth goal of the national
education goals categorically stated that the American child would be the first in the 
world in science and mathematics achievement by the year 2000 (FCCSET-CEHR, 

Interestingly enough, the *Goals 2000* as the FCCSET-CEHR publication is 
commonly called, raised concerns about the state of undergraduate education in science, 
mathematics, and engineering due to what it called its inadequacy to respond to the 
changing needs of the society of the time. Two key issues were raised: (a) there was not 
enough college graduates in the mentioned cognate areas and (b) both majors and non-
majors in the areas were not receiving an education that prepared them for future 
economic and technological needs (FCCSET-CEHR, 1991):

In addition to the aforementioned problems of degree production, many expects 
believe that undergraduate science, mathematics and engineering education has 
suffered from a lack of attention, which has left is stagnant, diminished its quality, 
and led to a dull and uninspiring student experience. As a result, there is concern 
about the quality of the academic experience itself, particularly during for [sic] 
the first two years of the four-year undergraduate sequence. (FCCSET-CEHR, 
1991, p. 40)

The observations made by the *Goals 2000* are sobering to say the least. 

Undergraduate course curricula of the time had remained the same for over 20 years. 

What was taught in the early 70s was virtually taught the same way in the 90s. There was 
a call therefore for faculty teaching undergraduate classes to “upgrade their teaching 
skills and, in some instances, become more familiar with scientific developments in their 
fields” (p. 40). There was a call for more hands-on experiences in genuine research and 
laboratory investigations.
AAAS (1990) devoted a chapter in their findings to what they called:

ten accounts of significant discoveries and changes that exemplify the evolution
and impact of scientific knowledge: the planetary earth, universal gravitation,
relativity, geologic time, plate tectonics, the conservation of matter, radioactivity
and nuclear fission, the evolution of species, the nature of disease, and the
Industrial Revolution. (p. 146)

The above represent great strides in the capabilities of the human intellect. But
what is even more sobering is the realization that these discoveries, having developed
almost over geologic time scales, have only been accepted and disproved in the last 50 or
so years. To mention just a few, the DNA structure was only finalized in 1953, plate
tectonic theory in 1960, the atomic theory, as we know it today, in 1932, and the age of
the earth in 1953. It is amazing to think of how the human species survived such
ignorance and yet what we know about nature is only a tip of the iceberg.

The chain of developments following each of these discoveries was mind-
boggling and science as was known prior to this time changed dramatically. This change
warrants both a change in what is taught in the high school and college undergraduate
science courses and how it is taught. Science can no longer be seen as rhetoric of
conclusions (Lawson, Rissing, & Faeth, 1990) but as a process of knowledge
construction and generation.

No Child Left Behind, Before It’s Too Late (2000 and Beyond)

Reference to this time period is the President Bush’s (1989) national education
goals that called for, among other things, American students to be first in the world in
science and mathematics achievement (FCCSET-CEHR, 1991). The Third International
Mathematics and Science Study (TIMSS) showed that there was no way the American student would be first in the world in mathematics and science achievement (National Commission on Mathematics and Science Teaching for the 21st Century (NCMSTC), 2000; NRC, 1999).

To add salt to an injury, the NCMSTC published a report that echoed the same failures of past reform efforts and for the American child to be first in mathematics and science achievement. To emphasize the urgency of the matter, the committee warned that the time to act was “now–before it’s too late” (National Commission on Mathematics and Science Teaching for the 21st Century, 2000). The emphasis had changed though. Rather than just concentrating on school science reform as had been the case in the past, the report recognized that the American workplace and the globalization of market economies, national security, the American common life, history, and culture, as well as everyday decision making were becoming more and more dependent on the use of mathematics and science related knowledge.

The committee saw a window of opportunity to make a striking blow at reform because (a) the American people were now focused on education as a result of past reform efforts, (b) there were surplus resources that could be invested in education, (c) there was an anticipated shift on the teaching force demographics due to retirement, (d) there was a wealth of knowledge on learning and teaching generated over time, and (e) college graduates were again showing interest in teaching as a profession (National Commission on Mathematics and Science Teaching for the 21st Century, 2000).
As if all that was going on was not enough to make a teacher trying to follow reform recommendations lose his/her mind, President George W. Bush’s education act of 2001 demanded that no child be left behind. The law called for an increase in the subject matter knowledge and teaching skills for mathematics and science teachers, more professional development initiatives, and a concerted effort to recruit more people into science teaching (Bush, 2001; U.S. Department of Education, 2002). This was an attempt to address issues of untrained, ill-prepared, or teaching out of area of study personnel in science classrooms. The NCMSTC report had called for the reform effort to improve education to start at the core of education itself – teacher preparation, in-service, and recruitment.

Relation of US Science Education Reform to Other Nations of the World

This study is not a comparative study and as such will not look in detail at what educational practices take place in other regions of the world. There are four major characterizations of comparative education (Kaiser, 1999, p 5 -7) and these are:

- Identification of what happens elsewhere so as to help improve another system of education
- Description of similarities and differences in educational practices between systems of education and interpreting why such exist
- Estimation of the relative effects of variables on outcomes and
- Identification of general principles concerning education effects
This study seeks to use the characterization as outlined in the first bullet. It is felt that bringing in too many nations for comparison would bring in a lot of factors that may not be easy to account for. This is made especially critical by the fact that science education in Botswana is at its infancy and has not developed enough to compare internationally. It is perhaps this developmental stage of the science curricula in Botswana that necessitates the study of what other nations of the world like the US have had to go through to be where they are.

With Kaiser’s, (1999) cautionary notes borne in mind, it is still hoped that there is something that a developing country can learn from the successes and pitfalls of a great nation like the United States of America. He cautioned “some comparative educators argue that the so-called Third World countries may not be destined to repeat the educational and socio-political history of Europe because of their special cultural traditions and current conditions” (p. 7). The flip side is also true however “a debate had taken place which sees educational development as a powerful tool to overcome specified conditions, such as traditional attitudes or political and social structures, which are in the way of progress” (p. 7).

Some would argue though that modeling educational reform of the more powerful developed nations by the Third World countries would only help maintain the status quo and perpetrate the political and economic dominance of the industrialized nations (Kaiser, 1999). Whereas this may be true, I am of the opinion that if these are initiatives by the less developed countries themselves, it is less likely that the more powerful nations push their own agenda.
The choice of the US as a comparison country stems from two reasons. Materials on the educational undertakings of the US are readily available. Secondly, whereas all major international studies that compared developed and developing countries did not have the US perform as one would have expected, the country continues to excel economically. It is against this realization that the development of the US educational system is used in the comparison aspect of the study with the hopes of adapting its success to the young nation of Botswana (TIMSS, 1993).

The First International Mathematics Study (FIMS) conducted in 1964 involved twelve countries and tested two student populations. In both student populations, the US students performed badly against nations like Israel, Japan, and Belgium (Kaiser, 1999). The First International Science Study (FISS) was conducted in the period 1966-1973 whilst the Second International Science Study (SISS) was done between 1980 and 1989 (Robitaille & Beaton, 1999).

The second comparative study in mathematics education, the Second International Mathematics Study (SIMS) of 1980-82 had twenty countries participate in the study on very similar student populations, as was the first one. Criticisms level against FIMS were accounted for in the SIMS in articulating the different curricular that may possibly exist, namely the intended curriculum, implemented curriculum, and attained curriculum. These were then taken into account in assessing student performance in the different countries (Kaiser; TIMSS, 1993).

The Third International Mathematics and Science Study (TIMSS) of 1995 had more than 40 countries participate and included science, unlike the previous studies, which had
separated mathematics and science in the studies. Three student populations were used, 9 and 13 year olds as well as final year high school students (Kaiser, 1999; Robitaille & Beaton, 1999; Schmidt et al., 1996). The TIMSS study was a more refined study that did not only look at achievement by students but looked at a host of other factors that affected performance. Societal contexts, student effort, attitude, and personal interests were some of the factors considered that were not previously looked into (Howson, 1999; Robitaille & Beaton). Again the United States did not perform at the expected level in this study.

There have been a host of other less encompassing studies like the ones carried out by the Educational Testing Services in 1988 and 1990/91. The Michigan studies of 1979-80 and 1985-86 looked into mathematical achievements of US, Japanese and Taiwanese students. The Kassel-Exeter study compared German and English mathematics teaching and showed significant differences in classroom teaching styles and student learning styles. Japanese students were seen as better than their American counterparts in problem-solving tasks (Cogan & Schmidt, 1999; Kaiser, 1999).

Whereas science is a universal study in as far as its concepts are concerned, the teaching of science is not. This comes about as a realization that teaching is embedded in the culture in which it is done (Schmidt, Jorde, Cogan, Barrier et al., 1996). Schmidt et al. describe teaching episodes of teachers interacting with students in classrooms across six different nations of the world. Previous international studies leading to TIMSS provided evidence for this finding and hence the case by the researcher to not only pay attention to
achievement, but look into the different curricula across nations and the contexts in which they are implemented.

The value that is hoped to be attained in looking at the historical development of science education in the US has been captured by Howson (1999), “it must be emphasized that ‘value for use’ does not necessarily mean supplying direct answers to questions, but rather in enabling planning and decision-taking to be better informed” (p. 166). It is hoped that some strategies can be learnt from the development of science education in the United State that can be adapted for Botswana in a way that will be relevant to the national needs of the country in terms of especially human resources. Botswana as a developing country is in need of trained personnel in the scientific and technological fields and therefore needs efficient ways in which her young can be trained in these fields.

A Developing Country Twist – The Case of Botswana

Botswana gained her independence in 1966 after 80 years of British rule (National Development Plan (NDP) 9). Since independence, the country has worked hard towards giving her citizenry the best possible education. The epitome of this aim is enshrined in what has become commonly known as Vision 2016 – a framework that envisions Botswana being an educated, informed, prosperous, productive, innovative, just, caring, open, democratic, accountable, moral, ethical, and tolerant nation by the year 2016 when she shall be celebrating her fiftieth year of independence (Presidential Task Group for the long Term Vision for Botswana, 1996, 1997).
The country has had two National commissions on education. The first commission was in 1977 and the core of its recommendations was a call to expand the country’s educational system both in terms of physical infrastructure and total enrolments. This led to a change in the educational system from a 7-3-2-4 (7 years of primary education, 3 years of junior secondary education, 2 years of senior secondary education and 4 years of college) to a 7-2-3-4 structure with the ultimate aim of achieving a 6-3-3-4 system (National Commission on Education (NCE), 1983). More schools were built, with a near 100% access to primary education and significant increases in enrolments at all other levels. The idea was to go with the first NCE recommendations for a free 9-year basic education for all children in Botswana.

The change to the structure of the educational system was not successful though and as a result, the second National Commission on Education recommended a change back to the 7-3-2-4 system, which was immediately adopted in 1995. Among the reasons given for the change was the argument that children in the 7-2-3-4 system finished their junior schooling so young and immature they could not be absorbed by the Botswana workforce (NCE, 1983; Revised National Policy on Education (RNPE), 1994). This was particularly the case since a good percentage of them were not admitted into senior schools as the senior schools could absorb only less than 50% of the junior school graduates.

Table 1.1 shows how school enrolments changed over the years since the first NCE to date. It is interesting to note that in 1977, the same year that the first NCE was commissioned, transition from primary to junior school was only 35%. This has risen
to 100% now. Transition from junior to senior school was 33% in 1978 around the time of the first NCE, 27% in 1993 (the second NCE was this year), and has risen to about 50% by 2003. This means that half of the Botswana student population finish their formal schooling at around 18 years of age and have to look into joining the work force of the nation. The big question to ask becomes, is the science that they have been exposed to by this level of education enough to enable them to thrive in the world of work into which they emerge, to use Lederman’s words (Marshall, Scheppeler, & Palmisano, 2003)?

There were only 33 junior schools in 1984 and by 1991, the number had skyrocketed to 146, there are currently about 261 junior schools in the country. There were only two senior schools at independence in 1966, 23 by 1994 and there are currently 27 government senior schools with a handful of privately owned senior schools.

The massive expansion of the school system brought with it problems of quality assurance. The second NCE therefore recommended that the issue of quality of education be addressed, among a host of other recommendations. Specifically, the second NCE blamed the poor performance of students in mathematics and science at the senior secondary school level on the poor quality of instruction at that level and the lack of a clear science education policy in the nation. Botswana has been affected by the HIV-AIDS pandemic like no other country in the Sub-Saharan region (NDP 9). Could a more science literate people be better placed to understand how best to protects itself and function in a time plagued by disease outbreaks such as our generation?
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Sources: Educational statistics 2000, NDP-9, & NCE-1993

Table 2.1: Expansion of the Botswana education system

The 1993 NCE, regarding science and technology education in Botswana recommended that:

- The formulation of a science and technology policy should be finalized as soon as possible, and that the policy should pay special attention to providing guidelines for Science and Mathematics education.
➢ The shortfall in Science and Mathematics teachers which is being met through recruitment of expatriate teachers should be addressed through an aggressive and deliberate long-term project to specifically train Science and Mathematics teachers for senior secondary schools. Special incentives should be developed to attract suitable candidates for training and subsequently retain them in the teaching profession.

➢ Equipment, materials and facilities for the teaching of Mathematics and Science at senior secondary school level should be better utilized. A well-structured and comprehensive in-service training programme for teachers and on-the-spot assistance by Education Officers should be instituted to ensure improved instruction and optimum utilization of resources. …

➢ Intensified measures to popularize science among students and to develop an interest and positive attitudes towards Science and Technology should be developed through Science and Mathematics fairs and other competitive activities, special awards, the establishment of a Science and Technology park and so forth.

➢ Special measures should be developed to increase the participation and performance of girls in Science, Mathematics and Technology.

➢ Techniques of using technology to teach technology be encouraged. This calls for teachers to avail themselves of technology based teaching aids on one hand, and on the other hand for students to be exposed to the practical
applications of Science and Technology and to gain hands-on experience of them. p. 180–181

The recommendations outlined above are fair, but not specific enough for the condition that science, mathematics, and technology education is in Botswana. The situation can only be addressed via very rigorous measures. The much called for science and technology council could perhaps bring the much desired change by actively promoting innovation and invention in Botswana (Presidential Task Group for the long Term Vision for Botswana, 1996), but as of now, such a council has still not been realized. The Botswana Government endorsed all these recommendations and in fact adopted as one of its overall objectives of national education as a call “to emphasize science and technology in the education system” (RNPE, 1994, p. 5).

The Botswana Government is making strides in improving science and mathematics education by the use of technology, especially computer technology. In the just released NDP 9 publication, government pledges to intensify its fight for technology in schools by connecting school laboratories to the Internet with the key aim of having students acquire basic computer literacy skills during their basic education (NDP 9, 2003).

Climatic Condition in Botswana

Botswana lies between latitude 18 °C S and 27 °S and longitudes 20 °C and 29 °C. The country has an area of 582,000 square kilometers. It is completely landlocked with an average elevation of 1000 meters. Temperatures vary on daily basis in Botswana because of the desert conditions prevailing in the country. Extreme maximum and
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Table 2.2: Maximum and minimum daily temperatures in °C for November 2002
minimum temperatures recorded in Gaborone for the period 1985-1995 were 40.40 °C (104.72 °F) in 1990 and -6.50 °C (20.3 °F) in 1988. The highest recorded temperature for Gaborone is 43.9 °C (111.02 °F) (Department of Meteorological Services, Botswana, 2003)

Table 2.2 shows maximum and minimum daily temperature in °C for the month of November 2002 in Gaborone. The hottest months in Botswana are December and January. The temperature indicated here are therefore far from typical high temperature for the country.

*Putting it All Together*

The history of science education reform in the United State is a very rich one. Different committees recognized diverse needs over time. All the findings were valid at the times they were made. Certain elements transcend decades in the reform evolution: competition with other nations, security, health, science and technology dependence to make informed personal, national and global decisions, to mention just a few (American Geophysical Union, 1996; Baker & Piburn, 1997; FCCSET-CEHR, 1991; Hassard, 1992; National Commission on Mathematics and Science Teaching for the 21st Century, 2000; NCEE, 1983).

All reform efforts call for a teaching of science that will not only have students regurgitate facts at teachers, but be able to synthesize information and solve problems that may be unfamiliar. This calls for a deep and comprehensive understanding of the complexities and interrelatedness of science concepts. The American Geophysical Union
(AGU) argues for what they call the earth systems education. They contend that in order to achieve the depth of knowledge called for by reform efforts there should be a move away from the compartmentalization of the sciences, to an integrated, interdisciplinary Earth system approach comprising the Earth and Space Sciences (American Geophysical Union, 1996).

The AGU (1996) argues that the Earth systems education poses advantages on a number of fronts. The impact of human activities on global process, international cooperation in resolving resource and environmental problems, geologic time scales changes to climate, and the globalization of markets and consequences for minerals and agriculture, can better be understood through the systems approach.

The Basis for a Theoretical Framework

Figure 2.1 depicts an understanding of teaching and learning conceptions by experientialists and social behaviorists. Social behaviorists believe that the teacher knows it all and wants to empty him/herself into the students. This is a very common scene in the college science classes.
Figure 2.1: Comparison of educational views held by social behaviorists and experientialists
(With kind permission of Kluwer Academic Publishers)
I remember my own college science experiences. Dr. Johnson (a pseudo name) would go on rumbling and writing notes on the board and if a student tried to stop him to ask a question, his reply would always be “I have so much to cover and so little time within which to do it.” It did not matter to him whether or not we understood, what mattered was whether or not he emptied his head into ours. Little did he know that our heads were always almost as empty at the end as at the beginning of the class period.

Taylor (2002) after observing Dr. Stern in his college classroom came to the same conclusion, “how students were to see the important relationships he [Dr. Stern] valued was somewhat of a mystery, even to him [Dr. Stern]. But one thing was certain: It wouldn’t occur in class” (p. 12). Dr. Johnson really did not expect us to learn anything in class, but to take notes that would come in handy in preparation for examinations – commit to memory and regurgitate into the examination answer paper.

Experientialists are cognizant of the fact that students meaningfully construct their own knowledge. The argument here is not so much which camp is wrong or right (Zeidler, 2002), but rather which way of doing things is likely to benefit students more. In other words, which way of learning is likely to lead to conceptual understanding of one’s teaching subject? We already have established that conceptual understanding is better than factual recall of conclusions, which is no proof of understanding.

That there is a need for change cannot be overstated. Taylor, Gilmer, and Tobin (2002) in the preface to the book they edited about undergraduate science teaching, decried the teaching that goes on in many colleges of arts and sciences:

But undergraduate science teaching, breeding ground of teachers of science, has remained largely unaffected [by the transformations toward more learner-sensitive
standpoints], teacher-centered teaching remains the dominant epistemology of practice in many lecture theatres and laboratories. … newly graduated science teachers arrive in school science classrooms ill-prepared to practice learner–sensitive teaching. (p. i)

Change from “I am teaching you content so you can have a strong background in science, so that you will be comfortable to teach science” (Roth & Tobin, 2002, p. 151), to a realization of “science as a social construction” (Taylor et al., 2002, p. i), that regards what is already known as a foundation for the learning of science is overdue in the colleges of arts and sciences lecture theatres and laboratories. Cognizant of Ausubel’s meaningful learning theory, it becomes every teacher’s responsibility to find out what students know, can do, and teach them accordingly (Taylor et al.).

**Psychological, Philosophical, and Theoretical Underpinnings**

The whole idea of reform in science education is to create, at all levels of education, conditions that will favor good scholarship of teaching and promote learning in students that will make them better consumers of the scientific information. Decision making at all levels, personal, family, societal, or even national require that science knowledge be used in very appropriate ways.

**Social behaviorists – students as empty vessels.**

Johann Herbart (1776-1841) stressed the study of the psychological processes of learning as a means of devising educational programs based on the aptitudes, abilities, and interests of students. Wilhelm Wundt (1832-1920) held the view that the essence of learning was a psychophysical process, an organic response mediated by both the
physiological and the psychological. He pioneered the concept of stating mental events in relation to objectively knowable and measurable stimuli and reactions. Edward Thorndike’s (1874-1949) classical and operant conditioning held the view that for learning to occur, a stimulus has to be present.

The implications of the above views on learning are that the teacher (professor) has to provide the stimuli with the ultimate aim of measuring students’ abilities and thus separating them into groups. Instruction is therefore teacher-centered, outcome-based with a specific body of content knowledge transferred to students (Zeidler, 2002). Teaching is done as if students do not have any prior knowledge. They are as is commonly said, blank slates or empty vessels to be filled. The teaching-learning interaction is measured by how much teaching took place as opposed to how much learning takes place. Yet teaching and learning do not necessarily always occur together.

**Experientialists-Students as Cognizing Beings.**

On the other hand, experientialists take cognizance of the fact that students do not come to class empty headed. They bring with them ideas from a vast range of settings, this is particularly true in this age due to the explosion of knowledge that is not always scientifically valid. The Internet, as a source of knowledge that is usually not reviewed for accuracy, poses an even greater challenge for teaching.

Jean Jacques Rousseau (1712-1778) expounded a new theory of education at the time emphasizing the importance of expression rather than repression to produce well-balanced, freethinking students. This allows for students to have their own opinions that
may not be that of the instructor. This kind of learning is also liberating as opposed to oppressuring instruction that treats students as machines.

Friedrich Froebel (1782-1852) held the view that the student is at the center of every learning activity. The teacher’s role is important, but the student has to be given the freedom for development. Froebel also recognized the importance of play in students’ learning. Children’s play activities usually show what they are capable of achieving. The less restricting the learning environment is, the more likely it is for students to express themselves freely and thus benefit from the teaching-learning encounter.

John Dewey’s (1859-1952) contribution to education can be summarized in his famous quote regarding what the purpose of schooling is:

I believe that education is the fundamental method of social progress and reform. All reforms which rest simply upon the law, or the threatening of certain penalties, or upon changes in mechanical or outward arrangements, are transitory and futile... But through education society can formulate its own purposes, can organize its own means and resources, and thus shape itself with definiteness and economy in the direction in which it wishes to move... Education thus conceived marks the most perfect and intimate union of science and art conceivable in human experience (quoted in Craig A. Cunningham, 2002, p. 1)

As can be seen from the previous quote, to Dewey, schooling was more than just memorizing facts and regurgitating them during examination time; it was more about the building of a society and the realization that learning is a social process. Dewey’s theory extended both Rousseau’s and Froebel’s theories by adding the social dimension to learning in particular and schooling in general.

Jean Piaget (1896-1980) developed four stages of cognitive development. Of particular interest to us are the last two stages. The concrete operational stage for children ages 6 through to 11 is characterized by comprehension of reversibility, succession,
classification, and conservation. Proportional thinking, control of variables, and hypothetical-deductive thinking characterize the formal operational stage, (ages 11 to 15).

Piaget’s work stresses the importance of human interaction and physical manipulation of objects in the acquisition of knowledge (Stiff, Johnson, & Johnson, 1993). It is important to note that the development through the stages is not clear-cut as may be implied by the categories. Some students may be at the interface between the concrete and formal operational stages or be at one stage in certain tasks and a different stage in other tasks.

Out of Piaget’s theory came two key concepts that instructors have to be cognizant of in their teaching. Assimilation is the process by which new experiences are placed into the cognitive structure such that they make sense to the learner. If a place cannot be found for the new experience, then the learner accommodates it. Accommodation is the restructuring of the cognitive schema so that new information should fit well in the learner’s mental framework. A schema can be thought of as the mental frame that helps learners fit new information into the old. There are indications in literature to the effect that constructivism was birthed out of Piaget’s theories of learning and as such he can be regarded as the founding father of the theory.

Jerome Bruner (1915-) looked at knowledge acquisition at three levels or modes. These are the enactive mode, which involves learning by doing or manipulating objects, the iconic mode, which involves students forming mental pictures without concrete objects, and the symbolic mode, which allows students to work with symbolic
representations of real objects. Bruner’s modes of cognitive development are very similar to Piaget’s stages of development in that they range from the concrete to the abstract.

There is controversy in literature as to whether or not Bruner founded discovery learning or he just provided the theoretical framework for it (Collete & Chiappetta, 1989; Shulman, 1970). Whatever the case may be, discovery learning refers to the manipulation of learning materials by students in order to find relationships among them and thereby learn. The key idea in discovery learning is that students find out information for themselves as opposed to being told by the teacher.

David Ausubel advocated what he called meaningful learning for students. This in fact means that what the students learn has to connect or relate to something they already know. The sequencing of curricula material is a direct application of Ausubel’s meaningful learning theory. Nielson (1980) in quoting Ausubel succinctly captured his theory in writing:

… the acquisition of new materials is highly dependent in the relevant ideas already in cognitive structure and that meaningful learning in humans occur through an interaction of new information with relevant existing ideas in cognitive structure. (p. 11)

The conceptual change model calls these relevant existing ideas a student’s conceptual ecology. The student’s conceptual ecology is his/her acquired concepts that ultimately determine how learning materials are comprehended—meaningfully, to use Ausubel’s language.

The experientialist’s view to learning is that students’ background knowledge plays a vital role in their ability to comprehend materials given to them to learn. Instructors therefore have to pay close attention to this knowledge and build on it to help
students construct meaningful knowledge out of the materials they are exposed to.

Leonard (1997) drives the point home in saying that:

Constructivism is a theory of learning which asserts that knowledge is not primarily received, but actively built and that the function of cognition is adaptive and serves the organization of the experiential world. Rooted in Piagetian thought, information processing and concept mapping, constructivism assumes that learners build upon prior experiences. The learner has a neural network which organizes and relates previously-learned knowledge. New knowledge is constructed by the learner out of experiences. Constructivism holds that learning is an interpretive process, as new information is given meaning in terms of the student’s prior knowledge. Each learner actively constructs and reconstructs his or her understanding rather than receiving it from a more authoritative source such as a teacher or textbook. (p. 9)

One therefore expects that a classroom that is informed by such a way of learning should be very different from the social behaviorist classroom. The activities that students engage in should be informed by what the teacher or professor believes learning and teaching entail.

**What Do We Know About Learning Capabilities of College Students?**

According to Lawson (quoted in Leonard, 1997), it is estimated that 50% of college students in the USA are formal thinkers. Surprising enough, this is also true of the general adult population. The good news though about Lawson’s findings is that most college students who self-select into science are formal thinkers. A large majority of science students who are education majors are not self-selecting, and may not all be at the formal operational stage. They may just be in the borderline (transition stage) between the formal and concrete operational stages because whilst they may handle the concrete
aspects of science, they may not be cognitively developed enough to go all the way into its abstractions.

What is disheartening about Lawson’s findings regarding non-science majors (education students included) is that 25% of them are in the transitional stage between concrete and formal stages of development. A further 25% of the remaining 50% are concrete thinkers! Leonard (1997) concludes that this situation “posed a serious challenge for the large-enrollment in science courses, in which students are exposed to ten to thirty (perhaps even more) abstract concepts per lecture” (p. 8). A large range of cognitive development such as this is a major drawback in many science classes in college and is even more reason why a lot of planning should go into teaching college science classes.

Leonard (1997) concludes that the implications of his findings are that educational practice should be based on what he called active learning, an educational practice in which learners are actively engaged physically, emotionally, and mentally with the skills and concepts to be learned. This, Leonard argues, promotes deeper understanding and retention of concepts, which is consistent with constructivist views of learning.

**Potentialities**

Figure 2.2 shows a possible science education reform model based on the literature review discussed for this study. This is the researcher’s rendition of what the literature surveyed and read seem to suggest. This model will not be tested in this study, nor will it be used in any direct way.
Figure 2.2: A Possible science education reform model.
It will however be used to inform some of the discussions and interpretations that will result from the study. A further investigation of the science education reform model suggested here could form a study on its own. In fact this model is used in certain quarters, what needs to be done is to carry out a more empirical study based on the model. The small size of the Botswana school system makes it a suitable candidate for the study.

The model in Figure 2.2 suggests that the problems associated with science education reform are cyclic. It has already been mentioned that students who come from high schools into colleges were taught by teachers, who were in turn taught by the science faculty in the colleges. It is these same science faculty members in the colleges who complain that the high school teachers do not do a good job of teaching the students and grounding them in key science concepts. “I wish that they had not taught them any chemistry at all because when they come here, we have to first of all “unteach” them before we start teaching them chemistry” (A chemistry professor quoted in a seminar class, Spring, 2003)

The model suggests that change can occur, and it has occurred in certain places, when the preparation of teachers at college level is a concerted effort between the faculty members in both the colleges of science and education. Teaching assistants in the sciences should, as is happening in some places (Druger, 1997b; Glasson & McKenzie, 2001), be trained in pedagogy so that by the time they are professors, they would be in a better position to teach in ways that engage students. This exposure should help them prepare more conceptually sound science teachers.
Education faculty should also keep up with the new developments in theories of learning and new teaching methods so that the student teachers are exposed to cutting edge methods in teaching that take on board the technologically advancing world of work. The doctoral students in science education need to be also involved in what goes on in pre-service teacher preparation courses so as to be kept abreast with the new developments. These are the future education faculty who also need to evolve as the students evolve.

Teachers, once they graduate, should be kept abreast of new developments both in content and methods of instruction. It should be impressed upon them during training that the methods they learn are evolving. This way, change will not come to them unexpectedly and they will be more prepared for it.

The critical point is the point of change for high school science teachers, where reformed teaching from both colleges - science and education, impact the science teachers. The reformed faculty members are written in bold, an indication that they are not what they used to be, they are new breeds, cognitively engaging their students in active learning methods. The teachers will themselves emulate their professors and do a good job of teaching high school students.

If no change occurs at the critical point, the process becomes cyclic, and the circle becomes more vicious as it winds more and more and the effects of bad teaching accumulate, leading to dismal student performance. Reform is the only hope to ending this predicament.
The Botswana educational system is suited for such a change model because of the way it has been structured. The Ministry of Education runs everything from the capital. This may be seen as a top-down reform, but if all the stakeholders are involved from the onset, the model stands a chance of success. It is not implied by any means that the envisaged change will take effect overnight. Change even for a small educational system such as is the case in Botswana is a very slow process. But the smaller the educational system, the higher the likelihood of effective change occurring in a shorter period of time.

Change is a very uncomfortable experience. It requires conviction from within. The same is true of educational change; unfortunately, it has often assumed a top-down or outside-in model (Berenson & Stiff, 1990/1991). This model is not likely to work with professionals who like what they are doing and are convinced that there is no other way of doing it. The elevated status that society gives the science faculty does not allow them to reflect on their practice especially as it relates to undergraduate teaching. But a more supportive, suggestive, and friendly environment over a period of time may convince the science faculty and cause them to want to change, change that comes from within (Berenson & Stiff, 1990/1991) endures and perseveres.

Zywno (2001) disagrees with this view of reform and suggests that in order for change to occur in the way teaching takes place in the colleges of arts and sciences, there needs to be a top down mandate for change and cites examples of places where such a model of change has worked. What I question though is whether a mandatory forced change can be sustained.
This study will not look into this model of change as it would be more time consuming and can take longer than time would allow for a dissertation research. The model though is a viable one and warrants further attention in future. Instead, the model will be used to inform the interpretation and discussion of the results from the UVR research section of the study. It is hoped that once these are put together, the link between the model and the study carried out will become more clear.

_Undergraduate Science Education_

Most reform efforts in science concentrated on K-12 education. It was believed that if students’ were exposed to scientific methods of inquiry at those levels, they would be grounded enough to be able to survive the technological way of life that was becoming a reality in everyday life. It soon became evident that there was need to go beyond K-12 and extend the crusade to include undergraduate science (National Science Board Task Committee on Undergraduate Science and Engineering Education, 1986).

There was a call to the overhauling of undergraduate science education ranging from physical facilities, equipment, updating of curricula, to improvement of the quality of undergraduate science students educational experiences. As a result of these recommendations, a number of support programs organized through the NSF were put in place to serve undergraduate science programs from as early as the 50s (National Science Board Task Committee on Undergraduate Science and Engineering Education, 1986).

Two key issues crop up when undergraduate teaching is mentioned. Instructors in the college science classrooms are not trained teachers (Druger, 1997b; National
Advisory Group of Sigma XI, 1989; Stepans, Shiflett, Yager, & Saigo, 2001; van Sickle & Kubinec, 2002). Most of them therefore have difficulties getting the subject matter of their disciplines across to students. No doubt that these are professionals and that they know their content very well, but telling, teaching, and learning cannot be equated. More importantly, teaching does not necessarily lead to learning. This rather unfortunate lumping of content and pedagogy is a medieval conception of master-student relationship (Shulman, 1986).

Back then, it was believed that if you knew it, you could also teach it. But we know better now, we know that students, even people in general, learn better when they are actively engaged in what they are learning (Glasson & McKenzie, 2001; Zeidler, 2002).

The second issue that crops up is the fact that while undergraduate teaching is a key component of a science faculty’s job description, it is not weighed equally with the other two component, research and community service (AGU, 1996; Committee on Recognizing, Evaluating, Rewarding, and Developing Excellence in Teaching of Undergraduate Science, Mathematics, Engineering, and Technology, 2003; Gilmer, 2002; National Science Board Task Committee on Undergraduate Science and Engineering Education, 1986) The gradient for the expectations on all three areas is a function of whether the university is one with or without research emphasis. The situation is worse in large research institutions where research takes the upper hand, with even more complications made by the involvement of teaching assistants (TAs) in teaching some courses. These TAs lack both the experience and subject matter knowledge (SMK), and
in some cases communications skills as in the case of some international TAs (National Advisory Group of Sigma XI, 1989; Zeidler, 2002).

Teaching and Learning.

The realization that many college professors teach the way they were taught despite the changes in content, technology, and the students taught, has been with us for some time now (American Geophysical Union, 1996; Harker, 2001). What perhaps took longer to realize was the connection between the teaching that goes on in college science classrooms and K-12 science classrooms (Advisory Committee to the National Science Foundation, 1996). This committee recognized the fact that science learning at whatever level is part of a continuum:

The various parts of this continuum are interdependent; undergraduate SME&T (science, math, engineering, and technology) education depends on the students who come from K-12, relies on faculty who come out of graduate programs, and prepared teachers for the K-12 system and the students for graduate school. (p. i)

The Students

The student population has changed. This is a harsh reality that teachers at all levels of the educational system have to face. A middle school science teacher of many years of experience had this to say about the students that we now have in our schools, “they are not willing to learn any more, you really have to push them for them to do anything in class” (T. McLean, personal communication, April 3rd, 2003).

I have been in a privileged position of supervising M.Ed. science student teachers who are trained to teach across the board from grades 7-12 and have observed how
teachers literally have to beg students to do their work both in class and as homework. It takes a lot to keep them interested in what is going on in class and teachers better come to terms with this realization as it is here to stay. It is these same students who graduate high school and go on to pursue courses in M S E & T in colleges that are not only ready for them, but are not aware of the new evolved species of students. They are not the same anymore. We cannot blame them since they are living in a completely different environment than that we lived in as students. They do not, and cannot understand why we say they have changed because they do not know any differently. What they know now is all they have experienced. In fact, they can not understand why we put up with the things we had to put up with, like having to every time retype the whole page after making a typing mistake on a type writer.

The Faculty

J. J Daniels (personal communication, Autumn quarter, 2002), a college professor who has adopted an earth systems education for his 100 level geology classes in a very large research university shared the same sentiments when he said “the students have changed and faculty do not seem to realize it.” He referred to how difficult it was to try and bring changes to the way he taught a course in geology for his first year college students.

What complicates the matter further is the combination of the students who have evolved, with faculty who have been teaching for the past 30 or so years. These, it would seem, are the most difficult to convince to change because they’d been teaching long
enough to know that it works. It does not seem to matter to them that if it worked for students 30 years ago, it may not necessarily work for the new generation of students. The M S E& T education reform efforts are caught up in between these contrasting generations of students and their teachers/faculty.

The Link to Science Teacher Reform

Teaching is a very complex occupation. Shulman (1987) paints a very vivid picture of Nancy, a veteran teacher of English with such resolution that you can almost see her as she goes about her classroom:

Thus Nancy’s pattern of instruction, her style of teaching, is not uniform or predictable in some simple sense. She flexibly responds to the difficulty and character of the subject matter, the capacities of the students (which can change even over the span of a single course), and her educational purposes. She cannot only conduct her orchestra from the podium, she can sit back and watch it play with virtuosity by itself. (p.3)

This description gives us some idea of what to expect of reformed science teachers in our schools. They do not only possess what Kennedy (1997) calls recitational subject-matter knowledge, but a conglomerate in the right proportions, of what has come to be known in educational circles as subject matter knowledge (SMK), pedagogical knowledge (PK), and pedagogical content knowledge (PCK) (Anderson, 2002; Kennedy, 1997; Lederman & Gess-Newsome, 1992; Shulman, 1986, 1987; Zeidler, 2002).

Consensus has still not been reached as to which of the three areas in a teacher’s life should take the upper hand (Kennedy, 1997; Zeidler, 2002), but it is at least agreed that to be effective as a teacher, Zeidler’s tripartite maggot bites should be present. Anderson (2002) argues though that the teacher’s role is central in the process of
educational reform. It therefore follows that whatever is done in an attempt to improve education in general, and science education in particular, there is need to look into what makes a good teacher. Lederman and Gess-Newsome (1992) argue that PCK, PK and SMK are the three main constituents of an effective teacher – the ideal gas law of science teaching as they put.

Reform efforts point to the idea that science teachers need to have conceptual understanding of their subject matter, an ability to “convey the underlying details and constructs in their field of specialization in a manner that makes it accessible to their students” (Zeidler, 2002, p. 28). This is the teacher’s PCK, which “is directly concerned with the ways of representing and formulating subject matter that make it comprehensible to others” (Lederman & Gee-Newsome, 1992, p.6). Associated with conceptual understanding of the subject matter is the teacher’s and consequently the students’ deep understanding of the central ideas and issues in a subject, its relation to other subjects, and applicability to real-life situations such as health issues alluded to in this paper (Kennedy, 1997).

If science teachers are expected to teach in this manner, it is no doubt that they need to be taught in the same way. New practicing teachers for the most part can only remember the facts, but not the flow of ideas. They can hardly say it any different than it was stated in the text they referred to in preparing for the lesson because they do not know it any differently. Their conceptual ecologies have not been cultivated and developed enough to span the possible questions that the students they teach may have (Suping, 2003).
A Societal Health Conscious Science Education Program

The Botswana NDP 9 (2003) for the financial years 2003/04 through to 2008/09 points to the HIV/AIDS pandemic that has caused alarm in the country in recent years as a “major challenge that must be addressed during the Plan period” (p. 280). As a result, it calls for an infusion of HIV/AIDS concerns in the school curricula and a full-fledged war against the condition, involving all educational stakeholders in the country. This is a worthy cause and warrants the attention that it has been given. There is however more than just HIV/AIDS that will need to be infused into the curricula over time. Burning issues in science education need to be identified from time to time and necessary action taken to make sure that the young of the nation are very much aware of them.

There is need perhaps to add to the mandates of Vision 2016 and caution that without a healthy nation, all that the Vision aims at will be in vain. There is a need to push for scientific literacy at all fronts in an attempt to have by the year 2016, an educated, informed, and healthy nation as called for by Vision 2016. Issues that affect the health of the nation, that are specific to the conditions prevailing in the nation should be given top priority in the national curricula.

Scientific Literacy

The citizenry of the nation should be able to function well in a world that is complicated by the need not only to be computer literate, but to also be science literate. The quality of education called for by The Revised National Policy on Education (1994) should include among other things, a clear push for graduates of the Botswana school
system to be able to fit and function well in the global economies that are dictated by an understanding of science related fields.

*Nailing Down the Beast*

Trying to define scientific literacy is like trying to take an aim at a moving target on earth from out in space (See DeBoer, 2000). No one has cared enough to attempt to define scientific literacy at the time when the phrase was coined and as a result, it has been even more difficult to attempt to. Different authors prefer to use working definitions in their works and no two such definitions are the same.

The most basic definition is that given by Miller (1998) who suggested that scientific literacy might be defined as “the ability to read and write about science and technology” (p. 204). This ability should entail a clear comprehension of the conceptual ecology of the subject under discussion. Miller though immediately realized that there is more to scientific literacy than just reading and writing about science and technology and drew from ideas developed by Shen (quoted in Miller, 1998) who suggested that the construct, scientific literacy, (Miller does not seem to differentiate between scientific literacy and the public understanding of science and technology) can be divided into practical scientific literacy, cultural scientific literacy, and civic scientific literacy.

This categorization, while operationally sound, poses problems. One of its implications is a proliferation of working definitions that will make anything go as far as scientific literacy is concerned. There is need to narrow down the operational definitions,
especially for purposes of empirical type works where attempts are made to measure the concept.

For a comprehensive list of the different definitions in literature see Norris and Phillips (2003) who have put together a list of all the different definitions as given by the authors that they cited in their study.

In an attempt to pin down a definition for scientific literacy, Norris and Phillips (2003) differentiated between the concept in its fundamental and derived senses. Scientific literacy in the fundamental sense, according to the authors, refers to reading and writing when the content is science, whereas the derived sense refers to being knowledgeable, learned, and educated in science. These are fair operational categorizations given the viscous and dicey nature of the concept, but the derived sense, it seems to me, implies expert knowledge in science related issues. Yet whenever scientific literacy is discussed, it is the general public that is the target, not the scientists or people who work in science related fields.

It comes as no surprise that Miller (1998) proposed what he called civic scientific literacy with two related dimensions: (a) one dimension that allows one to read and comprehend competing scientific views in a newspaper or magazine because he or she possesses the required science vocabulary, and (b) an understanding of the process or nature of scientific inquiry. Miller originally had a third dimension that dealt with “some level of understanding of the impact of science and technology on individuals and on society” but later abandoned it because it varied in content across national boundaries (p. 205). This third aspect of scientific literacy is still important and should be harnessed so
as to look into what the general public thinks of the impact of science, especially the negative ones.

DeBoer (2000) outlines the historical development of the concept scientific literacy and traces it as far back as the pre-1950s. It is evident from the historical development of the concept that science has always been regarded highly in matters of improving the quality of human life and as a result there was need for all people to have access to this kind of knowledge. All people needed to fit in the social milieu in which each individual would be protected “from the possible excesses of arbitrary authority and enable them to participate more fully and effectively in an open democratic society” (DeBoer, p. 583). By the 50s it had also been realized that there were negative aspects of science and technological developments. This realization promoted the civic aspects of scientific literacy, as there was need by the general public to be involved in decisions about how scientific knowledge should be used. The possible dangers in science related endeavors were especially magnified by the events of World War II.

Science as a socially and culturally negotiated enterprise tilted the scale towards the idea that students needed to be made aware of the relationship between science and the rest of human knowledge (DeBoer, 2000). Such conceptions of science raised the debate about whether science education should be “primarily about science content or primarily about science-based social issues” (DeBoer, p. 589) to the extent that social science activists wanted “social issues and not disciplinary content” (p. 588) to be used as organizing themes in science teaching. There was no agreement on these conceptions of science teaching from all quarters, and there still is none to the present time.
A Working Definition

I do not wish to define scientific literacy in this work, but wish to draw from works cited and define what it is am looking for in the students for the purposes of this work. DeBoer (2000) concluded that “scientific literacy has usually implied a broad and functional understanding of science for general education purposes and not preparation for specific and technical careers” (p. 594). This observation ties in well with my dissatisfaction with Norris and Phillip’s (2002) derived sense of scientific literacy as it seems to imply that science education should be about making science expert out of all students. This is not what scientific literacy is about though.

Norris and Phillip (2002) made very valid judgments about the differences between written texts and the spoken word. They alluded to the fact that written passages, be they in a newspaper article or magazine:

contain expressions of the wide range of degrees of doubt and certainty applied to statements in science; texts are used to differentiate the status of scientific statements, from observations, to causal generalizations, to hypotheses, to descriptions of method; and texts indicate the role in reasoning played by various statements in science, whether they be statements of evidence, predictions, or speculations. (p. 234)

Norris and Phillip (2002) argue that a scientifically literate person ought to be able to do much more than just read what is written in a text. They should be able to “determine such meanings as degree of certainty being expressed, the scientific status of statements, and the roles of statements in the reasoning that ties together the elements of substantive content” (p. 235). Norris and Phillip argue that scientific literacy means that an individual does not only have “the concepts, skills, understandings, and values
generalizable to all reading, and knowledge of the substantive content of science”, but also has the ability to determine ‘when something is an inference, a hypothesis, a conclusion, or an assumption; when something is an asserted truth, an expressed doubt, or proffered conjecture; when something is evidence for a claim, a justification for an action, or a stated fact to be explained” (p. 235).

Defined this way, the many categorizations that different authors have come up with become futile. It would not matter if the problem being faced is of a personal, civic/social, cultural, practical nature, or whatever other nature is out there; if the problem being dealt with is a newspaper report written by a journalist with the intent of exaggerating the problem at hand (as they usually do) or a technical report written by a panel of experts on a particular issue; if the individual has to read the report or the report has to be read out loud in a public meeting, the same level of understanding will be arrived at and scientifically informed decisions made. The point being that there seem to be a need to come up with a definition that can be used to deal with this very important concept of scientific literacy especially as it relates to developing countries such as Botswana.

The link between societal health issues, scientific literacy, and UVR and its effects on the human skin in this paper is made by the idea that the Botswana climate conditions dictate that the residents know how to protect themselves against the harsh UVR in the summer months. One would expect the educational system to be such that it makes the students aware of the environmental conditions and ways in which they can protect themselves against it. This should then make them citizens who are scientifically
aware of their environment and can make policy decisions that would benefit society in
general.

According to the National Committee on Science Education Standards and
Assessment (1996) of the National Research Council, the goals of school science are:

- experience the richness and excitement of knowing about and understanding
  the natural world;
- use appropriate scientific processes and principles in making personal
  decisions;
- engage intelligently in public discourse and debate about matters of scientific
  and technological concern; and
- increase their economic productivity through the use of the knowledge,
  understanding, and skills of the scientifically literate person in their careers.

The committee states that the goals describe a scientifically literate person and the
content standards describe what a scientifically literate person should be able to know,
understand, and do after 13 years of schooling. The other separate standards for
assessment, teaching, professional development, science education program, and science
education system compliment and describe the conditions necessary to achieve the goals
of scientific literacy that students should have after graduation from school. Knowledge
about UVR and its effects on the human skin would demonstrate students’ ability to use
appropriate scientific processes and principles in making personal and in other cases,
community decisions.
Why the Sun and Ultraviolet Radiation

The sun is a major source of ultraviolet radiation (UVR) on earth. Based on its biological effects UVR can be divided into UVA, B, and C. UVC has the highest photon energy but is fortunately effectively absorbed by the ozone layer. The ozone layer is thus an important factor in the amount and intensity of UVR that reaches the earth. Latitude, seasons, and altitude are also factors in the amount of UVR at a given time (Dobbinson, 1998; Jendritzky, Staiger, & Bucher, 1997).

The human organism needs small doses of UVR to produce vitamin D, which is required among other things for bone production (Barth, 1997). Very high doses have unwanted effects like sunburn, skin cancer, acceleration of skin aging leading to skin coarseness, wrinkling, laxity, thickening and pigmented spots, damage to the immune system and to the eye, (Fukuda & Takata, 1997; Jendritzky et al., & Oikarinen, 1997). According to Jendritzky et al., the skin responds differently to UVR depending on whether or not it is accustomed to it. There is also evidence to suggest that UVR reduces the production of collagen through a number of mechanisms (Oikarinen). According to Oikarinen, once premature aging has occurred due to UV exposure, any treatment course undertaken seems to have lots of side effects.

The human skin reacts to UVR by producing erythema a few hours upon exposure and this process take up to 20 hours (Césarini, 1997). Melanin production is increased by exposure to UVR. Darker skin responds quickly with very little exposure and repeated exposure may produce pigmentation that lasts for years after first exposure (Bech-Thomsen, 1997). Childhood and teenage years (up to age 20) are most critical as this is
the time when overexposure to high intensity UVR occurs during outdoor activities. There is research evidence that links high incidence of skin cancer in prone populations to history of sunburn or spending a month or more in intense sunlight (Lowe, Balanda, Stanton, & Gillespie, 1999).

All three forms of skin cancer (malignant melanoma, basal cell carcinoma (BCC), and squamous cell carcinoma (SCC)) have been associated with exposure to UVR at one time or another, especially during the age before 20 (Lowe et al., 1999; Rhodes, 1995). Melano-compromised people always have sunburn, hardly develop a suntan, and are prone to skin cancer whereas melano-competent people occasionally develop sunburn and are able to develop a protective suntan (Césarini, 1997). Blacks residing in the same area as whites are about 68 times less prone to skin cancer due to an effective protection from the color of their skin (Bech-Thomsen, 1997; Graffunder, Wyatt, Bewerse, Hall, Reilley, & Lee-Pethel, 1999). The harmful UVR still has adverse effects on the black skin and makes it look blacker, have uneven pigmentation and in some case develop a whole range of other facial skin problems like acne.

Cloud cover does reduce the amount of UVR reaching the earth, and this is a function of the amount and type of clouds (Jendritzky et al., 1997). Sunscreens with a sun protection factor (SPF) of 15 or greater have been shown to be effective especially if started at an early age (Glanz, Lew, Song, & Cook, 1999; Rhodes, 1995). Rhodes found that sunscreen use before the age of 18 reduced by 78% the incidence of both BCC and SCC in one’s lifetime.
With all this in mind, it is a sad reality that the information given above is out of reach for an average person. It is much more so in developing countries than in developed countries. The call made in the 70s for an enlightened citizenry as opposed to an educated elite of individuals makes science education reform to look into issues of making informed decisions regarding scientific phenomena more pronounced (Schmidt & Wang, 2002). The new curricula that were developed were geared towards more humanistic, value-oriented curricula that would help people deal with personal, societal, and environmental concerns (Schmidt & Wang). These would have a spiraling effect in that more students would have interest in science related careers and thus develop the much-desired scientific literacy.
CHAPTER 3

RESEARCH METHODS AND PROCEDURES

Research Design

The Setting

Botswana is a Southern African completely landlocked country with a population of about 1.6 million people. Almost half of the country is semi-desert with very little annual rainfall. As a result, the summers are usually very hot, dry, with very high ultraviolet (UV) radiation indexes. The nationals therefore should be encouraged to use sunglasses, sunscreen, and other measures like appropriate clothing for protection against the harsh conditions, especially children as they go and come back from schools. This is standard practice in other countries with similar conditions like Australia. This is made imperative by the fact that most students walk very long distances to and from school. Their long walks from schools are usually from 1:00 pm to around 4:30 pm when the UV radiation is at very high levels.

The Botswana educational system is a very centralized one run by the Ministry of Education (MOE) from the capital city, Gaborone (24.67°S, 25.92°E, 1000 m altitude).
The only difference may be with privately owed schools, which may follow different syllabi in addition to the basic requirements set by the ministry. As far as government schools are concerned therefore, students from the different parts of the country follow the same course of study throughout their educational system.

The Botswana educational system follows a 7-3-2-4 system. There are six teacher-training colleges and a couple other vocational colleges that offer 3-year post secondary certification. Most students in the country only go up to 10 years of basic education in line with the recommendations of the National Commission on Education of 1994, by which time it is hoped that they can function well in this technologically advanced global economy.

How the Botswana educational system students are able to perform after their ten years of basic education has been a subject of debate for sometime. Most employers are not willing to absorb them as it is felt that they lack even the ability to be trained. Even government has no room for these students, and prefers those that have done a further two years of senior secondary education. This is more so in mathematics, science, and technology related occupations. There is need therefore to look into reforming and tailoring the educational system such that the students are able to somewhat be absorbed by the employers in the country.

*The Instrument*

Instrument development took a series of steps which included making sure that it covered issues that are typically related to UVR and somewhat looked into issued of
scientific literacy. The aim was not only to look into what the Botswana educational system students know about UVR but also how exposed in general they were about the concept. The last section of the questionnaire was designed such that it probed this latter idea of scientific literacy as conceptualized in chapter two of this dissertation.

The measuring instrument consisted 29 Likert scale items with 5 possible responses each ranging from strongly agree to strongly disagree on the opposite end. The items were created by carefully reading literature related to the question under study and coming up with statements that would give an indication of how familiar the students were with ultraviolet radiation exposure and its effects on the human skin. Students were then required to indicate if they strongly agree (SA), agree (A), do not know (DK), disagree (D), or strongly disagree (SD) with each of the statements on the questionnaire.

Students were made to think through the same ideas by being asked to respond to open ended questions following a scenario about UVR and its effects on the human skin. The questions that followed the scenario were phrased such that they probed into students’ ability to think in context and their understanding about the effects of UVR on the human skin. It was hoped that misconceptions, if any, would also be picked up in the answers to these questions. Literature is filled with misconceptions about UVR and its effects on the human skin. It was hoped that these would be a common feature in the student responses and would be particularly looked out for. A lot of the misconceptions found in literature were incorporated into the Likert questionnaire that was given out to students.
A graduate student in the Mathematics, Science, and Technology Education Department was given a copy of the instrument for her input into the way the statements were phrased. Her suggestions were incorporated to further improve the instrument’s validity and reliability. After these suggestions were incorporated, the questionnaire was given to a panel of graduate students in our discussion group, which has my advisor as the leader. This group had graduate students at different stages of their doctoral studies ranging from those who had just started to those who had passed their dissertation defense. Since the statements in the questionnaire were related to practical medical/health issues, a medical doctor was given the questionnaire to makes judgments on the validity of the statements and the statements were found to be valid as written. Due amendments were made based on suggestions from the panel of graduate students and medical doctor to further polish the statements and the questionnaire.

The Sample

The Botswana educational system has three levels of education. Primary education is a seven-year level and students start at age six. Progression to junior secondary school, which is the next level, is at 100% and the level takes three years. The junior students do integrated science for the three years of their junior education. This covers all the three sciences (biology, chemistry, and physics) equally. The next level in the educational system is senior secondary level with a progression of near 50% from junior secondary. These students do three types of sciences differing in depth of content. Pure science covers all three major sciences separately, biology, chemistry, and physics.
in depth whereas the double and single award sciences cover the same subjects in less depth and to differing extends. The single award science is the weakest of the three.

Because of financial constraints, the sample was conveniently chosen as junior and senior secondary schools within 50 km of the capital, Gaborone. This covered four school districts but diversified the sample enough to be representative of the school going ages in the country. There are a total of 38 junior and senior schools in the area, 31 junior secondary schools, 13 of which are in an urban setting and seven senior secondary schools, four of which are in an urban setting. Since there were too many schools at the junior level in the districts of interest, a stratified random sample of the schools was chosen such that both urban and semi-urban schools were equally represented.

Rather than just choose a few schools in which to administer the questionnaire, more schools were covered by doing a stratified random sample of schools and choosing only two classes at each school at each level that was studied with an estimated class size of 40 at the junior schools and 30 at the senior schools. By doing it this way, it was hoped that the sample would be more representative of the districts and therefore the country. Following this strategy, six senior schools were visited, three each of urban and semi-urban, and four junior schools, two each of urban and semi-urban. The differences in the number of schools came about because the class sizes are not the same for junior and senior secondary schools. It was hoped that this way there would likely be equal sample sizes per category.

There is only one university in the nation and so there was no choice in the students at college level. Students specializing in science subjects at college level and
those in the humanities were selected for the study. These students were administered the questionnaire in the same manner, as were the other students in the junior and senior schools. It was thought these students represented opposite ends of a spectrum in terms of their science exposure and would give a better picture of college students’ knowledge of UVR and its effects on the skin.

The university is structured such that students start concentrating on their main area of study as early as their first year of study. The researcher administered all the questionnaires in the school sites visited with the help of the teachers and college professors responsible for the classes. As a result, the schools were visited in the afternoons during times in the secondary schools system when students are given preparation time without instruction by the teachers. At college level, laboratory class periods were used for the science majors whereas tutorial periods were used for the humanities students.

The sample therefore consisted of form 1 students in junior secondary schools. These students have practically completely the primary school course of study and will therefore be treated as such. The second group in the sample was form 4 students who have also successfully completed 3 years of junior secondary education, thus completing their 10-year basic education as stipulated in the RNPE of 1994.

Transition from junior to senior secondary education is currently about 50%. So these are students who did very well in their junior secondary education. The third and last group was first year students at the University of Botswana. These students had just started their college education after successfully completing their 2 years of senior
secondary education. The academic year for the University of Botswana starts in August and ends in June of the following year whereas for all other institutions of learning, the academic year starts in January and ends in December.

The geographic areas that were covered by this study are Gaborone, Tlokweng, Mogoditshane, Ramotswa, Moshupa, and Mochudi. These areas are all in the Southeastern part of the country, but since the schools system is very centralized, results can still be generalized to the other districts and the whole nation.

Methods of Data Analysis

Quantitative Section

The results of the Likert scale statements were analyzed using SPSS 11 for Macintosh computers. Exploratory factor analysis was performed to determine how many underlying constructs could be used to determine students’ knowledge of UVR and its effects on the skin. Exploratory factor analysis was used as opposed to confirmatory factor analysis as no study was found that had looked into the predictors of same phenomenon.

Once the number of factors was determined, multivariate analysis of variance (MANOVA) was used to determine differences between groups by factors to determine what students knew and how much they knew about UVR. The differences by school type helped determine if students’ knowledge about UVR increased as they progressed through grades or not.
Follow-up test were performed as was deemed necessary to answer the research questions. Discriminant analysis was performed to look into pair-wise differences by groups and where necessary, independent sample t-tests were also performed as follow-up to the discriminant analysis to pin point why certain results were significant and others were not.

**Qualitative Section**

Rather than analyze all of the 760 scripts from the students, a stratified random sample of 110 scripts was used for the analysis such that about equal number of scripts from each science group were selected: junior science, senior single science, senior pure science, college humanities, and college science (Ryan & Bernard, 2000). The decision to sample was made based on the fact that it was thought that analyzing the whole 760 scripts would take much longer without necessarily enriching the data.

The responses that students gave for the open-ended part of the questionnaire can be looked at as a form of interviewing students to “understand” the students’ views or “perspectives” on UVR and its effects on the human skin (Fontana & Frey, 2000). Fully cognizant of the fact that “interviews are not neutral tools of data gathering but active interactions between two (or more) people leading to negotiated, contextually based results” (Fontana & Frey, 2000, p. 646), the questions and statements that students were made to respond to were very structured so as to limit the scope of their responses. It was not the correct answers that were looked for, but what the students’ thoughts and views were regarding the issues raised.
It was still hoped that students would respond within the context of the culture in which they live and that their responses would add to the already existing knowledge about students’ knowledge about UVR. The developing country twist, it was hoped, would bring new dimensions to what is already known mainly from research in developed countries like the United States and Australia about students knowledge about UVR and its effects on the human skin.

*Data Coding and Analysis*

The four questions in the open-ended section of the questionnaire were designed such that they probed into students’ commonly held misconceptions about UVR and its effects on the skin found in literature. Question one addressed the idea that students think that there can be no sunburn on a cloudy day since clouds would shield all the sunrays. Questions 2a addressed the context specific nature of Thabo’s sunburn whereas 2b probed students understanding of the UVR intensity differences in summer and winter. The last question, question three, addressed the use of sunglasses for protection against UVR. Certain sunglasses are better than others for protection against UVR and yet students are generally not aware of this.

Since students responded to the open ended questions using free flowing text and or diagrams/representations, a sociological tradition for text analysis stance was adopted that would treat text as a window into students’ thought process or knowledge and experiences about UVR and its effects on the human skin (Ryan & Bernard, 2000). This was particularly relevant given the nature of the study.
The open-ended section of the questionnaire was aimed at filling the gaps normally left by the closed questions like the Likert type scale used here (Denzin & Lincoln, 2000). It was hoped that the open-ended questions would give students opportunities to express their views and understanding of UVR and its effects on the human skin freely. Key misconceptions on the concept were already included in the Likert scale, it was however hoped that students would bring up culture specific ideas and or misconceptions in their responses to the open ended questions.

Students’ responses to the open ended questions were first written out according to the question number and their identity kept by science type and student number. For example, (2a) # 288 (SP) shows student number 288 who is in the senior pure science group response to question 2a. This was necessary to be able to differentiate among responses from different science groups. Once the responses were all typed out, they were grouped by question number such that the answers to question one were together.

A grid was then made on an A4 sheet of paper such that at the top of it was different science groups and on the side were the categories they came up as the answers were read. The process was repeated for each question incase some answers were not coded correctly. Tallies were then kept as to which science group subscribed to which or raised which category. Each question had its own grid. Once all the scripts were read for a question, the different categories were carefully examined to determine if some of the categories could be combined to form themes. Themes were induced from the coding based on both literature read and my own experience as a science teacher in Botswana (Ryan & Bernard, 2000). Since these themes were for the most part content specific,
Ryan and Bernard’s suggestion to use key words in context (KWIC) to identity meanings was used.

The idea behind reading through the students’ responses was an attempt to look into students’ reasoning as they were answering them. It was hoped that by looking at the responses in this manner, it would be possible to identify students’ thinking patterns and conceptions about UVR in general and its effect on the human skin in particular. Once the data was reduced through coding and identifying themes, individual student responses were looked at again to identify the different themes and how they differed across the different sciences taken by the students.

It must be hinted that the coding scheme was only used by the researcher and not validated with any other person. This may be a weakness in method, but perhaps a strength, in that there is likely to be consistency in the way the responses were coded and analyzed. An ideal situation would have been for another researcher to look at the same coding scheme as a measure of reliability and validity check. This was not done. It is therefore up to the reader to read between the lines, make judgments on the themes developed, and the evidence provided to support the claims.

The same level of expectation was placed on all respondents irrespective of educational level. The Likert scale questionnaire and the free response items were kept separate as it was felt that they represented different measurements of the same concept.
CHAPTER 4

RESULTS AND ANALYSIS

This chapter presents the findings of this study. The demographics are given in the first section of the paper to show frequencies and the number of students in each of the variables studied. The next sections deals with factor analysis and the factors that were arrived at. The factors are then described and named based on the items that loaded on them.

The descriptive statistics provided in this chapter are by the factors in the study. Overall group descriptive statistics are given in the appendix section to provide more information about the sample. MANOVA results are given based on the tests that were carried out. Three main tests were done for the MANOVA analysis, a two-way MANOVA on school type and gender, a one-way MANOVA on science type, and a one-way MANOVA on school location. Relevant appropriate follow-up MANOVA tests results are also given for the different sections.

The last section of the results section has the qualitative part of the study that deals with the free response questions on the questionnaire. This qualitative part is arranged by responses to questions. Then the misconceptions that were identified are
also reported with possible explanations as to why students are likely to conceive of ideas in the way that they did.

Demographics

A total of 760 students returned the questionnaire. Because these were administered within each classroom, a near 100% return rate was achieved. It was only in a few cases where some questionnaires were not completed to the researcher’s satisfaction that they were discarded. Six questionnaires were discarded for non-completeness. It was felt that a lot of information, especially demographic information was missing from them to be of any use to the study. Questionnaires that missed parts of answers to the open ended questions but were complete on the Likert scale were accepted, but if more than 50% of the Likert scale was also not filled in, then they were discarded as incomplete. Any part of the Likert scale that was not filled in was assumed to be in the “Don’t Know” scale and given a score of three.

Out of the 760 students, 261 were from junior schools, 268 from senior schools, and 231 from college. 353 of the 760 students were male. 285 of the 760 students were from sub-urban schools. Students from college were classified as urban students since the college was situated in the capital city. A large majority (56%) of the students surveyed aged between 17 and 20. Those between the ages of 12 and 16 made 37% of the students surveyed. Students aged between 21 and 25 years accounted for only 5.8% of the students and those aged 26 and above accounted for only 1.1%. The age brackets were used based on the age by which students were expected to have started formal schooling.
Since it was thought that formal science teaching and the type of science track that a student pursued may influence knowledge about sun exposure and its effects on the human skin, student’s science track at school was considered an important factor to study. All students at the junior school level do one science called integrated science. These students were therefore not classified by this factor. Of the 268 students at the senior school level, 145 of them did single science whereas 123 of them did pure science. 101 of the 231 college students were science majors whilst 130 of them followed non-science careers.

**Factor Analysis**

Since the instrument used had 29 items, it was felt that doing factor analysis would help in reducing these seemingly many factors into a few that could be used to determine students’ knowledge of the concept under study. Doing factor or reliability analysis on the entire sample could possibility not give very good results because of the spread in performance expected from the range of students surveyed.

To avoid this complication, the college science major students were thought of as a more homogeneous group than the rest of the groups and so were used for exploratory factor analysis as well as reliability per factor to determine Cronbach’s alpha for each factor. There were a total of 123 students in the college science group and these students were used for the factor analysis portion of the analysis.

It was determined that the factors that were derived were not correlated in anyway from the exploratory factor analysis results using maximum likelihood extraction and
oblimin rotation. Kaiser normalization gave factors with very poor correlations. It was decided therefore that varimax rotation should be appropriate with the assumption that the factors measured different components of the same concepts of UVR exposure and its effects on the human skin. This theoretically makes sense that a sum of the measurements will add up to make a theoretical construct that measures students’ knowledge of the UVR phenomena.

The Bartlett’s test of sphericity for the test was significant at the $\alpha = .001$ level, $\chi^2 = 557.28$, df = 406. This indicated that factor analysis was in order to perform. With 123 subjects in the college science group, only items with factor loadings of .472 are significant at the $\alpha = .01$ level and should be used for interpretation of the factors. It was however felt that since the actual sample size is much larger, it would compensate for use of items that would have otherwise been non-significant. This is especially valid because according to Stevens (2002) the Kaiser criterion (retain only components with eigenvalues greater than one) for the number of components to retain is only accurate when the communalities for the items are greater than .70 for a questionnaire with 29 items.

The Kaiser criterion to retain only factors with eigenvalues greater than one suggested that 12 factors could be retained. The scree plot test suggested that only two factors were possible to isolate. With two factors to retain the Q/P ratio is .069, which is less than the critical .30 value. Stevens (2002) suggests that a value less than .30 is more credible. It was therefore determined that four factors will be retained. The value of four was arrived at looking at the scree plot, which seemed to suggest that two factors was
where it began to level off and also looking into the fact that the Kaiser method suggested a much larger number. Retaining four factors brought the Q/P ratio to .138, which is still less that the .30 value as suggested by Stevens. The four factors explained 20\% of the variance. They were named as per Table 4.1.

Cronbach alpha reliability tests were performed on the isolated factors to give the best possible alpha values. Items that lowered the Cronbach $\alpha$ statistic were deleted and the resulting factors were as given in Table 4.2. After items were removed, the resulting instrument had 21 items. According to Stevens (2002) this is a moderate numbered instrument and should give stable results.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Eigenvalue</th>
<th>% variance</th>
<th>Cumulative %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diseases related to UVR</td>
<td>2.610</td>
<td>6.505</td>
<td>6.505</td>
</tr>
<tr>
<td>Items used for protection</td>
<td>2.352</td>
<td>5.566</td>
<td>12.071</td>
</tr>
<tr>
<td>Misconceptions</td>
<td>1.929</td>
<td>4.182</td>
<td>16.253</td>
</tr>
<tr>
<td>General</td>
<td>1.542</td>
<td>3.287</td>
<td>19.540</td>
</tr>
</tbody>
</table>

Table 4.1: Eigenvalues, % of variance, and cumulative % variance for the factors
<table>
<thead>
<tr>
<th>Item</th>
<th>Factor loading</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor 1: Diseases related to UVR exposure ($\alpha = .533$)</td>
<td></td>
</tr>
<tr>
<td>12. Too much exposure to the sun during childhood leads to wrinkles</td>
<td>.656</td>
</tr>
<tr>
<td>and premature aging of the skin.</td>
<td></td>
</tr>
<tr>
<td>28. Excessive sun exposure eventually lowers the body’s immune system.</td>
<td>.542</td>
</tr>
<tr>
<td>14. Being exposed to the sun from a very young age to around age 20</td>
<td>.459</td>
</tr>
<tr>
<td>increases my chances of getting skin problems or skin cancer.</td>
<td></td>
</tr>
<tr>
<td>15. Bathing thoroughly after exposure to the sun can help prevent skin</td>
<td>.315</td>
</tr>
<tr>
<td>problems associated with sun exposure.</td>
<td></td>
</tr>
<tr>
<td>11. Too much exposure to the sun leads to skin problems like pimples,</td>
<td>.286</td>
</tr>
<tr>
<td>acne, and pigmentation.</td>
<td></td>
</tr>
<tr>
<td>3. The sun’s rays are most dangerous between 10 am and 4 pm.</td>
<td>.239</td>
</tr>
<tr>
<td>18. Most skin cancer types can be cured if diagnosed early enough.</td>
<td>.235</td>
</tr>
<tr>
<td>29. Using UV protective sunglasses from an early age can help</td>
<td>.222</td>
</tr>
<tr>
<td>prolong one’s eyesight.</td>
<td></td>
</tr>
</tbody>
</table>

Factor 2: Items used for protection against UVR ($\alpha = .381$)

<table>
<thead>
<tr>
<th>Item</th>
<th>Factor loading</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. To work best, sunscreen needs to be applied at least 30 minutes</td>
<td>.693</td>
</tr>
<tr>
<td>prior to sun exposure.</td>
<td></td>
</tr>
<tr>
<td>25. Most sunscreens protect us from all three ultraviolet ranges</td>
<td>.406</td>
</tr>
<tr>
<td>(UVA, UVB, &amp; UVC).</td>
<td></td>
</tr>
<tr>
<td>27. It is ok to get as much skin tan as you want if you put on</td>
<td>.348</td>
</tr>
<tr>
<td>sunscreen.</td>
<td></td>
</tr>
<tr>
<td>1. You can get suntan/sunburn on a completely cloudy day.</td>
<td>.215</td>
</tr>
</tbody>
</table>

Table 4.2: Factor loadings, naming for Varimax orthogonal rotated results with Maximum Likelihood extraction method (CONTINUED)
Table 4.2: CONTINUED

<table>
<thead>
<tr>
<th>Factor 3: Misconceptions about UVR</th>
<th>(α = .545)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4. I only need to protect myself from the sun in the summer months.</td>
<td>.553</td>
</tr>
<tr>
<td>21. Water in a swimming pool can act as a sun block and protect me from the sun’s harmful rays.</td>
<td>.432</td>
</tr>
<tr>
<td>26. All three ultraviolet light ranges (UVA, UVB, &amp; UVC) are equally harmful to the skin.</td>
<td>.386</td>
</tr>
<tr>
<td>7. All sunglasses can protect eyes from harmful rays from the sun.</td>
<td>.372</td>
</tr>
<tr>
<td>8. People of all skin types are equally at risk of skin cancer due to excessive exposure to the sun.</td>
<td>.327</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Factor 4: General knowledge on UVR exposure</th>
<th>(α = .375)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6. Using sunscreen can protect me from the sun’s harmful rays.</td>
<td>.473</td>
</tr>
<tr>
<td>9. An umbrella is good for protection against the sun’s harmful rays.</td>
<td>.402</td>
</tr>
<tr>
<td>5. Sun bathing is good for vitamin D production in the human body.</td>
<td>.236</td>
</tr>
<tr>
<td>17. The dark colored skin can get used to the sun’s rays and protect itself from further damage by becoming even darker.</td>
<td>.236</td>
</tr>
</tbody>
</table>
The factors extracted contained items as shown in table 4.2 and were named as indicated in the same table. Item 22 from the original instrument was removed from factor one based on factor Cronbach alpha reliability results. For factor two, items 10, 16, 23, and 24 were removed. Factor three had items 19 and 20 removed whilst factor 4 had item 13 taken out. From now on, these factors will be referred to by name. The short names will be “Diseases” for factor 1, “Items” for factor 2, “Misconceptions” for factor 3, and “General” for factor 4.

Factor Description and Naming

The first factor, named Diseases, had items that dealt in general with different conditions that can occur as a result of over exposure to UVR. The conditions range from cancers, pigmentation, pimples, acne, wrinkles, and premature aging of the human skin. Perhaps more interesting was the item that talked about the relationship between the human immune system and exposure to excessive UVR. This is more so given the already high prevalence of the HIV/AIDS conditions in the Sub-Saharan African region. This fact was also explored in the literature review section of the paper. Typical skin problems in young people are pimples and acne whereas in grown ups they include skin pigmentation, wrinkles and premature aging of the skin. The black skin is resilient to skin cancer but prone to skin problems whereas the white skin seems to be the exact opposite. Items in factor one covered these ideas.

The second factor, called Items, contained items that looked into more than just protection against UVR. They looked into the effects, for example, of starting protection
practices at an early age versus at an old age like use of sunscreen and UVR blocking sunglasses from childhood. It is not only wise to use sunscreen, but it is equally important to be away of the best ways to use it like applying it a couple of minutes before exposure as opposed to when one is already exposed. Item one in the questionnaire was a very important and interesting item. The general population, students in particular, do not seem to realize that UVR are electromagnetic waves and have properties that enable them to pass through clouds and reach earth surface.

The third factor, named Misconceptions, covered a wide range of misconceptions held by the general population about UVR. These misconceptions are not only found in school going age children and young adults, but also professions some of whom are in science related fields. Commonly held misconception include ideas that if it is cold or cool, sunburn can not occur or that the effects of UVR on the skin can be removed or minimized by bathing thoroughly after sun exposure.

The fourth factor was named General and dealt with items that could not be classified on any of the other three factors. These ranged from beneficial effects of UVR as in vitamin D production, to how different skin color types respond differently to UVR exposure. The idea that sunscreen does not offer 100% protection and the fact that one has it on does not necessarily mean that they can get all the exposure they want without getting skin damage was also covered in this factor.

Cronbach alpha reliability analyses were performed for each of the new factors and it is worth mentioning that they all had average alpha values. These were not as high as one would have wanted them to be. Diseases factor had an alpha reliability value of
.533. The Items factor had an alpha value of .381 whereas the Misconceptions factor had a value of .545. The General factor had an alpha value of .375.

*Overall Descriptive Statistics*

Tables 4.3 to 4.5 give descriptive statistics for the different groupings in this study. The sample sizes, means, and standard deviations are given for each of the five factors named after factor analysis.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Junior School</th>
<th>Senior School</th>
<th>College</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n = 261</td>
<td>n = 268</td>
<td>n = 231</td>
<td>n = 760</td>
</tr>
<tr>
<td>Diseases</td>
<td>2.633 .471</td>
<td>2.527 .460</td>
<td>2.512 .390</td>
<td>2.559 .447</td>
</tr>
<tr>
<td>Items</td>
<td>3.224 .498</td>
<td>3.211 .516</td>
<td>3.134 .495</td>
<td>3.192 .504</td>
</tr>
<tr>
<td>Misconceptions</td>
<td>2.992 .621</td>
<td>3.010 .688</td>
<td>3.310 .537</td>
<td>3.095 .637</td>
</tr>
<tr>
<td>General</td>
<td>2.450 .574</td>
<td>2.471 .529</td>
<td>2.353 .502</td>
<td>2.428 .539</td>
</tr>
</tbody>
</table>

Table 4.3: Statistics by school type and factors
The Likert scale was set up such that a score of three indicated that the students did not know much about UVR and its effects on the human skin whereas a score less than three would suggest some form of knowledge. One sample t-tests with a test score of three were performed for each of the factors. All four factors gave significant $t$ test results at the 95% confidence interval and 759 degrees of freedom. Students performed better than expected on the Diseases and General factors ($t = -27.226$, and -29.267 respectively). They did not do better on the Items and Misconceptions factors ($t = 10.507$, and 4.109 respectively).

Table 4.4 shows a pattern that develops based on school type. As we move from junior to college level students, the means drop across all five factors. The same happens to the standard deviations. College students’ scores are less spread compared to those of the junior and senior students. This justified the use of the group scores to perform factor analysis.

Table 4.4 shows scores by school type and science type. Whereas students at the junior level do the same science, those at the senior and college levels have some sort of specialization. Since knowledge on all five factors is somewhat science based, it is expected that performance may differ as a function of the type of science a student does at the senior and college levels.
Table 4.4: Descriptive statistics by school type and science type

<table>
<thead>
<tr>
<th>Factor</th>
<th>Junior School</th>
<th>Senior School</th>
<th>College</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Integrated Science</td>
<td>Single</td>
<td>Pure</td>
</tr>
<tr>
<td></td>
<td>N = 261</td>
<td>n = 145</td>
<td>n = 123</td>
</tr>
<tr>
<td>Diseases</td>
<td>2.633 .471</td>
<td>2.582 .422</td>
<td>2.462 .495</td>
</tr>
<tr>
<td>General</td>
<td>2.450 .574</td>
<td>2.524 .496</td>
<td>2.409 .561</td>
</tr>
<tr>
<td>Factor</td>
<td>Junior School</td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------------</td>
<td>---------------</td>
<td>---------------</td>
<td>---------------</td>
</tr>
<tr>
<td></td>
<td>Integrated science</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
<td>Male</td>
</tr>
<tr>
<td>n</td>
<td>113</td>
<td>148</td>
<td>47</td>
</tr>
<tr>
<td>Diseases</td>
<td>2.699</td>
<td>.473</td>
<td>2.582</td>
</tr>
<tr>
<td>Misconceptions</td>
<td>2.933</td>
<td>.600</td>
<td>3.037</td>
</tr>
<tr>
<td>General</td>
<td>2.460</td>
<td>.647</td>
<td>2.443</td>
</tr>
</tbody>
</table>

Table 4.5: Means and standard deviations for groups by schools and gender (CONTINUED)
Table 4.5: CONTINUED

<table>
<thead>
<tr>
<th>Factor</th>
<th>College</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Humanities</td>
<td>Science Majors</td>
<td>Humanities</td>
<td>Science Majors</td>
<td>Humanities</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
<td>Male</td>
<td>Female</td>
<td>Male</td>
</tr>
<tr>
<td></td>
<td>n = 50</td>
<td>n = 80</td>
<td>n = 81</td>
<td>n = 61</td>
<td>n = 61</td>
</tr>
<tr>
<td>Diseases</td>
<td>2.518 .413</td>
<td>2.538 .378</td>
<td>2.494 .406</td>
<td>2.475 .328</td>
<td></td>
</tr>
<tr>
<td>Items</td>
<td>3.165 .478</td>
<td>3.100 .548</td>
<td>3.151 .467</td>
<td>3.125 .448</td>
<td></td>
</tr>
<tr>
<td>Misconceptions</td>
<td>3.144 .571</td>
<td>3.288 .528</td>
<td>3.385 .497</td>
<td>3.510 .552</td>
<td></td>
</tr>
<tr>
<td>General</td>
<td>2.405 .451</td>
<td>2.488 .498</td>
<td>2.216 .515</td>
<td>2.238 .448</td>
<td></td>
</tr>
</tbody>
</table>

Table 4.5 shows results by school type, science type, and gender for each factor. The numbers of students in each group is shown for each gender. The table shows very unexpected and interesting trends. Certain groups of students did better than expected on some factors than others. For example the male junior students did better than both male and female senior students who do pure sciences on the misconceptions factor. One
would have expected especially the science majors at college level to do a lot better because they have wide science background knowledge.

Given that intact class units were used for the analysis, numbers here are representative of schools used. It can be argued therefore that the numbers are also representative of the Botswana schools student population. Research findings about the gender disparity in enrolments in science related fields are immediately confirmed by the number of students enrolled in the science related fields at college level.

It is interesting to note that the number of males and females at the junior level are comparable, 113 boys to 148 girls. At the senior level, the weaker science has twice as many girls as there are boys whereas the pure and stronger science has about equal number of boys and girls. Yet when it comes to college enrolments, the female students in the science fields make only 20% of the student population whereas they make a whooping 70% in the humanities. This is a worrisome finding. What has become of all the female students who did the pure sciences at senior level? If they went into the humanities, was it of their own choice or because they were not successful in the sciences?
MANOVA Results

Since four factors were isolated from the factor analysis results, it was felt that MANOVA was the best methods to use for comparison of the different groups of students. Multiple ANOVA analysis could also have been done instead of MANOVA at an adjusted alpha level to correct for cumulative type I error. This is especially relevant since it has already been determined that the different factors are not significantly correlated with each other. Nevertheless, the robustness of MANOVA over multiple ANOVAs for multiple dependent variables cannot be ignored. Correlations among variables is taken into account when using MANOVA, the additive differences over variables may only be detected using MANOVA rendering it more powerful than multiple ANOVAs.

Groupings per school type made it difficult to perform one multiple independent variable MANOVA. For example the junior students all did the same science subject called integrated science and could not therefore be subdivided into science groups. On the other hand, senior and college students could be grouped into two different sciences. There was also a problem with the school location variable. Only two locations were chosen for the study, urban and semi-urban. The college students fell into the urban group since their school is located in the city, but they do not have their corresponding group in the semi-urban grouping. This college students group was therefore not included in the analysis that looked into differences by school location.

Because there were three major MANOVA tests to perform, the MANOVAs were performed each at an alpha level of .0167 so that the overall alpha level was kept at the
95% confidence level. A two-way MANOVA involving the school type and gender variables was performed to look into multivariate difference by factor for all the students. To look into differences by science type a one-way MANOVA was performed by the factor. The last one-way MANOVA analysis involved only junior and senior students and looked at their differences by school location. Follow up tests were performed as was necessary.

**Assumption Considerations**

It was discussed in chapter 3 that students worked on the questionnaires individually under test taking conditions such that they were not allowed to interact during the activity. This should fulfill the independence of observations requirement for MANOVA analysis. The component score covariance matrix for factor analysis showed that the factors were not correlated in anyway. This leads us to conclude that the independence assumption is not violated in anyway.

Normality will be assumed based on the results of the univariate normality. Because of the large sample size in the study, it was a lot easier to graphically test for normality. Normal Q-Q probability plots showed straight lines. Stem-and-leaf plots showed normal distribution of the scores.

The Kolmogorov-Smirnov test gave significant results for all four factors and each of the school locations whereas the Shapiro-Wilk test was not significant for the misconception factor on the senior school group of students. This signifies a fair amount
of normality and so the distribution of scores will be assumed normal for subsequent tests.

**Differences by School Type and Gender**

Two-way MANOVA was performed to compare students across school types and gender at 98.33% confidence interval with four dependent variables. The results are given in Tables 4.6. The multivariate test for homogeneity of dispersion matrices was significant (Box M = 88.026; $F_{(50, 880165.2)} = 1.736; p = .001$). Since group sizes were fairly equal (largest n = 268, smallest n = 231 for the school types and large n = 407, small n = 353 for gender), there really should be no concern for covariance matrices being unequal with a significant Box M statistic. The inequality of group sizes would have bearing though on the type of sum of squares that we use in the analysis.

Table 4.6 shows that the multivariate test interaction between school type and gender is significant with Wilk’s $\Lambda = .973; F_{(8, 1502)} = 2.584; p = .008; \text{Eta}^2 = .014; \text{power} = .843$. The effect size of .014 is small but because there was enough power to detect treatment effects, there was significance at an alpha level of .0167. The significant multivariate interaction suggests that we should take care in interpreting the school type and gender multivariate tests. We cannot interpret one without taking the other into account because one influences the way the other behaves and vice versa.
## Table 4.6: MANOVA and ANOVA results for differences by school type and gender (CONTINUED)

<table>
<thead>
<tr>
<th>Source</th>
<th>dF</th>
<th>SS</th>
<th>MSS</th>
<th>F</th>
<th>p</th>
<th>Eta²</th>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Univariate Test Statistics</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Diseases</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>School type</td>
<td>2</td>
<td>2.280</td>
<td>1.140</td>
<td>5.815</td>
<td>.003</td>
<td>.015</td>
<td>.759</td>
</tr>
<tr>
<td>Gender</td>
<td>1</td>
<td>.701</td>
<td>.701</td>
<td>3.575</td>
<td>.059</td>
<td>.005</td>
<td>.306</td>
</tr>
<tr>
<td>Interaction</td>
<td>2</td>
<td>.645</td>
<td>.322</td>
<td>1.644</td>
<td>.194</td>
<td>.004</td>
<td>.204</td>
</tr>
<tr>
<td>Error</td>
<td>754</td>
<td>147.809</td>
<td>.196</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Items</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>School type</td>
<td>2</td>
<td>1.249</td>
<td>.624</td>
<td>2.461</td>
<td>.086</td>
<td>.006</td>
<td>.328</td>
</tr>
<tr>
<td>Gender</td>
<td>1</td>
<td>.126</td>
<td>.126</td>
<td>.495</td>
<td>.482</td>
<td>.001</td>
<td>.046</td>
</tr>
<tr>
<td>Interaction</td>
<td>2</td>
<td>.307</td>
<td>.153</td>
<td>.604</td>
<td>.547</td>
<td>.002</td>
<td>.070</td>
</tr>
<tr>
<td>Error</td>
<td>754</td>
<td>191.270</td>
<td>.254</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Misconceptions</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>School type</td>
<td>2</td>
<td>14.728</td>
<td>7.364</td>
<td>19.318</td>
<td>.000</td>
<td>.049</td>
<td>1.000</td>
</tr>
<tr>
<td>Gender</td>
<td>1</td>
<td>.333</td>
<td>.333</td>
<td>.874</td>
<td>.350</td>
<td>.001</td>
<td>.073</td>
</tr>
<tr>
<td>Interaction</td>
<td>2</td>
<td>5.090</td>
<td>2.545</td>
<td>6.677</td>
<td>.001</td>
<td>.017</td>
<td>.827</td>
</tr>
<tr>
<td>Error</td>
<td>754</td>
<td>287.429</td>
<td>.251</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>General</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>School type</td>
<td>2</td>
<td>1.420</td>
<td>.710</td>
<td>2.471</td>
<td>.085</td>
<td>.007</td>
<td>.330</td>
</tr>
<tr>
<td>Gender</td>
<td>1</td>
<td>.978</td>
<td>.978</td>
<td>3.405</td>
<td>.065</td>
<td>.004</td>
<td>.291</td>
</tr>
<tr>
<td>Interaction</td>
<td>2</td>
<td>.866</td>
<td>.433</td>
<td>1.508</td>
<td>.222</td>
<td>.004</td>
<td>.184</td>
</tr>
<tr>
<td>Error</td>
<td>754</td>
<td>158.998</td>
<td>.210</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 4.6: CONTINUED

Multivariate Test Statistic:

Interaction: Wilk’s $\Lambda = .973$; $F_{(8, 1502)} = 2.584$; $p = .008$; $\eta^2 = .014$; Power = .843

School type: Wilk’s $\Lambda = .925$; $F_{(8, 1502)} = 7.449$; $p = .000$; $\eta^2 = .038$; Power = 1.00

Gender: Wilk’s $\Lambda = .987$; $F_{(4, 751)} = 2.384$; $p = .050$; $\eta^2 = .013$; Power = .526

With a significant two-way multivariate interaction between gender and school type, simple effects test was done to determine the cause of the interaction. Tables 4.7 and 4.8 show the results for the multivariate and univariate simple effects tests $F$-values and $p$-values. The tables show that the male and female students performed differently at the senior school level, Wilk’s $\Lambda = .976$; $F_{(4, 751)} = 4.56$; $p = .001$ (from Table 4.7), and Table 4.8 shows that the difference came about as a result of differences in performance on the misconceptions factor $F_{(1, 754)} = 12.37$; $p = .001$. The junior and college school types did not have differences by gender at the multivariate or univariate levels on any of the factors.
## Table 4.7: Univariate test statistics for simple effects of gender and school type.

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MSS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Univariate Test Statistics</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Diseases contrasts:</strong> Gender differences at:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Junior school</td>
<td>1</td>
<td>.880</td>
<td>.880</td>
<td>4.49</td>
<td>.034</td>
</tr>
<tr>
<td>Senior school</td>
<td>1</td>
<td>.520</td>
<td>.520</td>
<td>2.65</td>
<td>.104</td>
</tr>
<tr>
<td>College level</td>
<td>1</td>
<td>.028</td>
<td>.028</td>
<td>.14</td>
<td>.707</td>
</tr>
<tr>
<td>Error</td>
<td>754</td>
<td>147.809</td>
<td>.196</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Items contrasts:</strong> Gender differences at:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Senior school</td>
<td>1</td>
<td>.061</td>
<td>.061</td>
<td>.24</td>
<td>.625</td>
</tr>
<tr>
<td>College level</td>
<td>1</td>
<td>.150</td>
<td>.150</td>
<td>.59</td>
<td>.442</td>
</tr>
<tr>
<td>Error</td>
<td>754</td>
<td>191.270</td>
<td>.254</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Misconceptions contrasts:</strong> Gender differences at:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Junior school</td>
<td>1</td>
<td>.690</td>
<td>.690</td>
<td>1.81</td>
<td>.179</td>
</tr>
<tr>
<td>Senior school</td>
<td>1</td>
<td>4.715</td>
<td>4.715</td>
<td>12.37</td>
<td>.001</td>
</tr>
<tr>
<td>College level</td>
<td>1</td>
<td>.086</td>
<td>.086</td>
<td>.22</td>
<td>.636</td>
</tr>
<tr>
<td>Error</td>
<td>754</td>
<td>287.429</td>
<td>.381</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>General contrasts:</strong> Gender differences at:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Junior school</td>
<td>1</td>
<td>.020</td>
<td>.020</td>
<td>.07</td>
<td>.793</td>
</tr>
<tr>
<td>Senior school</td>
<td>1</td>
<td>.485</td>
<td>.485</td>
<td>1.69</td>
<td>.195</td>
</tr>
<tr>
<td>College level</td>
<td>1</td>
<td>1.265</td>
<td>1.265</td>
<td>4.40</td>
<td>.036</td>
</tr>
<tr>
<td>Error</td>
<td>754</td>
<td>216.667</td>
<td>.287</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Multivariate Test Statistic:

Overall differences: Gender by school type effect:
Wilk’s $\Lambda = .009; F_{(24, 2621.1)} = 309.49; p = .000$

Gender differences at junior school:
Wilk’s $\Lambda = .991; F_{(4, 751)} = 1.72; p = .143$

Gender differences at senior school:
Wilk’s $\Lambda = .976; F_{(4, 751)} = 4.56; p = .001$

Gender differences at college level
Wilk’s $\Lambda = .993; F_{(4, 751)} = 1.36; p = .248$

Table 4.8: Multivariate test statistics for simple effects of gender and school type.

It can therefore be concluded that the cause of the multivariate interaction of gender and school type was due to the differences in performance of senior school students by gender on the misconceptions factor. Based on the $F$-statistic ($F_{(1, 754)} = 12.37; p = .001$) of the male and female students at the senior level on the misconceptions factor, the female students performed better than the male students. This is not a surprising
finding as experience has taught us that women are generally more informed on issues that affect their skin, especially their facial skin. Since the effects of UVR are more pronounced on the facial skin, one would expect female students to be more informed about it, possibly having heard or seen their elder sisters or mothers take care of their facial skin to reduce the possibility of skin problems in future.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Junior school</th>
<th>Senior school</th>
<th>College level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
<td>Male</td>
</tr>
<tr>
<td>Diseases</td>
<td>2.700 2.582</td>
<td>2.580 2.491</td>
<td>2.503 2.525</td>
</tr>
<tr>
<td>Misconceptions</td>
<td>2.933 3.037</td>
<td>3.171 2.901</td>
<td>3.293 3.332</td>
</tr>
<tr>
<td>General</td>
<td>2.460 2.443</td>
<td>2.420 2.506</td>
<td>2.288 2.438</td>
</tr>
</tbody>
</table>

Table 4.9: Means by school type and gender (n for each group is given in brackets).
The multivariate test statistic for gender was not significant at the 99.98% confidence level (Wilk’s Λ = .987; F(4, 751) = 2.384; p = .050; η² = .013; power = .526). The multivariate test statistic for school type was significant though (Wilk’s Λ = .925; F(8, 1504) = 2.384; p = .000; η² = .038; power = 1.000). Because of this significance, follow-up tests are in order. On the school type univariate test statistics, only the Diseases (F(2, 754) = 5.815; p = .003; η² = .015; η = .759) and Misconceptions (F(2, 754) = 19.318; p = .000; η² = .049; η = 1.000) factors were significant. The Misconceptions (F(2, 754) = 6.677; p = .001; η² = .017; η = .827) factor had a gender by school type bivariate interaction that was significant at the test confidence level whereas the Diseases factor interaction was not significant (F(2, 754) = 1.644; p = .194; η² = .004; η = .204).
Figure 4.1: Interaction plot for school type by gender for the Diseases factor.
Figures 4.1, 4.2, 4.3, and 4.4 show the types of interactions present in the gender by school type factors for both the Diseases and Misconceptions factors. Note that the plots have been plotted both ways to show the type of interaction present. As can be seen from the plots, the interactions are disordinal, making it difficult to discuss any of the main effects without making reference to the interaction. This is especially so since interchanging the variables on the axis did not change the kind of interaction present.

Figure 4.2: Interaction plot for gender by school type for Diseases factor.
Since no theory is known to interpret these interactions, analyses for these variables were not continued any further.

Figure 4.3: Interaction plot for school type by gender for the Misconception factor.
Figure 4.4: Interaction plot for gender by school type for the Misconception factor.
Differences by Science Type

Student differences by science type were looked into as a separate one-way MANOVA because of grouping problems as already mentioned. This is not an ideal procedure as there may have been some interactions with other factors that would have required careful interpretation of results. The reader is therefore cautioned to bear this possibility in mind in going through these results. The $\alpha$-level was set at .0167 for the MANOVA analysis and the Box’s $M = 105.455$ test was significant for this test ($F_{40, 7586.8} = 2.603$). The multivariate test statistic was also significant, Wilk’s $\Lambda = .857$; $F_{(16, 2298.036)} = 7.439$. The effect size was .038 and the power associated with the test was 1.000. The means and standard deviations are shown in Table 4.7 by science type and the MANOVA results are summarized in Table 4.8.

The Levene’s test of equality of variance was significant for the Items and Misconceptions factors but not for the other two factors. The variance equality was not too violated though since the significance level did not differ much from the test alpha level. This suggests that we may have to be careful in interpreting the univariate results and take the error variances into account. Table 4.8 shows that the Diseases factor gave significant univariate results ($F_{(4, 755)} = 4.114; p = .003; \text{Eta}^2 = .021; \text{power} = .834$). This factor looked into typical effects of UVR exposure on the human body like cancers and skin problems such as pimples and pigmentations. This suggests that students across the different sciences differed on their knowledge of the diseases that they may likely contact as a result of being overly exposed to UVR.
Table 4.10: Means and standard deviations for factors by science type.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Junior science</th>
<th>Senior single science</th>
<th>Senior pure science</th>
<th>College humanities</th>
<th>College science</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mean</td>
<td>std. dev.</td>
<td>mean</td>
<td>std. dev.</td>
<td>mean</td>
</tr>
<tr>
<td>Diseases</td>
<td>2.633</td>
<td>.471</td>
<td>2.582</td>
<td>.422</td>
<td>2.462</td>
</tr>
<tr>
<td>General</td>
<td>2.450</td>
<td>.574</td>
<td>2.524</td>
<td>.496</td>
<td>2.409</td>
</tr>
<tr>
<td>Source</td>
<td>dF</td>
<td>SS</td>
<td>MSS</td>
<td>F</td>
<td>p</td>
</tr>
<tr>
<td>---------------</td>
<td>----</td>
<td>------</td>
<td>------</td>
<td>--------</td>
<td>------</td>
</tr>
<tr>
<td>Diseases</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment</td>
<td>4</td>
<td>3.230</td>
<td>.808</td>
<td>4.114</td>
<td>.003</td>
</tr>
<tr>
<td>Error</td>
<td>755</td>
<td>148.197</td>
<td>.196</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Items</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment</td>
<td>4</td>
<td>1.936</td>
<td>.484</td>
<td>1.915</td>
<td>.106</td>
</tr>
<tr>
<td>Error</td>
<td>755</td>
<td>190.891</td>
<td>.253</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Misconceptions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment</td>
<td>4</td>
<td>7.580</td>
<td>6.895</td>
<td>18.544</td>
<td>.000</td>
</tr>
<tr>
<td>Error</td>
<td>755</td>
<td>280.721</td>
<td>.372</td>
<td></td>
<td></td>
</tr>
<tr>
<td>General</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment</td>
<td>4</td>
<td>5.973</td>
<td>1.493</td>
<td>5.258</td>
<td>.000</td>
</tr>
<tr>
<td>Error</td>
<td>755</td>
<td>214.396</td>
<td>.284</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Multivariate Test Statistic:**

- Treatment: Wilk’s $\Lambda = 0.857$; $F_{(16, 2298.036)} = 7.439$; $p = .000$; $\text{Eta}^2 = .038$; Power = 1.00

Table 4.11: Results of MANOVA and follow-up ANOVAs by science type
The Items factor gave a non-significant result ($F_{(4, 755)} = 1.915; p = .106; \eta^2 = .010; \text{power} = .409$). It is not however surprising that there was no significance here given the weak power for the analysis and the very small effect size. This factor dealt with things that can be used to protect oneself from UVR. The Misconceptions factor dealt with commonly held misconceptions about UVR and the univariate test gave a significant result ($F_{(4, 755)} = 18.554; p = .000; \eta^2 = .089; \text{power} = 1.000$). There was enough power and effect size to be able to detect differences between groups. The last factor, General, dealt with items that could not be put into any specific category and the test was also significant ($F_{(4, 755)} = 5.258; p = .000; \eta^2 = .027; \text{power} = .929$). Again this factor had a good power to detect differences.

With a significant MANOVA, Hotelling $T^2$ and univariate $t$ tests procedures were performed to try and determine which pairs of groups differed significantly on the set of factors. These procedures were in order so as to be able to answer the research question that sort to determine if students’ knowledge on UVR differed based on the type of science that they do at school. It would also be interesting to know if the students performed differently on the different factors, which would help us determine if certain areas of the whole idea of UVR exposure are more important than others. This was especially important since it has already been established that the different factors, though related, measure different components of knowledge on UVR exposure since they were not correlated.
Table 4.12: Stepwise discriminant function analysis Wilk’s Lambdas and F values

<table>
<thead>
<tr>
<th>Step</th>
<th>Factor</th>
<th>Variables in discriminant function</th>
<th>Wilk’s A</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Misconceptions</td>
<td>1</td>
<td>.911</td>
<td>18.544*</td>
</tr>
<tr>
<td>2</td>
<td>General</td>
<td>2</td>
<td>.881</td>
<td>12.289*</td>
</tr>
<tr>
<td>3</td>
<td>Diseases</td>
<td>3</td>
<td>.863</td>
<td>9.488*</td>
</tr>
<tr>
<td>4</td>
<td>Items</td>
<td>4</td>
<td>.857</td>
<td>7.439*</td>
</tr>
</tbody>
</table>

*p < .001

To determine pair-wise differences across factors simultaneously, discriminant analysis was performed by science type. Discriminant analysis is a procedure of choice since the sample size was large enough (190 subjects per factor) and is capable of giving us the kind of comparison we wanted. The results of discriminant analysis as a follow-up for the significant MANOVA show that the step-wise pair-wise Wilk’s Lambdas were significant at each of the four steps that involved addition of a factor at each step. Wilk’s As at each step of the stepwise analyses are shown in Table 4.9. The multivariate pair-
wise comparison between the difference science groups is significant. That is, across all four factors, the different science groups differed in performance. This can be seen by looking at the Wilks’ Lambda for the final step in the step-wise analysis where Wilks’ Lambda = .857, and with 4 and 752 degrees of freedom, F = 7.439; p = .000. We can therefore conclude that the science groups differed from each other across all four factors.

The stepwise pair-wise group comparisons show that in the first step when only the Misconceptions factor was included, the senior pure science group did not differ from both the college humanities (F (1, 755) = 011; p= .918) and college science students (F (1, 755) = 5.133; p= .024) whereas the college humanities students also did not differ from the college science students (F (1, 755) = 4.821; p= .028) on the factor. The rest of the groups differed on the factor. In step two, after adding the General factor, the only groups that did not differ were the senior pure science and college humanities students (F (2, 754) = .249; p= .780). The rest of the groups performed the same on the average of the two factors.

At step three when three factors were averaged after adding the Diseases factor, the senior pure science and college humanities groups were significantly different from each other (F (3, 753) = .578; p = .630). The final step had all four factors included in the analysis after adding the Items factor. At this step, the junior and senior single science students did not perform differently (F (4, 752) = 2.783; p=.026) and the senior pure science and college humanities students did not perform differently either (F (4, 752) = .538; p= .708). The rest of the pair-wise groupings differed significantly from each other.
<table>
<thead>
<tr>
<th>Comparison</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Junior - Senior Single Science</td>
<td>2.783</td>
<td>.026</td>
</tr>
<tr>
<td>Junior - Senior Pure Science</td>
<td>6.738</td>
<td>.000</td>
</tr>
<tr>
<td>Junior - College Humanities</td>
<td>5.471</td>
<td>.000</td>
</tr>
<tr>
<td>Junior - College Science Majors</td>
<td>14.602</td>
<td>.000</td>
</tr>
<tr>
<td>Senior Single Science - Senior Pure Science</td>
<td>9.948</td>
<td>.009</td>
</tr>
<tr>
<td>Senior Single Science - College Humanities</td>
<td>9.521</td>
<td>.000</td>
</tr>
<tr>
<td>Senior Single Science - College Science Majors</td>
<td>20.643</td>
<td>.000</td>
</tr>
<tr>
<td>Senior Pure Science - College Humanities</td>
<td>.538</td>
<td>.708</td>
</tr>
<tr>
<td>Senior Pure Science - College Science Majors</td>
<td>3.400</td>
<td>.009</td>
</tr>
<tr>
<td>College Science Majors - College Humanities</td>
<td>4.370</td>
<td>.002</td>
</tr>
</tbody>
</table>

Table 4.13: Pair wise group comparisons by science type over all four factors (Step four).
Table 4.13 shows the F values for the pair wise group comparisons by science type over all four factors (for step four). As can be seen from the table, the only pairs of groups that did not differ over all when all four factors were considered were the junior school science and senior single science students \((F_{(4, 752)} = 2.783; p = .026)\) and the senior pure science and the college humanities \((F_{(4, 752)} = .538; p = .708)\).

The fact that the junior and senior single science students did not differ significantly is an interesting one even though the alpha value was trivial. That the senior pure science and college humanities students did not differ can be explained by the realization that the groups are comparable in terms of the science content done. The senior pure science students for the most part have done a lot more science topics than the college humanities group when they were still at high school. The bulk of the students in the college humanities group are those who did senior single science and those who may have done senior pure science but were not very successful at it.

The findings in Table 4.13 are disheartening given that the college humanities students are never going to be exposed to any formal classroom science content again in their lives, and yet they do not seem to be ready to do things that are so pertinent to their well being as they relate to UVR.

It is interesting to note that throughout the step wise analysis as factors were added, there was never a point where the senior school pure science group performed differently than college humanities group in terms of answering the statements on the questionnaire. A large majority of the senior pure students are the ones who will go on to be college science majors. This is a commendable finding given that the senior science
group was only in their first year of senior science while the college humanities group was in their first year of college education. The same cannot be said of the senior single science and college humanities students though. They differed at each of the four steps in the analysis.

With five groups to compare, a maximum of four functions could be extracted from the analysis. The coefficients are given in Table 4.14. The standardized canonical discriminant function coefficients show that all four factors contributed to the multivariate difference between the groups across the four factors. Function one accounted for 87.9% of the variance with an eigenvalue of .144. The second function accounted for 8.5% of the variance with an eigenvalue of .014. The last two functions accounted for 3.5% and 0% variance with eigenvalues of .006 and 0 respectively. Significance was attained when all four functions were tested with Wilks’ Lambda = .857; $\chi^2 = 11.6396$ and 16 degrees of freedom.

This suggests that the Misconceptions factor, which dominates the first function made the most contribution to the multivariate pair-wise differences followed by the Diseases factors. This is determined based on the variance explained by each function and the factor that has the highest coefficient on that function.

Independent sample $t$ test results give us some indication of why certain pair-wise comparisons were significant and others were not. In step four of the multivariate step-wise pair-wise analysis when all the factors were included in the analysis only the junior science-senior single science and senior pure science-college humanities pairs gave non-significant results at an alpha level of .0167.
Table 4.14: Standardized canonical discriminant function coefficients for science type analysis.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Function 1</th>
<th>Function 2</th>
<th>Function 3</th>
<th>Function 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diseases</td>
<td>-.267</td>
<td>.739</td>
<td>.655</td>
<td>.021</td>
</tr>
<tr>
<td>Items</td>
<td>-.202</td>
<td>.198</td>
<td>-.551</td>
<td>.802</td>
</tr>
<tr>
<td>Misconceptions</td>
<td>.877</td>
<td>-.016</td>
<td>.291</td>
<td>.394</td>
</tr>
<tr>
<td>General</td>
<td>-.392</td>
<td>-.751</td>
<td>.453</td>
<td>.331</td>
</tr>
</tbody>
</table>

The $t$ test results for the comparisons in Table 4.15 show that for the senior pure science and college humanities pair, none of the $t$ test results is significant for all the factors. The overall result was a non-significant difference between the groups. None of the factors contributed to the groups being different. On the other hand there is a significant difference between the junior science and senior single science on the Misconceptions factor ($t_{307.1} = 2.587 –$ two tailed). This difference did not however translate into a multivariate difference when all factors were considered. This can be
understood by looking at the p-value for the pair-wise test which was only .026 tested at an alpha level of .0167. The similarity between the groups was trivial.

In contrast, the junior-college humanities pair had only a significant difference on the Misconceptions ($t_{288.9} = -3.914$ – 2 tailed) factor too, but the difference translated into an overall multivariate pair-wise difference. The p-value for the pair wise comparison was .000. The misconceptions factor contributed to the differences in the pair since there were no significant differences between the groups on all the other factors. The senior single-college science and college humanities-college science pairs had significance on the Misconceptions and General factors. These factors therefore contributed to the differences found between the pairs. The junior-senior single science and senior single science-senior pure science pairs had significance on only the misconceptions factor indicating that the factor contributed to the differences between the pairs.

The senior pure science-college science had contributions to differences from the General factor but this did not translate into a multivariate significant pair wise difference. The junior science-senior pure science pair had major contributions from the Diseases and Misconceptions factors. The junior science-college science major pair had contributions from the Diseases, Misconceptions, and General factors to the differences that the pair had.

Overall it looks like the Misconceptions factor played a major role in differentiating between the different groups of students doing the various sciences. Except for one case of the senior pure science-college science pair, all other cases where there was a difference in the pairs, either only the Misconceptions factor or some other
factor(s) in addition to the misconceptions factor were involved. The difference between the senior pure science and college science majors was even trivial, as it did not translate into an overall multivariate pair wise difference.
## Table 4.15: Pair wise independent t test results for the groups. (JS = junior science, SSS = senior single science, SPS = senior pure science, CH = college humanities, CSM = college science majors. Degrees of freedom given in brackets for each test).

<table>
<thead>
<tr>
<th>Comparison</th>
<th>Diseases</th>
<th>Items</th>
<th>Misconceptions</th>
<th>General</th>
</tr>
</thead>
<tbody>
<tr>
<td>JS – SSS</td>
<td>1.113 (325.9)</td>
<td>-.769 (335.9)</td>
<td>-2.587* (307.1)</td>
<td>-1.359 (335.3)</td>
</tr>
<tr>
<td>JS - SPS</td>
<td>3.194* (229.0)</td>
<td>1.154 (204.3)</td>
<td>-3.067* (209.1)</td>
<td>.674 (244.2)</td>
</tr>
<tr>
<td>JS - CH</td>
<td>2.286 (304.5)</td>
<td>1.799 (247.5)</td>
<td>-3.914* (288.9)</td>
<td>-.101 (301.9)</td>
</tr>
<tr>
<td>JS - CSM</td>
<td>2.702* (360.0)</td>
<td>1.413(195.1)</td>
<td>-6.587 * (221.0)</td>
<td>3.758* (207.2)</td>
</tr>
<tr>
<td>SSS - SPS</td>
<td>2.106 (241.2)</td>
<td>1.669 (216.6)</td>
<td>-4.811* (236.6)</td>
<td>1.772 (245.8)</td>
</tr>
<tr>
<td>SSS – CH</td>
<td>1.063 (272.7)</td>
<td>2.361 (273.0)</td>
<td>-5.837* (272.9)</td>
<td>-1.160 (271.3)</td>
</tr>
<tr>
<td>SSS- CSM</td>
<td>1.755 (225.5)</td>
<td>1.967 (205.0)</td>
<td>-8.195* (234.6)</td>
<td>4.702* (214.1)</td>
</tr>
<tr>
<td>SPS – CH</td>
<td>-1.198 (232.0)</td>
<td>.388 (242.0)</td>
<td>-.098 (251.0)</td>
<td>-.717 (240.6)</td>
</tr>
<tr>
<td>SPS – CSM</td>
<td>-.458 (222.0)</td>
<td>.090 (221.2)</td>
<td>-2.169 (222.0)</td>
<td>2.652* (220.5)</td>
</tr>
<tr>
<td>CSM – CH</td>
<td>.767 (215.3)</td>
<td>-.325 (225.1)</td>
<td>-2.548* (221.8)</td>
<td>3.609* (210.8)</td>
</tr>
</tbody>
</table>

*p < .0167
Differences by School Location

Since the college students belonged to the urban setting and did not have counterparts in the rural setting, they were taken out of the analysis. Students in the junior and senior schools were the ones that were included in the analysis for school location according to their rural/urban school locations. There were 244 students in the urban setting and 285 students in the semi-urban setting schools.

Table 4.16 shows means and standard deviations by school location and factor. The Box’s M for the test of equality of covariance matrices is not significant (Box’s M = 11.658; F (10, 1258233) = 1.156; p = .315). Whereas this test is difficult to satisfy, the overall test for other assumptions were discussed at the beginning of this section. The test was done at an alpha level of .0167 just like the other tests. This stringent condition should somewhat correct for the unequal covariance matrices.

The Levene’s test for equality of error variances for the univariate test was not significant for any of the factors. Again the stringent condition of the test should compensate for the unequal error variances between groups. The problem with this correction though is that it hurt the power of the test and made it difficult to detect minute effect sizes as was the case in this particular case.

The Wilk’s Λ = .9997; F (4, 524) = .420; p = .794; Eta² = .003; Power = .068 is not significant. The effect size of .003 coupled with the power of only .068 was a problem and made it almost impossible to find differences even when there was a possibility that they could exist. The results are summarized in Table 4.17.
One would think that urban students should be better exposed to issues of UVR than semi-urban students. It looks like results show that this was not the case.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Urban mean</th>
<th>Urban std. dev.</th>
<th>Semi-urban mean</th>
<th>Semi-urban std. dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diseases</td>
<td>2.573</td>
<td>.465</td>
<td>2.584</td>
<td>.471</td>
</tr>
<tr>
<td>Items</td>
<td>3.221</td>
<td>.513</td>
<td>3.214</td>
<td>.501</td>
</tr>
<tr>
<td>Misconceptions</td>
<td>3.033</td>
<td>.663</td>
<td>2.974</td>
<td>.649</td>
</tr>
<tr>
<td>General</td>
<td>2.443</td>
<td>.516</td>
<td>2.476</td>
<td>.580</td>
</tr>
</tbody>
</table>

Table 4.16: Means and standard deviations for groups by school location.
It would have been interesting to find out how rural students would have faired in the same situations, but the area under study did not allow for what could have been called a rural setting. None of the univariate tests is significant. We can therefore conclude that there were no difference between the urban and semi-urban students on their knowledge about UVR and its effects on the skin. No further tests could be done on this dimension of the study.
<table>
<thead>
<tr>
<th>Source</th>
<th>dF</th>
<th>SS</th>
<th>MSS</th>
<th>F</th>
<th>p</th>
<th>Eta²</th>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diseases</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment</td>
<td>1</td>
<td>.016</td>
<td>.016</td>
<td>.072</td>
<td>.789</td>
<td>.000</td>
<td>.021</td>
</tr>
<tr>
<td>Error</td>
<td>529</td>
<td>15.716</td>
<td>.220</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Items</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment</td>
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<td>.007</td>
<td>.007</td>
<td>.027</td>
<td>.869</td>
<td>.000</td>
<td>.018</td>
</tr>
<tr>
<td>Error</td>
<td>529</td>
<td>135.368</td>
<td>.257</td>
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<td></td>
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</tr>
<tr>
<td>Misconceptions</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment</td>
<td>1</td>
<td>.454</td>
<td>.454</td>
<td>1.057</td>
<td>.304</td>
<td>.002</td>
<td>.086</td>
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<tr>
<td>Error</td>
<td>529</td>
<td>226.306</td>
<td>.429</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment</td>
<td>1</td>
<td>.149</td>
<td>.149</td>
<td>.490</td>
<td>.484</td>
<td>.001</td>
<td>.046</td>
</tr>
<tr>
<td>Error</td>
<td>529</td>
<td>160.349</td>
<td>.304</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Multivariate Test Statistic:

Treatment: Wilk’s Λ = .9997; F (4, 524) = .420; p = .794; Eta² = .003; Power = .068

Table 4.17: Multivariate and univariate results for the factors by school location
Free Response Questions Analysis (Response to Scenario)

The scenario that was given to students to respond to was aimed at looking into students’ responses in details in an attempt to look into their patterns of thinking and possible misconceptions that they might have regarding UVR and its effects on the human skin. Therefore rather than grade the students’ response for a quantitative score, their responses were looked into qualitatively.

Frequencies of Responses by Different Groups

The scenario was based on item one on the Likert questionnaire that looked into whether or not a person could get sunburn on a completely cloudy day. Specifically item one on the Likert scale read “You can get sunburn/suntan on a completely cloudy day”. Out of the 760 students surveyed, where they were asked to strongly agree, agree, do not know, strongly disagree, or disagree on a Likert scale, 5.1 % of the students strongly agreed with the statement. It was expected that the students would strongly agree or agree with the statement. Those who agreed formed 11.8 %. This means that a total of 17.0 % answered the statement correctly. Those who chose do not know made 12.2 % of the students. Seventy percent of the students strongly disagreed or disagreed with the statement. The overall mean for the item was 3.96 with a mode of 5 (5 being equivalent to strongly disagree).

On the same item, the students were divided into their different schools, junior, senior and college. Their results are summarized in Table 4.20. A good percentage of the students across school types either disagreed strongly or just disagreed with the statement
even though it was correct. What is interesting is the fact that even at college level, 66.7%
% of the students disagreed or strongly disagreed with the statement with a high
percentage strongly disagreeing. This is an indication of how convinced they were that
the responses were acceptable.

<table>
<thead>
<tr>
<th>Mean</th>
<th>mode</th>
<th>% s/agree</th>
<th>%agree</th>
<th>%don’t know</th>
<th>%disagree</th>
<th>%s/disagree</th>
</tr>
</thead>
</table>
| Junior school
| 3.95 | 5    | 5.4      | 9.6    | 14.2        | 26.4      | 44.4        |
| Senior school
| 4.05 | 5    | 4.9      | 12.3   | 8.6         | 21.3      | 53.0        |
| College
| 3.87 | 5    | 5.2      | 13.9   | 14.3        | 22.5      | 44.2        |

Table 4.18: Percent responses by school type on item 1 of the sun exposure and the skin
questionnaire.
<table>
<thead>
<tr>
<th></th>
<th>Males</th>
<th>mode</th>
<th>% s/agree</th>
<th>%agree</th>
<th>%don’t know</th>
<th>%disagree</th>
<th>%s/disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Junior school</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>3.99</td>
<td>5</td>
<td>4.4</td>
<td>7.1</td>
<td>18.6</td>
<td>24.8</td>
<td>45.1</td>
</tr>
<tr>
<td>Females</td>
<td>3.92</td>
<td>5</td>
<td>6.1</td>
<td>11.5</td>
<td>10.8</td>
<td>27.7</td>
<td>43.9</td>
</tr>
<tr>
<td><strong>Senior school single science</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>4.15</td>
<td>5</td>
<td>2.1</td>
<td>10.6</td>
<td>12.8</td>
<td>19.1</td>
<td>55.3</td>
</tr>
<tr>
<td>Females</td>
<td>4.20</td>
<td>5</td>
<td>5.1</td>
<td>8.2</td>
<td>5.1</td>
<td>24.5</td>
<td>57.1</td>
</tr>
<tr>
<td><strong>Senior school pure science</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>3.92</td>
<td>5</td>
<td>4.8</td>
<td>17.7</td>
<td>8.1</td>
<td>19.4</td>
<td>50.0</td>
</tr>
<tr>
<td>Females</td>
<td>3.87</td>
<td>5</td>
<td>6.6</td>
<td>14.8</td>
<td>11.5</td>
<td>19.7</td>
<td>47.5</td>
</tr>
<tr>
<td><strong>College humanities</strong></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Males</td>
<td>3.96</td>
<td>4</td>
<td>2.0</td>
<td>8.0</td>
<td>16.0</td>
<td>40.0</td>
<td>34.0</td>
</tr>
<tr>
<td>Females</td>
<td>3.78</td>
<td>5</td>
<td>6.3</td>
<td>16.3</td>
<td>16.3</td>
<td>16.3</td>
<td>45.0</td>
</tr>
<tr>
<td><strong>College science majors</strong></td>
<td></td>
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</tr>
<tr>
<td>Males</td>
<td>3.95</td>
<td>5</td>
<td>4.9</td>
<td>14.8</td>
<td>12.3</td>
<td>16.0</td>
<td>51.9</td>
</tr>
<tr>
<td>Females</td>
<td>3.65</td>
<td>5</td>
<td>10.0</td>
<td>15.0</td>
<td>10.0</td>
<td>30.0</td>
<td>35.0</td>
</tr>
</tbody>
</table>

Table 4.19: Percent response by school type and gender on Item 1 of the sun exposure and skin questionnaire.
Since gender proved to be an important classification variable in the quantitative section of the results, it was felt that it would be interesting to see how the students responded based on both the school type and gender. Table 4.19 shows the results. Very interesting patterns developed here. The modal response is still five virtually for all groups, where students strongly disagreed with the statement when they should have strongly agreed with it.

A large percentage of the students strongly disagreed with the statement for each of the science groups across school types. It is interesting to note that even for the college science majors, the same situation prevailed. There were minor differences by gender, for example, only 35% of the college science females strongly disagreed with the statement whereas 52% of the males did. But overall 65% of the college science females strongly disagreed or just disagreed with the statement and 68% of the males did.

**Responses by Question on the Free Response Questions**

This statement looked into whether or not students were aware of the electromagnetic nature of the UVR and how that they are able to penetrate clouds and still reach the earth even on a cloudy day. What did not seem to be clear to students overall was what seemed to cause the sunburn. Was it just sun’s radiation or a portion of the radiation from the sun? In analyzing the students’ responses, I separated their scripts by school type as an attempt to see if there were any major differences in their responses as they went up the Botswana educational ladder.
**Responses to Question 1**

The first question asked students to explain why Thabo had sunburn/suntan even though it was completely cloudy. It was expected that students would realize that the sun is a source of the whole range of radiation found in the electromagnetic spectrum and that the cause of the sunburn is solemnly due to UVR, which can penetrate clouds.

After the coding exercise for this question, 13 categories were recorded as explanations for the sunburn on a completely cloudy day. Of the thirteen, it was determined that any category with a total of less than nine tallies would not be included in the report as it was felt that they would not be representative enough of student ideas. Five categories were retained and formed themes to explain student conceptions of why Thabo had sunburn on a completely cloudy day.

The themes that extracted were sunrays, ultraviolet rays, sunscreen addiction, working in the open under no shade, and heat/temperature. A total of 28 % of the students in the sampled 110 scripts for the qualitative analysis ascribed Thabo’s sunburn to just sunrays as opposed to being specific about the type of sunrays. The students that wrote about sunrays were divided according the science type that they were taking. Of these students, 38.7 % were from the college science group. They were followed by the college humanities students at 25.8 %. The senior pure science group accounted for only 19% of the tallies. A large percentage of the students on this theme were the college science students.

A total of 22 (20%) students wrote that Thabo had sunburn due to ultraviolet radiation since they can penetrate clouds. Sixty three percent of the students in this
category were college science students. The rest of the responses on this theme were spread among the different science groups. This signifies the more advanced thinking by the college science students compared to the other groups. The more spread thinking was on the idea that the sunrays caused the sunburn.

For some students, rather than discuss what caused the sunburn, they decided to capitalize on the fact that Thabo had been using sunscreen. They therefore reasoned that the sunburn on a completely cloudy day was as a result of his skin being addicted to sunscreen use. 22 (20 %) of the total 110 students gave this reason. Almost half (45.5%) of these students were junior students, followed by the college humanities students with 27.3%. The idea that the sunburn was due to sunscreen addiction is not exactly what was expected for this question, but students did have a point in that the implication was Thabo’s skin would be much more sensitive than if he had not been using sunscreen. It is however lacking in concept development because irrespective of whether or not Thabo’s skin is addicted to sunscreen use, it would still need UV radiation to get the suntan that it had.

Some student responses were:

*Even when it is cloudy you can be sunburn. We would use to apply your sunscreen even it is cloudy if you don’t want your skin to be darker.* (Student 212 – junior school)

This is because he worked indoor most of the day, so he was not used the sun that much. Another thing (I think ) is because his skin was used to the sunscreen he used on his face and neck. Another reason is because he was on an open space so according to my thinking the rays were able to pass through the clouds and heat on his skin. (Student 298 - senior pure science)
Students also had the idea that sunburn is caused by heat or high temperature from the sun. These categories were initially kept separate but were later combined to form one theme. Nineteen percent (21) of the total students in the qualitative analysis sample reasoned this way. The students in this category seemed to think that the more heat and consequently the higher the temperature, the more the suntan. Surprisingly enough, the senior pure students accounted for 33.3 % of the students who reasoned this way. Both the junior and senior single science groups followed at 23 % each. The college science students did not have this idea whilst a small (14 %) percentage of the college humanities students held it.

Some students wrote:

Even though it was completely cloudy there is always heat in the atmosphere which can harm the skin. (Student 292 – senior pure science)

Even if there is cloud cover the temperature can be high. So Thabo was working maybe under high temperatures which made his skin tan and this was further aggravated by the fact that he was doing manual work/labour so he was over working. So he was over working, sweating and fatigue contributed. More blood flowing to the skin. (Student 430 – college science)

This means/shows that although the sun will be completely be hidden under the sun, the heat from its rays can penetrate through the clouds, and producing as much harmful heat that is enough to burn people. (Student 586 – college humanities)

I think the temperature was though there was no sun. Sometimes it becomes so hot still without sun. It goes by temperature of the atmosphere. (Student 593 – senior single science)

Even though there was cloud they might had been the heat of the sun from the ground goes to the clouds at night then the heat get bounced by the cloud and goes back to the ground surface and the day become hot and that rays burns the skin of Thabo. (Student 629 – senior pure science)
Sixteen (14.5 %) of the 110 students attributed the sunburn to the fact that Thabo was working in the open or was not in any shade for a long period of time. Whilst the scenario does make reference to this fact, the answer when given in this way does not state what the real cause of the sunburn was. The groups higher in the educational level were the ones that for the most part, gave this reasoning. The single pure, college humanities, and college science each had 25 % of this explanation. The junior students accounted for 18.8 %.

Some students wrote:

_Thabo didn’t use sunscreen to protect himself from the sun’s rays and during cloudy day there is sun under clouds and the sunrays penetrate the cloud and cloud heat the ground. He was working under an open space and his not under any shade for most of the time._ (Student 287 – senior pure science)

_Thabo had sunburn he was thinking that the sun will not affect him anyway and he didn’t put on sunscreen on his face and neck as usual. He was not under any shade for most of the time. He realized that he had sun burn on his skin when he arrived at the city._ (Student 289 – senior pure science)

_The sunrays can penetrate the clouds in the sky so this implies that as Thabo was running around in open fields he got sunburn due to sunrays. The rays mostly being ultraviolet rays that affect or sunburn the skin could penetrate the cloud. The ultraviolet rays having high frequency and short wave length implies its penetration power or energy through the cloud hence Thabo eventually got sunburned._ (Student 362 – college science)

_I think it is because even in black skinned people if you spend too much exposed time to the sun your skin will become even more darker than it was before. And also because he worked most of the time at the cattle post not under any shade and the only protected area was the eyes because was putting on sun glasses._ (Student 56 – junior school)

Student responses in general revealed that the college science majors were much more advanced in their thinking than any of the other groups for this question. This was expected given the amount and depth of the science they had done compared to all the
other groups. Based on comparison of the responses, the senior pure science group followed the college science students in terms of their concept development. Junior school students seemed to have had problems figuring out that the sunburn is as a result of the UVR from the sun. They either left the response blank or gave responses that were not scientifically acceptable.

This concept may have been a little more advanced for their level, especially given that they do not cover the subject in their formal school syllabus. The fact that this may be true still solidifies the argument that the UVR issue needs to be drafted into the Botswana school syllabus at all level to afford students as much exposure to the subject as possible very early in their lives. Student 61, junior school student, wrote; “The sun hides in the clouds but still have the rays penetrate the clouds.” This answer is partly correct. It does not contain the key words that were sort in the answer – that UVR has high penetrating power and can therefore penetrate the clouds and reach Thabo.

In contrast, a senior pure science student, Student 282 wrote: “This is because the UV rays can still penetrate through the clouds even though it’s cloudy, …”. The mention of UV rays shows some further development of concepts by this student and some knowledge of the fact that the sun produces a whole range of electromagnetic rays. Student 602 in the senior single science group wrote “… And when it is cloudy the sun’s rays can penetrate through the clouds that’s why you can see that is light when it cloudy.” This answer is comparable in content to the one given by Student 61. They both are lacking in concept development though, the conceptual ecology of the students regarding the subject are not developed enough.
Student 362, a college science major wrote, “The ultraviolet rays having high frequency and short wavelength implies its penetration power or energy through the clouds hence Thabo eventually got sunburned”. Students 374 and 450 further characterized the electromagnetic spectrum and indicated that clouds attenuate the rays from the sun but do not completely block them. There were still students in this group that showed misconceptions regarding this question.

Responses to Question 2a

Question 2a in the questionnaire asked students to explain in detail why Thabo had particularly serious suntan/sunburn on the day he was at the cattle post. It was hoped that the students would realize that since Thabo’s skin was not used to the conditions prevailing at the cattle post, it would not respond in a way that a skin that was used to it would.

Most students clearly got the idea that Thabo’s skin could have been somewhat addicted to the sunscreen use. Three themes dominated the answers to this question. Students raised the ideas of sunscreen protection and working in the open or without shade protection. The third theme developed out of responses that showed that the students responding had no idea whatsoever about what the correct response should be. There were so many other ideas that students threw around that may be worth flowing up perhaps in a follow-up study to this one. These ideas were scattered all over and could not be classified as themes. This is perhaps where the value of following students’ initial responses with sample interviews would have helped.
Students raised the idea that Thabo had not applied sunscreen on that day but since his skin was used to sunscreen used, he was most likely to get a serious suntan than a skin that was not used to sunscreen application. A little over half, 54.4 % (60) of the total 110 students raised this issue across the science groups. The highest percentage of the 60 students, 30.0 %, was from the college science group. These were followed by junior students with 21.7 %. The senior single science made only 20.0 % whilst the college humanities and senior pure science trailed with 16.7 % and 11.7 % respectively. This is still a strange finding. I had expected the college humanities and senior pure science students to have higher percentages on this theme.

Some student responses were:

*His skin is too dependent on the sunscreen as he uses it everyday. It is addicted and it is as if the skin cannot stay without the sunscreen.* (Student 65 – junior school).

… *Thabo’s skin is so adapted to having sunscreen in everyday that if he doesn’t apply one he is more at risk than somebody who does not use sunscreen at all.* (Student 354 – college science major).

*Because he didn’t use a sunscreen to protect himself so because the clouds absorbs the sun heat it is released even if it is cloudy that’s why people feel hot. So it affect someone if he/she usually use the sunscreen to protect him/her.* (Student 610 – senior single science).

Students also thought that since Thabo was working in the open or not under a shade, something that his skin was not used to, this could have contributed to his particularly serious sunburn. Of the 110 student questionnaires analyzed for this part of the study, 21 (19.1%) students raised this issue. A few, 38.1 % (8) of the 21 students were
college science students. Nineteen percent (4) were from the senior single science group. The rest of the groups had 14.3% of the students give this response.

Some student responses in this theme were:

*He spent the whole day at the cattle post running errands. He never had a chance to stay under the shade.* (Students 18 – junior school)

*He didn’t use any sunscreen as he usually would and he was not working out in the open the whole day as compared to other days when he worked indoors for most of the time.* (Student 366 – college science)

*He did not have his sunscreen applied this change made him even more susceptible on top of the fact that he spend most of his previous time indoor.* (Student 380 – college science)

*Thabo had a serious burn because his skin is not used to stay outdoors without being applied sunscreen. Thabo was used to stay indoors. His skin was not used to the outdoor temperature.* (Student 505 – senior single science)

There were student responses that were classified as having no idea as to why Thabo had serious sunburn on this day. These students were mostly in the junior science group. Six of the ten students whose ideas were put in this category were junior science students. Surprisingly enough, the other four students were divided equally between the college humanities and college science students.

It was also expected that students would give a second reason, which was the fact that in summer the UV rays have the highest penetration to earth as they travel directly to earth due to the sun being directly above the hemisphere that is experiencing the summer. In other words the radiation sees less atmosphere than it would in winter. Not one student in all the school groups gave this second reason for the particularly serious sunburn.

It can not exactly be concluded that they did not know this since some of them were able to raise the same issue in answering question 2b. It could have been that they
just had bad test taking skills. It is however still a major concern that even the college science majors could not see this as a major reason for the excessive sunburn.

Responses to Question 2b

Question 2b asked students to state whether or not they thought Thabo’s condition would have been the different if it were winter. It was not suggested to the student how the change was anticipated by not stating the expected direction of the change. Students there could not tell what direction of change the question expected. It was hoped that students would realize that in winter, the UV rays see a lot more atmosphere because of the earth’s tilt than in summer and are attenuated to a greater extent. This would result in less intense radiation for the same cloud condition and hence less sunburn.

Whereas students attempted the question, there seemed to have been some confusion, perhaps arising from the way the question was phrased. The question wanted students to give an answer to what they thought would happen for the same cloudy condition, only in winter. Some students went as far as speculate what weather conditions would most like prevail if it were winter as opposed to assuming the same weather conditions. This is not a surprising finding though because of the inherent interpretive nature of reading written text. Each student described the world that they read in the given text and gave answers as they saw their worlds (Silverman, 2000).

After working on coding and coming up with the concepts that students used to explain why they thought things would have been different for Thabo, six themes were
arrived at. Student ideas were much more evenly spread in this question than in any of the other questions.

Some students agreed that Thabo’s conditions would have been different but for reasons that are not scientifically acceptable. Forty two percent % (46) of the total 110 students said yes to the question. That is, they agreed that his condition would have been different if it had been winter. Of the students answering yes, the highest percentage was that of the senior pure science students with 28.3 % followed by the college science major with 26.1 %. The college humanities students had 15.2% whilst the senior single students had 21.7 %.

The reasons given for the yes response were generally not acceptable as scientific explanations for why we expect less UV radiation in winter. One of these was given as a theme. Students generally reasoned that in winter it is cold, thus the sunrays would be cooled thereby rendering them less effective at inflicting suntan on Thabo. This ties in well with their previous explanation for why Thabo had sunburn on a completely cloudy day. To them, it is the heat, and therefore in winter there should be less suntan as heat is reduced by the cold weather. The students who related heat or temperature to suntan for this question formed 20.9 % (23). This reasoning was even across groups. The percentage for the groups ranged from 17.4 % to 26.1 %.

Here are some responses:

Yes there would be a difference because cooled air cools the body they will be less heat from the sun rays. (Student 291 – senior pure)

It would be different because in winter is not as hot like in summer. You would find out that probably in winter during the day the sun does not appear mostly like in summer. (Student 42 – junior school)
In winter temperatures are generally lower which indicates the lower effect of radiation. So when there was less radiation Thabo condition could have been better. (Student 438 – college science)

Yes it could have been different because in winter the sun’s heat is low compared to that in summer. (Student 586 - college humanities)

Yes, I think so because it is not so hot only sometimes but not as much. It goes by how temp ranges. (Student 593 senior single science)

Less than half, 29.1% (32) of the total students said the conditions would not have been different for Thabo. All sort of reasons were given for this answer, none of which was satisfactory. Both the junior science and senior single science group had 34.4% each of the 32 tallies. The college science students had the next highest percentage at 28.1%. The College humanities and senior pure science groups followed with 21.9% and 18.8%.

It seems like students who opted to say that there would have been no difference did not understand what the question asked for. A few of the responses were:

No, because even when it is cold you can be sunburn. (Student212 – junior school)

No because the winter sun is just like the summer sun. (Student 345 – senior single science)

No. In winter there is still the same amount and strength of sunrays reaching earth. (Student 452 – college science)

No! It would have been even serious, I think, because the sunrays in winter seem even stronger. (Student 71 – junior school)

In general, the college science majors seemed to have figured out the scientifically acceptable response. These students formed 26.1% of the 46 students who
said they would expect there to have been a difference if it were winter. Some of their responses were:

Yes, this is because during winter the angle at which the sun is to the earth will have changed and the amount of sunrays reaching the earth will be decreased … (Student 354).

… during summer the earth is tilted towards the sun and receiving direct rays and in winter it is receiving slanted rays. (Student 355).

Yes, in winter the sun is facing away from the earth, so the sunrays are not as strong as if it is summer. (Student 356).

Yes it was going to be better in winter as now the sun had moved to another hemisphere increasing the distance between Thabo and it (sun) (Student 364). In winter the sun is further from the earth hence lowering the penetration power of the sun rays. (Student 371).

Yes because in winter the intensity of the sun is less so the ultraviolet rays emitted are less thus making a less serious sunburn/suntan. (Student 374).

There are still some misconceptions in the responses given by these students. Student 356 says the sun is facing away from the earth as if the sun moves. Student 364 solidifies this thinking by writing that the sun has now moved to another hemisphere increasing the distance between the earth and the sun. Such responses come from commonly held misconceptions that in the solar system the sun moves and the earth is stationary because it appears that way through the hours of the day.

The idea of the sun moving between hemispheres was very common with the college science students. This perhaps suggests that they had read or studied these concepts, but it shows that they still had a lot of misconceptions about for one thing, what causes seasons. Nine students from the total 110 brought up this idea; of these nine, six were college science students. The rest were shared among the other groups.
From the group that discussed the movement of the sun, there was also a discussion about the idea that there would be less radiation reaching the earth or as some put it “there would be less sun”. A total of 23 (20.9 %) gave this explanation. Of these 23, 34.8 % were college students. These were followed by senior pure science with 21.7 %. The college humanities students made only 17.4 %.

Responses to Question 3

Question three asked students to explain why the area around Thabo’s eyes that was covered by the sunglasses did not have sunburn. Students were expected to use words that would suggest that the UV rays were blocked/absorbed/scattered/reflected by the sunglasses and were not able to reach the area around Thabo’s eyes. This question also generated a lot of misconceptions. Students did not seem to understand how sunglasses work. After coding and combining the codes as was necessary for this question, three themes emerged.

Students wrote of the sunglasses offering protection by providing a shade around Thabo’s eyes. There were also some who stated it in terms of the sunglasses preventing the rays from passing through to the area around the eyes. Fifty (45.5 %) of the 110 students mentioned the idea of providing a shade and thereby offering protection. Of these 50, 30 % (15) were from the junior school group. The senior single science and college science followed with 26.0 %. The senior pure and college humanities were 14 % and 16.0 % respectively.
Some of the responses were:

*It did not have sunburn because he had covered his eyes with sunglasses. His eyes were protected.* (Student 18 – junior school)

*The area around Thabo’s eyes that was covered by his sunglasses did not have sunburn at all because the sunglasses were protecting the area by its shadow.* (Student 212 – junior school)

*The area around Thabo’s eyes that was covered by his sunglasses protect eyes from harmful rays from the sun.* (Student 291 – senior pure)

*The sunrays were reflected by the sunglasses.* (Student 292- senior pure)

*The sunglasses were effective in absorbing the excessive sunrays therefore it shielded away the area from the rays which caused tanning.* (Student 380 – college science)

Perhaps related to the idea of sunglasses offering protection from the sun, was student’s use of the idea that the sunglasses block or reduce the sunrays. Fourteen (12.7 %) of the 110 preferred to use this terminology. Of this 12.7 %, 42.9 % were college science students and 35.7 % were college humanities students. None of them were junior school students.

Overall this was one of the questions answered well by students. Student 67 (junior school) wrote “*Because he protected himself from the sunrays and he got the shade from it.*” Students did mention that the UV rays were prevented from reaching Thabo’s eyes but did not in general explain how. Student 85 (junior school) wrote; “*The ultraviolet rays did not hit the area under the sunglasses.*” Student 282 in the senior pure science group wrote;” *This is because the sunglasses prevent the penetration of the UV rays from damaging the area around his eyes.*” While this response is a little more refined compared to the ones given by the junior school students, it still does not specify
how the prevention occurs. Student 292 (Senior pure science) qualified the prevention by writing that the “The sun rays were reflected by the sunglasses.”

None of the junior students used qualifying terms like reflection and absorption. They used the word protection, perhaps an indication that they had not refined their knowledge of the wave properties of the electromagnetic spectrum. Only the senior pure (4 students), college humanities (2 students), and college science (1 student), of the 110 used the word reflection.

The junior science syllabus in Botswana does cover light and its properties, including reflection. But it does not extend to the electromagnetic spectrum and so may not have transferred their wave properties to other forms of waves like the UV radiation. This is one area that leads us to creating in students a scientific habit of mind that allows them to transfer knowledge and apply it in unfamiliar situations.

Surprising enough, only some of the college science majors gave specifics as to how sunglasses prevent UV rays from reaching their target. For example, student 583 wrote: “This is because they (the sunglasses) were of much protection because they have UV protection which helps in protecting the rays from penetrating.” But students 366, 438, 449, and 452 gave responses that were relatively satisfactory even though they still had some errors.

Sunglasses have UV filters that filter out the sun’s rays. … (Student 366).

Thabo’s sunglasses protect against ultraviolet radiation. i.e. part of the radiation is reflected by the glasses and fewer are able to penetrate through causing a relatively lower or no harm. The nature of the waves of radiation is rendered less harmful as it passes through the glass causing no harm (Student 438).
It’s because the sunglasses absorbed most of the sun’s rays, even those that were not direct to them (Student 449).

The glasses must have contained very effective UVA, UVB, and UVC sun filters… (Student 452)

**Misconceptions Found in Student Responses**

It has already been alluded to the fact that questions in the open ended section of the questionnaire were informed by misconceptions that were already found in literature. By doing this part of the questionnaire, it was hoped that culture specific misconceptions about UVR and its effects on the human skin could be harnessed and added to what already exists in literature. It became apparent going through the students’ responses and coding for themes that there were commonly held explanations for why certain things happen the way they do that were not scientifically viable. Some of these misconceptions were common in lower end groups of students like the junior and senior single science students but most were common across the board.

The different ways of explaining phenomena are given with evidence from students’ responses. These themes were found through coding to appear in a lot of the scripts read. Some of the misconceptions are already documented in literature but others are specific to the situation in Botswana and are very much influenced by the way certain phenomena are traditionally explained, perhaps by the elderly who may not have conventional scientific explanations.

1. Sunscreen lightens or bleaches and is addictive to the human skin.
Most students believed that since Thabo was using sunscreen on daily basis, his skin had gotten lighter as a result. This made it more susceptible to suntan/sunburn. This is not to be confused with the fact that students had correctly observed that Thabo’s daily use of sunscreen made his skin less tolerable to harsh condition and could not naturally handle over exposure to excessive UVR like a similar skin that had not had constant sunscreen applied to it. I do not suppose that this can be equated with addiction. The students thought of it much like skin lightning creams would. Student 13 suggested “The skin was used to being applied chemicals, so when it got to be exposed to natural chemical sunlight and air there was a problem.” Student 32 put the misconception explicitly:

As far as I am concerned Thabo is using the sunscreen which makes him light in complexion when putting it but the time he is not putting it on his pigmentation darkens as a result of his skin is used to this sunscreen (SPF 35)

This characterization of sunscreen as a skin-bleaching chemical is not surprising as there have been times when dark colored people have used skin bleaching chemicals to lighten their skin colors. Such chemicals have adverse effects on the skin and hence students thinking that the sunscreen could be doing exactly the same thing to Thabo’s skin. This may suggest how difficult it may be for children to be introduced to sunscreen, as they may tend to think that it will damage their skins. There may be a lot of teaching and counseling that will lead to students knowing exactly how sunscreen works and that it is not a skin bleaching cream.
2. Running in the sun when it is hot and consequently sweating, causes sunburn/suntan.

Students across the board did not seem to realize that what causes the sunburn is UVR from the sun and not just any form of radiation. Students kept making reference to heat from the sun causing the sunburn. The hotter it is the more severe the sunburn was students’ thinking pattern. Some students therefore made reference to the fact that sun rays cool as they travel from the sun to the earth and in winter the effect is more pronounced and hence the less intense sunrays in winter. Students also seemed to think that the reason there is more sunburn in summer is because as a person sweats, dehydration sets in, contributing to the sunburn. Some junior school students’ responses to the questions in the questionnaire are:

*When you run in summer, you gain heat and end up having sunburn. He had been running all day so his body got hot and now he end up having sunburn* (Student 79).

*… the sun in winter is hotter than in summer…* (Student 74).

*In summer the sunrays reach the earth still very hot despite the fact that it is hidden in the clouds* (Student 76).

*The sunburn must have been a result of high temperature. The sun in winter is further away from the earth and so the sunrays are not as hot as in summer, when it is directly over the earth and the rays reaching the earth still hot* (Student 82).

The senior students also had similar conceptions that it was the heat that caused Thabo to have sunburn. Some senior pure science students responded to some of the questions in the following way:
Thabo must have been affected by the heat of the sun. … but the heat was trapped under the clouds … so he was exposed to too much heat which ended up giving him suntan (Student 288).

… the sun rays penetrated the clouds and heat the ground (student 287). Even though it was completely cloudy there is always heat in the atmosphere which can harm the skin (Student 292).

… and when you run a lot during the day you sweat a lot (student 293).

… the heat radiated from the sun makes the person sweat this increases the sunburn (Student 283).
It would have been different because in winter it is always cold no sunrays that can affect the skin like in summer (Student 289).

Yes there would be a difference because cooled air cools the body there will be less heat from the sun rays (Student 291).

… the rays are low and weak because it is cold (Student 298).

Yes, because in winter is always cold, and sun’s rays are not harmful than in summer time (Student 294).

Some senior single science students wrote:

… I think again the sunburn was caused by the sweat when he was running (Student 615).

By the time he was running, his blood was flowing very fast and it means that he gets more hotter and as a result, it acts as the sun. It could be better if he had applied the sunscreen before he could run (Student 504).

I think the temperature was though there was no sun. Sometimes it becomes so hot still without sun. It goes by temperature of the atmosphere (Student 593).

Yes, I think so because it is not so hot only sometimes but not as much. It goes by how temp ranges (Student 593).

Thabo was burned by the hot air in the atmosphere (Student 505).

Yes Thabo had sunburn even though it was completely cloudy because the sun rays can move as warm air around in the atmosphere so this warm air masses came in contact with Thabo’s skin that is why he had sunburn (Student 515)
College students had this misconception too but these were not as prevalent as was the case with the junior and senior students. Comments from both the science majors and the humanities students show that there were some who still thought at the level of high school or even junior school students.

*Even if there is cloud cover the temperature can be high. … so he was over working, sweating and fatigue contributed. More blood flowing to the skin* (Student 430 - college science).

*… he had lost most of the water from his skin due to lot of running* (Student 451 – college science).

*Yes, because in winter the temperatures are not high enough to cause sunburn and the sun is also dimmer* (Student 353 – college science).

*This means/shows that although the sun will be completely hidden under the sun, the heat from its rays can penetrate through the clouds, and producing as much harmful heat that is enough to burn people* (Student 586 – college humanities).

*… he had sunburn because though it was cloudy, the temperature was high.”* (Student 571 – college humanities).

*Yes it could have been different because in winter the sun’s heat is low compared to that in summer* (Student 586 – college humanities).

*Yes because the cooler air from winter’s cold could have balanced the condition by meeting the hot air from the sun to make a warm environment* (Student 589 – college humanities).

Students’ explanations varied, the key idea though was that heat was responsible for the sunburn as opposed to exposure to UVR. The ideas of blood flowing faster because it is hot or that when it is cloudy heat is trapped in the atmosphere thereby causing sunburn were very prevalent. It would appear that students seemed to confuse or equate sunburn with the type of burning that is caused by fire. It is still surprising though
since in other aspects of the questionnaire, they answered the questions in the right context. It is not exactly clear how they related sunburn to what the atmospheric temperature is.

One possibility could be that in Botswana, the summers are very hot with temperatures that can easily reach 70–85 F (100.4–127.4 °C) range. It is during such times that the UV radiation would also be very high and cause the most sunburn. The simultaneous incidence of high temperatures (that the students can feel) and high UVR doses (that the students do not feel or see) may give the students the wrong impression that the resulting sunburn is due to the high temperature because they felt it.

Another possibility could be a lack of terminology in vernacular that students could translate into the English equivalence. The students being second language English speakers possibly faced the same dilemma that second language users face, of having sometimes to start with vernacular and then find an equivalent English word. The level of complication becomes high when the word is not even an everyday use word but a technical or scientific one and the user is young and therefore less experienced with the second language.

The technical words like radiation, ultraviolet, sunburn, suntan, and others used in the study do not have direct vernacular equivalents and may have posed problems for the students. Heat and radiation can be used interchangeably in the local language. Translating the questionnaire into vernacular would not have solved the problem. If fact it may have made it worse as some words would not have their equivalents in the local language, we would have had to then use both languages. It is worthwhile to note that
students were given the liberty to express themselves in vernacular if they so desired or if it made answering the questions easy. Very few did.

3. The sun moves from hemisphere to hemisphere resulting in the seasons.

This came as a surprise to me as I thought student at the junior school level and up would know that the sun is the centre of the universe and does not move. They should know at this stage in their educational level that it is the earth that moves around the sun. This may be another good example of a case where students fail to transfer what they learned in class in one context to a context that they did not exactly use in class. This is where issues of scientific literacy become relevant. If the way we teach the student science is such that they can only understand contexts as they were presented in class, then we have a big problem because everyday problems do not come to us in the compartments that we have divided nature into. This issue was discussed at length in the literature review section of this paper.

A significant number if not all the junior students had no idea why Thabo’s sunburn would have been different in winter. An indication perhaps that this was something that they may not have been taught formally before. Their simple response was to write that since it is cold in winter, there should not be as much sunburn as in summer. The misconception here came from a significant portion of the college students, especially college science majors.

Yes, in winter the sun is facing away from the earth, so the sunrays are not as strong as if it is summer (Student 356).

Probably not since the sun is usually not strong during winter (Student 358).
Yes it was going to be better in winter as now the sun had moved to another hemisphere increasing the distance between Thabo and it (sun) (Student 364).

In winter the sun is further from the earth hence lowering the penetration power of the sunrays (Student 371).

Yes, the sun’s rays are not as harmful in winter due to geographical reasons of where the sun is, the southern hemisphere will be further away from the sun than it is in summer (Student 660).

All the students above are college science majors except student 660 who is a college humanities student. Whereas these students have some idea that the intensity of the sunrays would be different in winter than they are in summer, their rationale for the differences are not exactly in line with what is accepted scientifically. This could be due to poor expressions in writing the answers but it looks like its more than just students’ inability to write expressively.

4. Sunglasses protect the eyes by making a shade/shadow over them.

This was a very strange reasoning that most students had. It did not seem to register to students that in order to make a shade, the object must be opaque to light and also that the culprit in sunburn was actually UV light as opposed to visible light from the sun. Students across the board wrote more or less the same things, that the shade made by the sunglasses protected the area around Thabo’s eyes, thus explaining why it did not have sunburn.

Because he protected himself from the sunrays and he got the shade from it (student 67).

Because some sunglasses can also protect sunburn so, because he covered himself with them, they intended to protect his skin from heat (student 72).
The sunglasses made a shade and protected the area around his eyes (student 596).

Because it was under-shade of the glasses and I think it was not open that much that can cause sunburn to him (student 615).

The first two students are junior school students and the last two are senior single science students. As was mentioned previously, these students did not seem to look at the interaction between light and the sunglasses using the wave properties nature of light. In order that the sunglasses protect Thabo from the sunrays, they ought to be able to interact with the light from the sun. These interactions can come in the form of a reflection, refraction, absorption, and scattering that are normally associated with interaction of waves with matter. Students who realized this interaction mostly picked on the reflection aspect only and very few in the college science majors were able to include absorption of UV light.

There is a commonly used language in Botswana to refer to sunglasses as “shades”. This arises from the fact that they do cover one’s eyes with a shade but not that it is the shade that protects the eyes. There is a likelihood that this loose use of words could have contributed to students’ thinking that the shade made by the sunglasses effective in protecting the eyes. This may suggest that teachers ought to be aware of everyday usage of terms or words that are likely to conflict with scientific development of concepts and whenever possible, address the misconceptions that are likely to surface.

5. Ultraviolet rays from the sun can linger around in the earth’s atmosphere and still affect people.
This is related to misconception number four already discussed. UV rays are waves just like other waves and are changed by interaction with matter. It is therefore not possible for them to linger around in the same form even after interacting with matter. Students also seemed to think that UV rays reflected off the earth surface would still be UV rays and could possibly affect people. They most discussed this in relation to green house effect saying that more heat would translate into more sunburn. It was nevertheless interesting how students formulated explanations that were, to them, consistent with a lot of their observations.

To students, heat causes sunburn. Heat from the sun, and sometimes UV rays linger around and are concentrated by cloud cover causing more heat, which leads to pronounced sunburn. This led students to come to the conclusion that the sun’s UV rays are stronger under cloud cover than in direct sunlight. On and by itself, this conclusion does not make sense, but seen in the light of their reasoning, then it should really work.

*Thabo was burned by the hot air in the atmosphere* (Student 505).

*Yes Thabo had sunburn even though it was completely cloudy because the sunrays can move as warm air around in the atmosphere so this warm air masses came in contact with Thabo’s skin that is why he had sunburn* (Student 515).

Whereas these misconceptions came from students’ responses to the questionnaire, it must be emphasized that they cannot be generalized to the student population. There were students especially in the senior pure science and college science majors that gave very seasoned and scientifically sound responses to some of the question even though not one student gave acceptable responses to all of the questions. Some
students figured out certain questions whilst others figured out different ones. It would be interesting to see how students do if these misconceptions could be put in a questionnaire form and administered to them.
DISCUSSION, SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

This study attempted to determine if the Botswana educational system teaches students such that they are in a position to be informed on a central health issue that is peculiar to the country or region. Interest was also on whether the type or amount/depth of science topics covered at the different educational levels influenced the type of understanding about health issues that students end up having. Specifically, answers to the following questions were of particular interest.

1) Are Botswana students at all educational levels:
   
a. aware of the effects of UVR on the human skin?

   b. aware of simple procedures for protection against UVR?

   c. able to answer simple questions related to UVR when given in a context they have not seen in class before?

2) Are there differences in knowledge by school type (junior high, senior, and college), school location (urban vs. semi-urban)

3) Are there differences for the senior secondary students depending on the type of science the students do?
4) Are there any differences in knowledge about UVR by gender?

Summary and Conclusions

Science Education Reform and implications for Botswana

The science education reform in the US has made key strides in developing a robust educational system. The scientific and technological success that the nation has enjoyed to be the wealthiest nation in the word attests to this success. Not everyone agrees with this reasoning. Schmidt and Wang (2002) came to the same conclusion albeit at a different wavelength. They concluded that the science education reform movement recognized that what needed to change in order that reform could be achieved was the curriculum. The many attempts made in time past were to Schmidt and Wang, fragmented and called for a focus on what students needed to know and be able to do at the end of their formal schooling.

Schmidt and Wang (2002) concluded their evaluation of the reform movement by emphasizing that unless the curriculum is focused and coherent, policy and practice would continue to produce teachers who are ill prepared to teach science. The situation in the US is such that centralizing the curriculum would be a daunting task because of the size of the country. The Botswana situation on the other hand lends itself to such an arrangement because of the size of the school system. Monitoring reform and formulating policies can be a task that is achievable and may not require a lot of resources provided key steps are put in place to make sure that teachers are prepared and ready for the
change that is to occur. Teachers would need to be prepared both mentally and professionally.

Change is a very difficult process, more so when it involves human beings. The sheer size of US has made rapid change very difficult. The decentralized nature of the school system both at the federal and state levels has meant that effecting change takes a long time for it to trickle down the system. This is not to suggest that decentralizing an educational system is a bad thing, it has its own merits but may make change an especially a daunting task.

Schmidt and Wang (2002) concluded of the TIMSS study that its relevance to the science education reform movement in the United States could be appreciated in term of the organization, coherence and rigor of the curriculum. Used this way, the TIMSS study serves as a basis for hypotheses generation about what needs to be done to improve science education.

Most if not all institutions of high learning that are involved with the preparation of science teachers have seen and made the connection between good educational programs and teacher success in the classroom. We have suggested, based on literature review, a model for science education reform that some institutions in the US are already practicing albeit in a non-systematic way. It has become apparent that there is need for a concerted effort in the training of science education teachers. All parties involved in this training should work together in a seamless manner and produce teachers who do not only master their content but also the art of teaching.
Professors teaching content need to aim at not only getting their content to students but also a sense of conceptions underlying their trade. This will not only aid science students understand science at college level but will also help those that go on to be science teachers to be better teachers with a better conceptual ecology of their teaching subjects. This is made an imperative by the fact that science even for developing countries is no longer just for the chosen few. There is need for all to have enough exposure to science to be able to function well in this world driven by scientific and technological developments. Life is becoming more and more a matter of the choices that we make as individual on a day-by-day basis. Health, politics, the environment just to name a few dictate that one has to have some basics of science to make wise decisions.

Botswana as a small developing country with a very centralized educational system is well suited for the model proposed. It would be a lot easier to try it out and test its success. The small school system will make change easy to manage and monitor. Results can also come quicker than in a big system such as found in the US and other developed countries. Resources may pose a challenge. A lot of the professors in the sciences may need incentives that would lure them into agreeing in the first place to participate in whatever cooperative efforts are planned between them and the education professors. They are not likely to want to participate in something that they know will not bring a lot of bearing towards their promotions.

Once such change has occurred, bringing science literacy to the student population would be an effortless endeavor. More areas that are pertinent to human life and survival can be infused into the curriculum without compromising the quality of
science education that ensues in each classroom. Students who live in a country like Botswana should know about the effects of UV radiation on the human skin. They should also know about effective ways in which they can protect themselves from these rays.

It is not a matter of whether or not they have been taught such a topic or concept but of when it will be taught to them. It is a matter of life and death to them. Botswana, as have other countries in the Sub-Saharan subcontinent, has been hit hard by the AIDS/HIV pandemic. A link has been made between depletion of the immune system and over-exposure to UVR. This is not something that can be taken lightly. What do Botswana school going children know about UVR? To answer the question we turn to the sun questionnaire results.

One major thing the reform movement in the US has clearly come up with is the emphasis that science should have on what students learn. Science is very practical subject. Scientific literacy therefore deals with the practical applications of science one of which is the science and society debates. Students should practically apply what they learned in their science lesson in the decisions that they make related to the application of science in society. What health threats do certain applications of science pose to the people in the area? The reform has thus helped prioritize issues that should be addressed in the science standards. It is perhaps in light that the results of the reform movement can have directions to bear on what developing countries can do. What priorities should be set for the science curriculum in Botswana?
Major Findings

Do Students Generally Know Anything About UVR and Effects on the Skin?

Over all the Botswana school system students do not seem to know as much about the effects of sun exposure as one would like it to be the case. Of the four indicators (factors) of knowledge of UVR and its effects on the skin, t-test results showed that students differed significantly from a test score of three on all four indicators. A test score of three was the midpoint of the Likert scale where a three was equivalent to “Don’t Know” as opposed to neutral. It was argued that students in Botswana would feel compelled to make a commitment to answer if the neutral point was phrased differently than it usually is because of the culture that prevails in the country. It is not likely that a student can acknowledge not knowing an answer to a question and would therefore be compelled to choose one of the other options, which was what was desired.

This suggests that students in the country are not generally aware of the effects of UVR on the human skin. They are also not aware of simple procedures like the use of hats and clothes made of cotton when they are exposed to the sun. The use of sunscreen was an alien concept to them as shown by their responses to the open ended section of the questionnaire. In fact, at one of the sub-urban schools that I administered the questionnaires, one student called me and asked me what sunscreen was. I was thrown off by the questions as I had expected them to at least know what sunscreen is and what it is used for. It can also be concluded that given context specific question on familiar concepts, the students failed to make sense of things that they would otherwise have been able to make sense of.
The topic of UVR is not covered in the school syllabus at the junior and senior levels. There is a likelihood that the science major at college might cover aspects of it but not as it relates to human health. The senior secondary science syllabus has UVR as part of the electromagnetic spectrum. There is no mention of what depth should be covered when the topic is discussed. Since most of the science teachers are products of the same system, they are less likely to explore the environmental aspects of UVR especially if they are not compelled to do so. It is no wonder then that the students are generally not exposed to ideas of UVR. This is a strange finding given the prevalent high UVR in the country.

These findings bring us to the idea of scientific literacy in the 21st century. What should students that graduate from our school systems be able to do once they are out in the world of work? What is the purpose of school? Only to secure us good paying jobs? Should schooling also make us more informed citizens? What topics, issues, and concerns should be addressed by science education in the school system? Shouldn’t we expect a student who has graduated high school to know about environmental issues that pertain to his/her health enough to know what precautionary measure to take to protect himself or herself? Is this asking for too much from a school system? This is only a tip on the iceberg. Science education, of all the subject taught in the school curricula, should be more relevant to student lives than ever before because their lives depend on it.

The recent scares on AIDS, SARS, bird flue and who knows what else is coming our way, demand that students and the citizenry in general know how to use their science knowledge to make better more informed decisions. A lot of these decisions have to be
made at a more personal level as business professional begin to weigh the benefits of profits in traveling against the risk of getting such diseases if one chose to travel despite warnings not to. The finding that the Botswana students do not know more than is expected from them is a sobering one. Curriculum developers should make attempts on frequent and periodic time scales to research on issues of both human and environmental importance and infuse them into the science curricular. The issue of UVR and its effects on the human skin is one such issue given the adverse effects that UVR has on the skin of color.

*Differences Among Students*

The four indicators used to look into students’ understanding of UVR proved to be very good indicators since they were able to separate the students on a number of ways. The multivariate test statistic for school type was significant, Wilk’s Λ = .925; F$_{18, 1502} = 7.449; \ p = .000; \ Eta^2 = .038; \ Power = 1.00$. This answers the research question that asked if there were differences in knowledge by school type. Indications from the univariate tests show that there were certain aspects of the indicators for knowledge of UVR and effects on the human skin that they knew more than others. For example, there were no significant univariate differences on the Items and General factors but the Diseases and Misconceptions factors had significant differences. It should be noted that very stringent conditions of 98.33 % confidence level were used since a number of tests were going to be carried out.
**MANOVA results lessons**

The interaction between the school type and gender complicated interpretation of the results for this test. The multivariate test for gender was not significant, Wilk’s $\Lambda = .987$; $F_{(4, 751)} = 2.384$; $p = .050$; $\eta^2 = .013$; Power = .526. None of the univariate tests were significant either. But simple effects tests showed that the males and females differed on the misconceptions factor ($F_{(1, 754)} = 12.37$; $p = .001$) at the senior school level (Wilk’s $\Lambda = .976$; $F_{(4, 751)} = 4.56$; $p = .001$).

A two-way MANOVA by school type and gender gave a significant multivariate interaction between school type and gender. The cause of this interaction was determined to be the differential performance by male and female students at the senior school level across the factors. Specifically, the male and female students at the senior level performed differently on the misconceptions factor ($F_{(1, 754)} = 12.37$; $p = .001$).

Table 4.9 shows the means by gender for the different factors. The mean for the senior males for the misconceptions factor was 3.171 whilst that for the females was 2.901. The female students thus performed better than the males on the misconceptions factor at the senior level. The differential performance at the senior level and not the other levels is not easy to explain. It would have made sense if the differences were at both the senior and college levels and not the junior level as it would be argued that the male and female students are not mature enough to know any better.

Another interesting finding is that Table 4.9 does not show significant differences anywhere else in factors by gender. Overall though, the means for the different gender groups are: (a) Junior level, male = 2.837 and female = 2.815, (b) Senior level, male =
2.841 and female = 2.780, and (c) college level, male = 2.810 and female = 2.850. These were not tested for statistical significance in this form as factors were used and tests performed based on them.

The male-female differences though can be explained by the observation that women are generally more informed on issues that affect their skin, especially facial skin. This is at least true in the Botswana culture. There is even a saying that tries to justify it, that can be directly translated that men are not supposed to be beautiful or handsome. As a result of this cultural dispensation, it is seen as being a sissy if a man spends time or money on his skin. Since the effects of UVR are more pronounced on the facial skin on the black population, it should be expected that the knowledge that moms and sisters have about taking care of the facial skin is likely to rub off onto the girl child than the boy child.

Difference by science types was one of the most important classification variables in this study because of the importance of science in technological developments and scientific literacy. By default, one would expect to find advantages in doing a science that is more involving such as the senior pure science than one that is less involving like the senior single science. One would wish still that the senior single science should be such that it gives the students enough grounding in science issues to make them scientifically literate citizens. This is more important because for a large majority of these students, this is the last time that they are doing science in a formal setting and are not likely to follow careers that are science based.
The multivariate test was significant at the 98.33% confidence level (Wilk’s Λ = .857; $F_{(16, 2298.036)} = 7.439; p = .000; \text{Eta}^2 = .038; \text{Power} = 1.00$). Finding significance with such a stringent test is a convincing evidence for differences by science type. This is a consoling finding as I regard this variable as very key to the study. The Items factor was the only one that did not give significant univariate test results. Despite the weak power (.409) and small effect size (.010) associated with the test, one would still have expected differences here by science type.

The Items factor dealt with items that covered what can be used for protection against UVR. Students surely should know what works and what does not work based on the properties of UV rays. Despite the weak power and small effect size, the fact that there were no significant differences across the sciences on this factor leaves much to be desired. College students at the very least should have differed from the junior students. There are two ways of looking into why there were no differences between the different science groups when they were expected.

It could be that the statements were stated such that one did not need to know much about UVR to answer them or that all the different groups did not know any better than the other in which case it would not matter how the statements were phrased. Either way, the bottom line is that the students did not differ on the factor and based on the t-test results, which suggested that the students were above the test score of three, it can be concluded that they did not know what items are better than others for protection against UVR.
The Diseases ($F_{(4,755)} = 4.114; p = .003$), Misconceptions ($F_{(4,755)} = 18.544; p = .000$), and General ($F_{(4,755)} = 5.258; p = .000$) factors gave significant results at the .0167 \( \alpha \)-level. To determine how differences arose, stepwise pair-wise group comparison showed that different science groups performed differently on the factors considered. The results help us determine somewhat how the different sciences prepare students to deal with environmental issues like the UVR one, for which they did not receive formal instruction. The results were a crude measure of the scientific literacy level of the students based on the argument leveled earlier that science instruction should be such that it prepares students to function well and make informed decisions on scientific issues.

The junior science/senior single science and senior pure science/college humanities pairs did not have significant differences on the four factors considered. This attests to the weakness of science that is done by the senior single science students. It was mentioned before that the majority of students who go on to do the humanities at college would have done high school single science. The college humanities students were no better after completing two years of senior single science than the senior pure science students who had just started their senior schooling. Whereas there could also be an element of science aptitude, where the students who follow certain science streams are self-selecting, one would still expect that science instruction should play a major role in influencing how these students responded to the questionnaire.

The same argument used for the senior pure science/college humanities pair can be used for the junior science/senior single science students. The senior single science students were in their first year of senior school and had completed their three years of
junior science and yet could not do better than the junior students who had just started their first year of junior science. An argument can be made that the content covered in the three years of junior science was not enough to make students aware of the adverse effects of UVR on the human skin.

It is sad to note that progression from junior to senior schooling is at about 50%. These poor students have reached the end of their formal science instruction and yet do not know enough to protect themselves against a very common natural element – UVR that is so prevalent in the part of the world where they live. The school system has failed to prepare them for the future roles that they are going to play as leaders of the nation. And yet it is this generation of students that will be hit hard by technological developments in their life time that will require that they know enough to make informed decisions regarding their own health and that of the communities in which they live.

It would seem appropriate to recommend a serious revamping of the senior single science curricular. Besides the fact that this was a very subject specific research, there has been evidence that the senior single science is really very weak and will not afford the students who graduate with it under their belt to survive in this technologically advanced global economy. It simply does not teach them enough to have a scientific habit of mind as has been argued in the science education reform literature.

The rest of the student science groups differed, as one would have expected given the progression of the students through the educational ladder and or maturity. For example, the senior single science students differed in performance from the senior pure science students. It can be concluded that the students generally differed based on the
type of science they were enrolled in. It therefore goes without saying that in order that students become aware of the effects of UVR on the human skin, know what things would be beneficial in using for protection when one is exposed to excessive amounts of UVR, be aware of possible diseases, and dispense of general misconceptions on UVR, a good understanding of science judged by the kind of science one does is needed.

A test to look into differences by school location was performed for the junior and senior school students only since the only college involved in the study was located in an urban setting. The test ended up a bad test. The effect size was only .003 and a power of .068 for the test. This test yielded non-significant multivariate results, Wilk’s $\Lambda = .9997$; $F(4, 524) = .420; p = .794$. We concluded therefore that there were no differences between the urban and semi-urban student populations in the Botswana school system. This finding goes against intuition as one would expect that urban students would be more exposed to issues of health and especially as it relates to how to better take care of the facial skin. This is so because the most drastic manifestations of the effects of over exposure to UVR would be on the facial skin in the form of pimples, acne, wrinkles, and pigmentations.

Since there is only one university in the nation, it was difficult to design the study such that proper results would be attained. There had been plans to include three–year colleges of education that prepares teachers who teach the junior schools students as well as those who teach at primary schools. Such an inclusion may have yielded better results as such colleges are at both urban and sub-urban settings. Financial considerations
mitigated extending the study to such institutions. It would be interesting to find out how a study that includes colleges would look like.

There had also been thoughts at the early stages of the study to included institutions that train the nation’s nurses and health personnel. It was thought that since they do content that is directly related to health, they would know better than their counterparts at the colleges of education. A study that compares the nursing colleges and colleges of education students performance on the scale used in this study would be an interesting one that can perhaps be more enlightening and generate some more hypotheses.

On a more tangential route it was interesting to find that some factors were more important than others in differentiating between students. For example, the Misconceptions factor contributed the most to pair wise differences between groups. Another way of looking at it was to look into the standardized canonical discriminant function coefficients and see how much each factor contributed to the function. Table 4.14 shows that the Misconceptions factor was the most important in function one, which accounted for 87.9 % of the variance. The next important function accounted for only 8.5 % and had the Diseases factor as the prevalent factor. Thus items present in these factors made differences between student groups by science more pronounced.

Qualitative findings

The qualitative findings show some very serious problems with students’ conceptions of electromagnetic radiation in general and UV light as was presented in the
study. Students at the junior level were not expected to know much about UV radiation as it relates to the electromagnetic spectrum, but it was expected that they would have what could be classified as common knowledge about UVR as it relates to the human skin.

Misconceptions are a big problem in students. They are easy to form in students’ conceptual ecologies, but once formed, are very difficult to deal with and correct. The idea for example, that students think of sunscreens as skin lightning creams creates problems when it comes to policy implementation. Government may adopt policies that would attempt to help students deal with the hash conditions that they find themselves in, but it may take more than just implementing policy as the students may not be willing to risk putting their facial skin through the trauma that skin lightning creams cause.

The misconceptions and alternative explanations that students have bring along serious implications for classroom teaching. Methods that teachers use to teach these concepts would have to be more than the conclusions that are typical of discourse in science classes, especially in developing countries. Strategies would have to be used that make students move from the conceptions they hold, to those that are scientifically accepted. This is not an easy task. Research shows that misconceptions are very difficult to deal with and correct. This calls for more than just infusing topics into the curriculum, but perhaps also a mandate for teaching methods that would address these issues better.

**Recommendations**

The object of this study was to find out if the science content taught to students in the Botswana school system throughout the education ladder was such that it prepared
them to be aware of key health issues related to over exposure to UVR. UVR was a topic of choice because of the geographic location of Botswana that makes her prone to high UVR indexes in the summer months, making it imperative that the citizenry is aware of the dangers involved in being over exposed to such elements. With the world becoming more and more scientifically and technologically advanced, there is consensus in literature (See for example Marshall, Scheppler, & Palmsano, 2003) that citizen are aware of the consequences of making decisions, not only for their own lives but also for those they live with.

This study found out that in general, the Botswana students are not exposed enough about the effects of UVR on the human skin and what measures can be taken for protection. It had also been found out that the amount of science taken by students in certain quarters does not seem to have an impact on what they end up knowing or how they end up thinking as it related to UVR. There was a strong correlation between the type of science one does or did and the level of comprehension demonstrated in responding to the questionnaire. The science at the junior level seems to be ok, but there are serious question marks about the senior science, especially senior singles science. It seems to be too shallow to be of any effect on the outlook that students have on issues of environmental health like UVR effects on the skin.

Perhaps the lowest level science at the senior level should be the pure science that seemed to expose students enough to enable to them to think outside what they were taught in class. Such a change will not come without a cost, but such a cost would be
worth all the efforts if it means protecting the future leaders of the nation and the citizenry in general.

The recommendations that follow are based on both the literature that was surveyed for this study and the findings from the knowledge of UVR and its effects of the human skin. It has been emphasized throughout the text that the small size of the Botswana educational system makes it a very good candidate for a successful educational reform movement in science education. A lot of effort will still be needed from the parties involved. The biggest huddle to overcome may not be attitudes of those that have to be involve, but may be the financial commitment that government would have to make to bring about such a change.

The Botswana Government through the Vision 2016 initiative is committed to a building:

- a prosperous, productive, and innovative society
- a just and caring society
- an educated and informed society
- an open, democratic, and accountable society, and
- a moral, ethical, and tolerant society.

I have lamented a lack of explicit documentation of the role that science and technology education should play in the carrying out of the vision and making sure that it comes to fruition. The vision called for the formation of what it called the science and technology council. One hopes that such a council will be more focused in directing the infusion of science related issues into the vision.
It is therefore recommended that:

Policy Recommendation

1. The science and technology council called for by Vision 2016 be set up as soon as possible to look into issues of science education reform. The science syllabus throughout the Botswana educational system should be revamped and made more robust and comparable to what is going on in other nations of the world. It is felt that the science taught at senior level for the single and double award sciences is too shallow to be of any help to students.

2. The science curriculum should be revisited in an attempt to address the need for science in Botswana to address factors that affect society and are science related. The science curricular should be seen to be relevant and applicable to the needs of the nation and address issues that are pertinent to the survival of the individual and society at large.

3. There should be established at the University of Botswana some means to address the way science is taught to create what is equivalent to initiatives like first year experience in the American universities. This will ascertain that the teachers that the university graduates have a better understanding of science concepts and posses a better subject matter knowledge, pedagogical knowledge, and pedagogical content knowledge in line with Zeidler’s (2002) dissection of teaching. This may come in the form of collaborations with science education professors/lecturers or initiatives to give support to
professors/lecturers in the faculty of science regarding teaching. This is the
direction that reform in science education has taken in US and it seems to
work a lot better than anything that has been tried so far.

4. Information on UVR and its effects on the human skin should be infused into
the science curricular in the Botswana education system from as early as
preschool. This is a matter of health. The same was done with AIDS. Our
outlook as a nation will depend on our knowledge of what our climatic
conditions demand that we change our live styles and become aware of the
dangers to our existence that it poses. This should come as a major
governmental initiative like it is the case in other similarly affected countries
like Australia.

5. Even though misconceptions are very difficult to dispel, they can be very
good tools to aid teaching and development of lesson plans that address issues
that students identify with. This is a skill that teachers nationwide would need
to be taught through in-service and professional development initiatives.
There need therefore to tailor the curriculum for pre-service teachers to use
strategies that specifically address conceptual change methods so as to address
such issues. Professional development initiatives should also aim at aiding
teachers in such new classroom strategies.

6. Information on the conditions of UVR should be made readily available in
ways that will be easy for Batswana to access nationwide. Specifically, it
should be made a part of the national weather forecast throughout the year, not
just in the summer months. This is because it has already been made clear that the UVR level are even moderately high in the winter months. This would also help dispel the misconception that sunburn cannot occur in the winter because it is cold.

**Research Recommendations**

7. This study can be modified, especially the instrument, to improve on its Chronbach alpha values. The more reliable instrument could then be used to include other groups of students like the students in the teacher preparing colleges as already alluded to. This would make comparisons at post secondary level more meaningful and provide semi-urban counterparts to the urban students at the college level.

8. A more interesting study may be to exclude secondary school level students and compare the health colleges that prepare nurses with other three-year colleges like those that prepare teachers. It would be interesting to find out how health students cope with what is going on in the world of science and technology as it relates to their area of study. One would expect the health students to be miles ahead of their teacher counterparts.

9. A more national study that does not only involve UVR but that seeks to look into other areas of critical change in the science education reform marathon is in order. For example, Botswana is a completely landlocked country with very scarce rain. Because of the scarce rain, surface water is a very precious and
rare commodity. The curriculum should be such that it addresses issues of application to technology and other related science topics that deal with such conditions. Such a study would be exploratory in nature, from which it can be determined how the curriculum should be improved to serve the nation. There is need to, from time to time, look into what needs to be infused into the curriculum to better serve the needs of the students. Science should not just be taught for the sake of science but should serve a very specific purpose in the students and the citizens in general.

10. Perhaps as a side note, it was determined that the Misconceptions factor made the most contribution to the multivariate pair-wise differences between groups followed by the Diseases factor. It may be of interest to also look into indicators of UVR and its effects on the human skin and systematically determine which are more important than others. Such a study would help inform curriculum developers to looks into areas that need emphasis. Teachers would also be in a position to address such areas to make sure that students leave school prepared to face whatever goes on out there.

11. A model for science education reform based on literature studied for the study was developed and presented in chapter two, but was not looked into as it was not the center of the study. This model seems viable for a small and centralized educational system like Botswana’s. There is therefore a need to design a study that could look into the implementation of a science education reform model like the one proposed.
APPENDIX A

SUN EXPOSURE AND THE SKIN QUESTIONNAIRE

Dear fellow student

This questionnaire seeks to measure your understanding about sun exposure and its effects on human health, particularly on the human skin. The questionnaire is divided into three equally important parts. Part I asks information about you. Part II is a list of general questions about the sun and its effects on human health. Finally part III presents you with a scenario and you are asked to answer open-ended questions related to that scenario.

This exercise should help you think about the possible effects of the sun’s rays on the human skin. Please respond to all parts carefully and diligently to the best of your ability. Your participation is very important and valuable. All responses will only be used for the purposes of this study and nothing else. Write your name on each sheet of paper used. Thank you for participating. For further information, contact Shanah Suping at The University of Botswana, Faculty of Education in the Department of Mathematics and Science Education.

Part I: Demographic Information: Circle all those that apply to you.

1. Gender  Male  Female

2. Age bracket  [12-16]  [17-20]  [21-25]  [>26]

3. School attending

   Junior School  Senior School  College

4. Subjects

   Integrated science  Single science  Pure science  College science  Humanities
### Part II: General knowledge.

For each of the statements below, mark with a cross in a box that best describes how you feel about the statement.

*SA=*Strongly Agree  *A=*Agree  *DK=*Don’t Know  *D=*Disagree  *SD=*Strongly Disagree

<table>
<thead>
<tr>
<th>Statement</th>
<th>SA</th>
<th>A</th>
<th>DK</th>
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<tbody>
<tr>
<td>1. You can get suntan/sunburn on a completely cloudy day.</td>
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<td>2. To work best, sunscreen needs to be applied at least 30 minutes prior to sun exposure.</td>
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<td>3. The sun’s rays are most dangerous between 10 am and 4 pm.</td>
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<td>4. I only need to protect myself from the sun in the summer months.</td>
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<td>5. Sun bathing is good for vitamin D production in the human body.</td>
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<td>6. Using sunscreen can protect me from the sun’s harmful rays.</td>
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<td>7. All sunglasses can protect eyes from harmful rays from the sun.</td>
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<td>8. People of all skin types are equally at risk of skin cancer due to excessive exposure to the sun.</td>
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<td>9. An umbrella is good for protection against the sun’s harmful rays.</td>
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<td>10. Too much exposure to the sun darkens the skin in dark skinned people.</td>
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<td>11. Too much exposure to the sun leads to skin problems like pimples, acne, and pigmentation.</td>
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<td>12. Too much exposure to the sun during childhood leads to wrinkles and premature aging of the skin at adulthood</td>
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<td>13. People with a darker skin are more likely to get skin cancer due to exposure from the sun than are light skinned people.</td>
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<td>14. Being exposed to the sun from a very young age to around age 20 increases my chances of getting skin problems or skin cancer.</td>
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<tr>
<td>15.</td>
<td>Bathing thoroughly after exposure to the sun can help prevent skin problems associated with sun exposure.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16.</td>
<td>Sunscreen with SPF 15 protects better against the sun’s rays than one with SPF 30.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17.</td>
<td>The dark colored skin can get used to the sun’s rays and protect itself from further damage by becoming even darker.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18.</td>
<td>Most skin cancer types can be cured if diagnosed early enough.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19.</td>
<td>Not all skin cancer types are fatal.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20.</td>
<td>If I apply sunscreen to my body, I do not have to worry about how long I am exposed to the sun.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21.</td>
<td>Water in a swimming pool can act as a sun block and protect me from the sun’s harmful rays.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22.</td>
<td>In a breezy day, when your skin feels cool, your skin will not be as affected by the sun’s rays as when it feels hot.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23.</td>
<td>Playing in a swimming pool in a hot sunny day may increase the intensity of the sunburn than playing in the open field.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24.</td>
<td>Clothes made of cotton are better at protecting against the sun than those made from man-made materials like nylon.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25.</td>
<td>Most sunscreens protect us from all the three ultraviolet ranges (UVA, UVB, &amp; UVC)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26.</td>
<td>All three ultraviolet light ranges (UVA, UVB &amp; UVC) are equally harmful to the skin.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>27.</td>
<td>It is ok to get as much skin tan as you want if you put on sunscreen.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28.</td>
<td>Excessive sun exposure eventually lowers the body immune system.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>29.</td>
<td>Using UV protective sunglasses from an early age can help prolong one’s eyesight.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Part III: Use of sunscreen

Read the scenario about Thabo below. Use the information in the scenario and any general science knowledge you have to answer the questions that follow. Be as clear in your answers as possible. If you think sketches can help in explaining your responses, feel free to use them in addition to the words that you use. If you need extra space, use the back of the paper for each of the questions. (Feel free to use any Setswana words that you do not have an English equivalent of).

Scenario

Thabo is a dark skinned city young man who works indoors most of the day. He uses a very effective sunscreen (SPF 35) on his face and neck every morning. One particular completely cloudy summer morning, he left for the cattle-post and thought that since it was cloudy, he did not need to use his sunscreen. He spent the whole day running the errands at the cattle-post under cloud cover but in the open. He was not under any shade for most of the time. He however, out of being used to it, had his sunglasses on the whole time he was working.

To his surprise, when he got back to the city, he found that he had very serious suntan/sunburn and his skin had gotten darker. So serious was his condition that he was embarrassed to go to work the following day and took a day off as a result.

Question 1

Thabo had suntan/sunburn even though it was completely cloudy. Explain in detail.
Question 2

(a) Explain in detail why he had particularly serious suntan/sunburn on this day.

(b) Would Thabo’s “particularly serious sunburn” condition been any different if it were winter? Explain in detail.
Question 3

The area around Thabo’s eyes that was covered by his sunglasses did not have sunburn at all. Explain in detail.

Thank you for participating in this questionnaire. Your response will be treated with utmost confidentiality.
Letter to Ministry of Education – Botswana Government

623 Start Ct
Columbus, OH
43210
USA

September 8, 2003

The Permanent Secretary
Ministry of Education
P/Bag 005
Gaborone
Botswana

RE: REQUEST TO CARRYOUT AN EDUCATIONAL STUDY IN BOTSWANA

Dear Sir/Madam

My name is Shanah M. Suping. I am an academic staff member with the University of Botswana currently on study leave at The Ohio State University in Columbus, Ohio in the United States of America. As part of my PhD requirements, I intend carrying out a study in the Botswana school system entitled:

Science Education Reform In The US and What a Developing Country Can Learn From it: The Case of Botswana with the Effects of Ultraviolet Radiation on the Human Skin – An Educated and Informed Nation.

This study looks into the effect of ultraviolet radiation on the human skin, as an example of an area that may necessitate curricula reform to meet the health needs of students and the population in general.
The issue of sun exposure and its adverse effects on the human skin is pertinent to the school age going students and participation in this study will at the minimum, make students think about the many things that can most likely happen to the skin that is over exposed to ultraviolet radiation.

I therefore write to request permission to administer a questionnaire to students in the Botswana school system. Once permission is granted, I will write to the individual schools that I want to visit to ask for permission to administer the questionnaire to their students. The questionnaire should not take more than 45 minutes for the students to complete.

Participation in this study is completely voluntary and students who do not wish to participate will not be disadvantaged in any way.

Attached is a copy of the questionnaire for your perusal.

Your assistance in this regard will be highly appreciated.

Thank you,

________________________________________________________
David L. Haury (Principal investigator)  Shanah M. Suping (Co-investigator)
Permission Letter to Schools

The Headmaster
Name of school
Address

Attn: Senior teacher – Guidance and counseling

Date:

RE: REQUEST TO ADMINISTER A QUESTIONNAIRE IN YOUR SCHOOL

Dear Sir/Madam

I am doing a study titled:

Science Education Reform In The US and What a Developing Country Can Learn From it: The Case of Botswana with the Effects of Ultraviolet Radiation on the Human Skin – An Educated and Informed Nation.

This study looks into the effect of ultraviolet radiation on the human skin as an example of an area that may necessitate the curricula reform to meet the needs of students and the population in general.

The issue of sun exposure and its adverse effects on the human skin is pertinent to the school age going students and participation in this study will at the minimum, make students think about the many things that can happen to the skin that is over exposed to ultraviolet radiation.

I therefore write to request permission to administer a questionnaire to your students. I need only two classes in your school. The questionnaire should not take more than 45 minutes for the students to complete.

Participation in this study is completely voluntary and students who do not wish to participate will not be disadvantaged in any way.

Attached is a copy of the questionnaire for your perusal and permission to conduct research from the Ministry of Education.

Your assistance in this regard will be highly appreciated.

Thank you

________________________________ _____________________________
David L. Haury (Principal investigator) Shanah M. Suping (Co-investigator)
PARENTAL CONSENT FOR PARTICIPATION IN RESEARCH

Dear Parent/Guardian,

I write to seek permission for your child to participate in a study I am currently conducting entitled:

Science Education Reform In The US And What A Developing Country Can Learn From It: The Case Of Botswana With The Effects Of Ultraviolet Radiation On The Human Skin – An Educated And Informed Nation

This study seeks to find out how much Botswana students know about ultraviolet radiation and what it can do to the human body. Participation in this study is completely voluntary. Your child’s participation though will help us find out what the Botswana students know about this topic and may help us change the science syllabus so as to address issues that are important to our health as human beings. I therefore encourage you to consider allowing your child to participate in the study. Participation involves answering a questionnaire that will take your child a maximum of 45 minutes to complete. If you choose to allow your child to participate in the study, you have to sign the form below. Read the form carefully before you sign it. Once you have signed it, keep the bottom copy and hand the top copy to the your child to take back to school.

I _______________________ __________________________________
(Father, Mother, Guardian) (Choose relevant one) give ___________________________ ________________________ (Name of child) permission to participate in the research entitled:

Science Education Reform In The US And What A Developing Country Can Learn From It: The Case Of Botswana With The Effects Of Ultraviolet Radiation On The Human Skin – An Educated And Informed Nation.

I acknowledge that I have read or had the form read to me and fully understand the consent form. I sign it freely and voluntarily. A copy has been given to me.

Date: ________________ Parent Signature: _____________________

Witness: ______________________________________

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CONSENT FOR PARTICIPATION IN RESEARCH

I consent to participate in the research entitled:

Science Education Reform In The US And What A Developing Country Can Learn From It: The Case Of Botswana With The Effects Of Ultraviolet Radiation On The Human Skin – An Educated And Informed Nation

Principal Investigator, Dr. David L. Haury or his authorized representative, Shanah M. Suping has explained the purpose of the study, the procedures to be followed, and the expected duration of my participation. Possible benefits of the study have been described, as have alternative procedures, if such procedures are applicable.

I acknowledge that I have had the opportunity to obtain additional information regarding the study and that any questions I have raised have been answered to my full satisfaction. Furthermore, I understand that I am free to withdraw at any time and to discontinue participation in the study without prejudice to me.

Finally, I acknowledge that I have read and fully understand the consent form. I sign it freely and voluntarily. A copy has been given to me.

Date: ____________________ Signed: ____________________

Participant

Signed ____________________
Principal Investigator/Authorized representative

Witness: ____________________
LETTER OF REQUEST TO PARTICIPATE

Dear Student

I am doing a study titled:

Science Education Reform In The US and What a Developing Country Can Learn From it: The Case of Botswana with the Effects of Ultraviolet Radiation on the Human Skin – An Educated and Informed Nation

This study seeks to find out how much Botswana students know about ultraviolet radiation and what it can do to the human body. Participation in this study is completely voluntary. Your participation though will help us find out what the Botswana students know about this topic and may help us change the science syllabus so as to address issues that are important to our health as human beings.

I therefore encourage you to consider participating in the study. Participation involves answering a questionnaire that will take you a maximum of 45 minutes to complete. If you choose to participate in the study, you have to sign a form that you agree to participate. Read the form carefully before you sign it. Once you have signed it, keep the bottom copy and hand the top copy to the researcher.

Once you are done with the questionnaire, you will be given a copy of some of the ideas that the researcher was looking for in your answers to the questionnaire. You will not be provided with answers to the statements in the questionnaire but ideas that the researcher feels that Botswana students should know given the climate conditions of the country.

Thank you for your consideration to participate in this study. Remember that participation is not forced, but will be very helpful.

Thank you

________________________  _____________________________
David L. Haury (Investigator)   Shanah M. Suping (Co-investigator)
Assent Letter to Students

ASSENT FORM FOR PARTICIPATION IN RESEARCH

I choose to participate in the research entitled:

Science Education Reform In The US And What A Developing Country Can Learn From It: The Case Of Botswana With The Effects Of Ultraviolet Radiation On The Human Skin – An Educated And Informed Nation

I have permission from my parents/guardian to participate in this study and I do so out of my own free will. I am aware that if I decide to pull out at anytime, I am free to do so without fear. I am also aware that pulling out of the study will not affect my performance in my everyday schoolwork.

The researcher, Dr. David L. Haury or his assistant, Shanah M. Suping has explained the purpose of the study, the procedures to be followed, and the expected time of my participation. The researcher has explained to me what I may most likely learn by participating in the study and that there is no likely harm that can occur to me.

I acknowledge that I have asked all the questions I had about the study and that these were answered to my satisfaction. Furthermore, I understand that I am free to withdraw at any time and to discontinue participation in the study without fear of being punished.

Finally, I acknowledge that I have read and fully understand this form. I sign it freely and voluntarily. A copy has been given to me.

Date: ___________________  Signed: ___________________

Participant

Signed ___________________

Principal Investigator/Authorized representative

Witness: ____________________________
Debriefing Script to all Students

INFORMATION ON ULTRAVIOLET RADIATION EXPOSURE AND THE HUMAN SKIN QUESTIONNAIRE

Dear Student

Following the questionnaire that you have just completed, I provide here some information that may help you think through some of the issues that the questionnaire raised. Note that the information provided here does not correspond one to one with the statements that were on the questionnaire, but covers all the areas that the questionnaire covered. Some of the scientific words used here may not be very familiar, but they are explained in the text as much as possible so that you can have some ideas of what they mean.

The sun is a major source of radiation including ultraviolet radiation (UVR) on earth. Based on its biological effects UVR can be divided into UVA, B, and C. UVC has the highest photon energy but is fortunately effectively absorbed by the ozone layer. The ozone layer is thus an important factor in the amount and intensity of UVR that reaches the earth. Latitude, seasons, and altitude are also factors in the amount of UVR at a given time.

The human organism needs small doses of UVR to produce vitamin D, which is required among other things for bone production. Very high doses have unwanted effects like sunburn, skin cancer, acceleration of skin aging leading to skin coarseness, wrinkling, laxity, thickening and pigmented spots, damage to the immune system and to the eye cataract. Scientific research has shown that the skin responds differently to UVR depending on whether or not it is accustomed to it. There is also evidence to suggest that UVR reduces the production of collagen (certain cells in the body below the skin) through a number of mechanisms. Once premature aging has occurred due to UVR exposure, any treatment course undertaken seems to have lots of side effects.

The human skin reacts to UVR by producing erythema (certain cells in the body that are associated with skin color) a few hours upon exposure and this process takes up to 20 hours. Melanin (skin color giving chemical) production is increased by exposure to UVR. Darker skin responds quickly with very little exposure and repeated exposure may produce pigmentation that lasts for years after first exposure. Childhood and teenage years (up to age 20) are most critical as this is the time when overexposure to high intensity UVR occurs during outdoor activities. There is research evidence that links high incidence of skin cancer in prone populations to history of sunburn or spending a month
or more in intense sunlight. This suggests that it is bad practice to play in the sun especially in the summer months without proper protection against UVR.

All three forms of skin cancer (malignant melanoma, basal cell carcinoma (BCC), and squamous cell carcinoma (SCC)) have been associated with exposure to UVR at one time or another, especially during the years before 20. Melano-compromised people always have sunburn, hardly develop a suntan, and are prone to skin cancer whereas melano-competent people occasionally develop sunburn and are able to develop a protective suntan. Blacks residing in the same area as whites are about 68 times less prone to skin cancer due to an effective protection from the color of their skin. The harmful UVR still has adverse effects on the black skin and makes it look blacker, have uneven pigmentation and in some case develop a whole range of other facial skin problems like acne. The scarring that develops from these pimples and acne is not very pleasant to look at and all attempts should be made to prevent eruption of skin problems.

Cloud cover does reduce the amount of UVR that reaches the earth’s surface, and this depends on the amount and type of clouds. Some clouds are better at shielding us from UVR than others. Sunscreens with a sun protection factor (SPF) of 15 or greater have been shown to be effective especially if started at an early age. It is advisable to apply it to the face and neck if you know that you are going to be exposed to the sun when there is a lot of UVR. The UVR is less intense in winter but this does not mean that we should not take precautions as we can still get skin damage and the adverse effects of UVR exposure. Research has shown that sunscreen use before the age of 18 reduces by 78% the incidence of certain skin cancers in one’s lifetime.

It is interesting to note that there are certain hours of the day when the UVR radiation is very high. This is typically from ten in the morning to around four in the afternoon. It is therefore important that we use protective clothing when working or playing in the open especially during summer months. Certain materials like cotton are better at shielding us from the UVR than say nylon. It helps therefore to choose clothes wisely if one knows that he or she will be exposed to the sun’s rays. Hats also help.

Last but not least, excessive exposure to UVR lowers the body’s immune system. This is a sobering finding especially in this age of AIDS and HIV. It can not be over emphasized how important it is for us to take care of our bodies and avoid unnecessary exposure to ultraviolet radiation that will make our body systems very weak.

I hope that the ideas presented her will help you to start thinking hard about how you conduct yourself when there is likelihood that you will be exposed to the sun. You can also talk to your younger brothers and sisters and help them take good care of themselves. We only have one body, and so let us take good care of it so that it lasts as a lifetime!

Sincerely
Shanah M. Suping
(Researcher – Ultraviolet radiation exposure and the human skin questionnaire).
# APPENDIX C

## INFORMATIONAL TABLES

<table>
<thead>
<tr>
<th>School Type</th>
<th>Junior</th>
<th>Senior</th>
<th>College</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Means</td>
<td>2.825</td>
<td>2.805</td>
<td>2.827</td>
<td>2.819</td>
</tr>
<tr>
<td>Std.’s</td>
<td>.311</td>
<td>.289</td>
<td>.281</td>
<td>.294</td>
</tr>
</tbody>
</table>

Table C 1: Means by school type
### Science Type

<table>
<thead>
<tr>
<th>Science Type</th>
<th>Integrated</th>
<th>Single</th>
<th>Pure</th>
<th>Humanities</th>
<th>C/science</th>
</tr>
</thead>
<tbody>
<tr>
<td>Means</td>
<td>2.825</td>
<td>2.799</td>
<td>2.812</td>
<td>2.836</td>
<td>2.812</td>
</tr>
<tr>
<td>Std.’s</td>
<td>.311</td>
<td>.251</td>
<td>.329</td>
<td>.301</td>
<td>2.55</td>
</tr>
</tbody>
</table>

Table C 2: Means by science type

### Gender

<table>
<thead>
<tr>
<th>Gender</th>
<th>Male</th>
<th>Senior</th>
</tr>
</thead>
<tbody>
<tr>
<td>Means</td>
<td>2.828</td>
<td>2.810</td>
</tr>
<tr>
<td>Std.’s</td>
<td>.289</td>
<td>.299</td>
</tr>
</tbody>
</table>

Table C 3: Means by gender
## Table C 4: Means by age bracket

<table>
<thead>
<tr>
<th>Age Bracket</th>
<th>12-16</th>
<th>17-20</th>
<th>21-25</th>
<th>&gt; 26</th>
</tr>
</thead>
<tbody>
<tr>
<td>Means</td>
<td>2.828</td>
<td>2.810</td>
<td>2.825</td>
<td>2.923</td>
</tr>
<tr>
<td>Std.’s</td>
<td>.313</td>
<td>.284</td>
<td>.278</td>
<td>.274</td>
</tr>
</tbody>
</table>

## Table C 5: Means by school type and gender

<table>
<thead>
<tr>
<th>School Type by Gender</th>
<th>Junior</th>
<th>Senior</th>
<th>College</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
<td>Male</td>
</tr>
<tr>
<td>Means</td>
<td>2.837</td>
<td>2.815</td>
<td>2.841</td>
</tr>
<tr>
<td>Std.’s</td>
<td>.310</td>
<td>.312</td>
<td>.300</td>
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<tr>
<td>Science Type by Gender</td>
<td>Integrated Male</td>
<td>Integrated Female</td>
<td>Single Male</td>
</tr>
<tr>
<td>------------------------</td>
<td>-----------------</td>
<td>-------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Means</td>
<td>2.837</td>
<td>2.815</td>
<td>2.824</td>
</tr>
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<td>Std.'s</td>
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Table C 6: Means by science Type and Gender
### School Location and Science Type

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<tr>
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<td>2.817</td>
<td>2.825</td>
<td>2.794</td>
<td>2.801</td>
</tr>
<tr>
<td>Peri-Urban</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

|                  |              | Std.’s     |        |      | Std.’s     |            | Std.’s     |        |      |
|                  |              | .265       | .251   | .348 | .301       | .255       | .337       | .253   | .305 |

* Peri-urban does not have humanities and college science counterparts since the college in the study was in the urban setting.

Table C 7: Means for school location by science type.
LIST OF REFERENCES


American Association for the Advancement of Science. (Fall, 1996). Project 2061’s influence on reform, 6(2), 12-16.


Barth, J. (1997). How much sun do we need to produce vitamin D? In P. Altmeyer, K. Hoffmann, & M. Stücker (Eds.), *Skin cancer and UV radiation* (pp. 128-130). Berlin, Germany: Springer.


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