UNIVERSITY OF CAPE COAST

FEMALE STUDENTS' PREFERENCES FOR PHYSICS COURSES AT UNIVERSITY OF CAPE COAST AND SENIOR SECONDARY SCHOOLS

ISAAC BUABENG

2009

UNIVERSITY OF CAPE COAST

FEMALE STUDENTS' PREFERENCES

FOR PHYSICS COURSES AT UNIVERSITY OF CAPE COAST

AND SENIOR SECONDARY SCHOOLS

BY

ISAAC BUABENG

THESIS SUBMITTED
TO THE DEPARTMENT OF SCIENCE AND MATHEMATICS EDUCATION
OF THE FACULTY OF EDUCATION, UNIVERSITY OF CAPE COAST
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE AWARD OF MASTER OF PHILOSOPHY DEGREE
IN SCIENCE EDUCATION

JULY 2009

DECLARATION

Candidate’s Declaration

I hereby declare that this thesis is the result of my own original research and that no part of it has been presented for another degree in this university or elsewhere.

Candidate’s Signature: …………………………….. Date: ………………………

Name: Isaac Buabeng

Supervisors’ Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast.

Principal Supervisor’s Signature: …………………….. Date………………….

Name: Prof. Joseph Ghartey Ampiah

Co-Supervisor’s Signature: ………………………… Date………………………

Name: Mr. Richmond Quarcoo-Nelson

ABSTRACT

The main aim of the study was to investigate what accounts for the low proportion of female participation in the study of physics at University Cape Coast (UCC) compared to biology and chemistry. The study also identified practical methods or ways that could be employed to make physics more appealing to female students in order to encourage greater female participation in the subject beyond Senior Secondary School (SSS) level.

The target population for the study comprised 208 female undergraduate students offering biology, chemistry and physics at UCC; 201 SSS female final year science students selected from four SSS in Cape Coast Metropolis and 11 physics lecturers and teachers. A cross-sectional survey was used for the study. The main instruments used in gathering data for the study were questionnaire on low female participation in physics (QLFPP), interview protocol for female students (IPFS) and interview protocol for physics lecturers and teachers (IPPLT). The model of analysis of data involved the use of frequency and percentage tables and Independent Samples t-test as well as explanatory information on students and teachers' reasons about the low female participation in physics at the university.

The study showed that several reasons account for females' preferences for biology and chemistry courses to physics course at the university. Among them are: abstract nature of physics; difficulty level of the subject (physics) and limited career opportunities in physics. It was recommended among other things that, in order to encourage greater female participation in the study of physics, serious efforts must be made by physics lecturers and teachers as well as physics departments to create awareness of career opportunities in the study of physics.

ACKNOWLEDGEMENTS

No work of this nature could be attributed to the sole effort of one person. Many individuals in various ways have made invaluable contributions to this study from the time of its inception to its conclusion.

My heartfelt gratitude is expressed, particularly to my supervisors, Prof. Joseph Ghartey Ampiah and Mr. Richmond Qaurcoo-Nelson, who in spite of their heavy schedules worked tirelessly to see me through the completion of this work. I gratefully acknowledge PRACTICAL Project and University of Cape Coast, for financial support, which enabled me to undertake and complete the study.

I also wish to express my indebtedness to Mr. Kenneth Asamoah-Gyimah, Mr. and Mrs. Kofi Ntim, Mr. Charles Domfeh, Mr. Kofi Ayebi-Arthur and Mr. Johnson T. Apollo who not only provided wise counseling and served as continuing source of inspiration for this work but also made available to me all their valuable resources.

I am equally grateful to Dr. T. A. Osei Anto, Forster Danso Ntow, Charles Deodat Otami, Miss Herty Kay Jackson and all PRACTICAL Project M.Phil students, UCC, for their advice, suggestions and contributions for the study.

I wish also to place on record my sincere and profound gratitude to Miss Mililand Blissett (popularly called Sister Amma), Madam Akosua Gyempeh, Emelia Ofosu, Vida Tawiah Antwi, Sarah Antwi, Ernest Akwasi Acheampong and Nana Gyau for their family support, encouragement and indulgence over the years.

A special note of thanks goes to Miss Theresah Antwi, Mountain State University, West Virginia, U. S. A. for her loving kindness and moral support.

DEDICATION

To Mr. Kenneth Asamoah-Gyimah for his encouragement and support during the course of my studies.

TABLE OF CONTENTS

		Page
ABSTRACT		iii
ACKNOWLEDGEMENTS		iv
DEDICATION		v
LIST OF TABLES		x
LIST OF FIGURES		xiii
Chapter		
1	INTRODUCTION	1
	Background of the Study	1
	Statement of the Problem	7
	Purpose of the Study	9
	Research Questions	9
	Significance of the Study	10
	Delimitation	11
	Limitations	11
	Organization of the rest of the Thesis	12
2	REVIEW OF RELATED LITERATURE	13
	Theoretical Review	13
	Sex-based Differences in Brain Function	13
	The Concept of Inherent Differences	16
	The Concept of Socialized Differences	19
	The Concept of Culture Bias of Physics	24

	Empirical Review	28
	Attitude of Females towards Physics	29
	Participation of Females in Physics Studies	30
	Enhancing Female Participation in the study of Physics	38
	What Parent Should Do	40
	What Schools Should Do	40
	What Teachers Should Do	41
	Strategies Proposed at IUPAP's International Conference Meeting (2002)	46
	Summary	47
3	METHODOLOGY	51
	Research Design	51
	Population	53
	Sample and Sample Technique	54
	Instruments	55
	Data Collection Procedure	57
	Data Analysis	60
4	RESULTS AND DISCUSSION	61
	Introduction	61
	Female Undergraduate Students' Preference for Biology, Chemistry and Physics Courses	61
	Physics Lecturers and Teachers' Contributions on what Accounts for Females' Preferences for Physics Courses	77

	Differences between Undergraduate Female Non-Physics Students (Biology and Chemistry) and Physics Students' Views about Physics	81
	Senior Secondary School Female Science Students' Preference for Physics as a Course of Study beyond Senior Secondary School Level	92
	Practical ways to make Physics more Appealing to Females	101
5	SUMMARY, CONCLUSION AND RECOMMENDATIONS	108
	Summary	108
	Overview of Research Problem and Methodology	108
	Key Findings	109
	Conclusion	110
	Recommendations	112
	Suggestions for Further Research	113
REFERENCES		115
APPENDICES		
A	Questionnaire for Female Biology and Chemistry Undergraduate Students	125
B	Questionnaire for Female Undergraduate Physics Students	129
C	Questionnaire for Senior Secondary School Final Year Female Science Students	133
D	Questionnaire for Physics Lecturers and SSS Science Teachers	137
E	Oppinionnaire on Females' Participation in the Study of Physics	141

F	Results of Females SSS Students Ranking for Reasons for Studying Physics beyond SSS Level	143
G	Results of Female Undergraduate Students and Teachers' Ranking of Ways to make Physics more Appealing to Females	144
H	Second Choice Programme to Pursue at the University by SSS Female Final Year Science Students	146
I	Third Choice Programme to Pursue at the University by SSS Female Final Year Science Students	147
J	Fourth Choice Programme to Pursue at the University by SSS Female Final Year Science Students	148
K	Semi-Interview Protocol used to Interview Female Undergraduate Students and SSS Students	149
L	Semi-Interview Protocol used to Interview Physics Lecturers and Teachers	150
M	Career Avenues in Physics	151

LIST OF TABLES

Table		Page
1	Female Undergraduate Students' Reasons for choosing Biology and Chemistry instead of Physics (N = 180)	63
2	Category and Example of Responses by Biology and Chemistry Female Undergraduate Students	64
3	Female Physics Undergraduate Students Reasons for Choosing to offer Physics but Not Biology or Chemistry (N=28)	66
4	Category and Example of Responses by Physics Female Undergraduate Students	67
5	Proportion of Biology and Chemistry Undergraduate Students who Expressed Regrets for Studying Biology or Chemistry (N = 180)	69
6	Reasons offered by Biology and Chemistry Undergraduate Students who Expressed no Regrets of Studying Biology or Chemistry (N = 171)	71
7	Proportion of Biology and Chemistry Undergraduate Students who would like to offer Physics at the University when given another Opportunity (N = 180)	72
8	Reasons offered by Biology and Chemistry Undergraduate Students who do not want to offer Physics if given another Opportunity (N = 160)	73

9	Example of Reasons offered by Biology and Chemistry Undergraduate Students who do not want to offer Physics if given another Opportunity (N = 160)	74
10	Reasons offered by Biology and Chemistry Undergraduate Students who would like to offer Physics if given another Opportunity (N = 20)	75
11	Reason offered by Female Undergraduate Physics Students who would not want to offer physics if given another Opportunity (N = 14)	76
12	Example of Reason offered by Physics Students who would still want to offer Physics if given another Opportunity (N = 14)	77
13	Mean, Standard Deviation and Percentage Responses of Biology Undergraduate Students' Views about Physics (N = 127)	82
14	Mean, Standard Deviation and Percentage Responses of Chemistry Undergraduate Students' Views about Physics (N = 53)	84
15	Mean, Standard Deviation and Percentage Responses of Physics Undergraduate Students' Views about Physics (N = 28)	86
16	Independent Samples t-test on differences between Undergraduate Female Non-Physics Students and Physics Students Views about Physics	89
17	Mean, Standard Deviation and Percentage Responses of Physics Lecturers and Teachers' Views about Physics (N = 11)	90

18	First Choice Programme of Preference of SSS Female Final Year Science Students	93
19	Proportion of SSS Female Students who would choose to offer Physics at the University instead of Biology or Chemistry (N = 201)	94
20	Reason offered by SSS Female Students who would not want to Pursue Physics as a Course of Study at the University (N = 166)	95
21	Reason offered by SSS Female Students who would like to Pursue Physics as a Course of Study at the University (N = 35)	97
22	Responses by SSS Female Students of ways to Encourage them to Study Physics beyond SSS Level (N = 201)	98
23	Category and Examples by SSS Female Students of ways to encourage them to Study Physics beyond SSS Level (N = 201)	99
24	SSS Female Students' Ranking for Reasons for Studying Physics beyond SSS Level (N = 201)	100
25	Non-Physics and Physics Students' Suggestions of Practical Ways to make Physics more appealing to Female Students (N = 208)	102
26	Physics Lecturers and Teachers' Suggestions of Practical Ways to make Physics more appealing to Female Students (N = 11)	103
27	Female Undergraduate Students and Physics Teachers' Ranking for Practical Ways to make Physics more Appealing to Females (N = 219)	106

LIST OF FIGURES

Figure		Page
1	Boxplot showing the distribution pattern of undergraduate female physics and non-physics students' views about physics	88

CHAPTER 1

INTRODUCTION

Background to the Study

Physics plays a key role in understanding the world we live in, and physicists contribute strongly to the welfare and economic development of nations. The knowledge and problem-solving skills of physicists are essential in many professions and industries and to society at large. To thrive in today's fast-changing, technological world, every country must achieve a highly educated population in physics, fully engaged in making decisions important to their well being (International Union of Pure and Applied Physics [IUPAP], 2002). Thus knowledge of physics is an important part of general literacy for every citizen. In addition, advancing in physics understanding is an exciting intellectual challenge that benefits from the diverse and complementary approaches to a nation's development. Currently women can and do contribute to this pursuit and, through physics, to the welfare of humankind, but only in small numbers: women are an underutilized "intellectual reserve." Only when women participate fully as researchers in the laboratory, as scientific leaders and teachers, and as policy makers will they feel equal partners in a technological society (IUPAP, 2002).

It is an undeniable fact that any country which wants to develop must place some emphasis on education. Education equips labour with the necessary skills for making production with the most efficient and up-to-date technology. Education also offers the opportunity for extensive research into any discipline and thus enables a nation to discover new ways of improving the economic and social welfare of its citizenry. Female education affects family health and nutrition, agricultural productivity and fertility, yet in many organizations and institutions people hold the view that particular jobs and activities are suitable for women and others are suitable for men. There is often more respect for male professionals than there is for female (United Nations Educational, Scientific and Cultural Organization [UNESCO], 1993).

Career women often have to work harder at their jobs to keep even with their male counterparts. Despite all these obstacles, women continue to move into different professions, including those traditionally seen as male jobs, such as engineering and architecture. Women can be found at senior levels in many organizations in many countries. They are also taking up various different professions such as law, medicine, politics among others but these women may be in the minority (United Nations Development Plan [UNDP], 1993).

The professional studies of engineering, architecture, astronomy and physics are dramatically underrepresented by females. While women represent over half the general population, they represent only a tiny minority of professionals in physics with majority going into biology (Donnellan, 2003). History has it that this imbalance was thought to be the result of differing brain structures and functions.

Indeed, some theorists still hold to that view. However, explanations based on gender-specific socialization have largely displaced the brain difference models. Theories of Socialization hold that females are directed away from physics and other related courses by parents, teachers, and peers (male and female) because such studies are considered to be unfeminine (Baird, 1996). Such theories according to Baird further argue that females themselves select out of physics courses because the careers involved in those fields do not match the careers with which girls are encouraged to be concerned. However, physicists may work in many fields which females seem to know little about. Examples of these fields are Medical Physics, Health Service, Computing, Communications, Meteorology, Environmental Physics, Geophysics (see Appendix M) (Gibbs, 2003).

In Ghana, issues on female enrolment in physics at higher education level are often taken for granted. It appears that in both official and private circles there is lack of awareness on female enrolment in physics. Either people do not have an interest in it or simply dismiss them as non-existent. In spite of the old adage that "educating a woman is educating a nation", no "special" opportunities are offered in Ghana to promote the education of women in physics.

Ghana Government and UNICEF (1990) reported that if women are to be empowered to actively participate in all levels of development planning, policy formulation, analysis and implementation, the level and quality of women's education must also be of some concern to all, especially those whose education has an impact on a nation's progress and development. But after the first 50 years of both colonial rule and independence, there is no doubt that females' education in physics lagged far behind. Even though there is now an increase in the number of females in higher education, there are still great disciplinary disparities especially in the sciences.

Female under-representation in science has been a topic of discussion and research within the science education community for several decades. In particular, physics is the least successful of all the sciences in attracting and retaining females within the field (Hazari & Potvin, 2005). It has been observed that at the higher educational level, few females choose to enroll in most science courses, both at undergraduate and postgraduate level and among these females who choose to enroll in science courses only a handful choose to study physics (IUPAP, 2002).

Donnellan (2003) has observed that the number of females taking science programs, particularly physics at the higher education level is low. Although lots of females take biology, far fewer take physics. In Ghana for example, at the Kwame Nkrumah University of Science and Technology (KNUST), female enrolment figures in physics, chemistry and biology reveal a low trend of female participation in physics. In 2004 out of a total of 109 female students who were admitted into physics, chemistry and biology, 12 (11%) of them offered physics while 36 (33%) offered chemistry and 61 (56%) offered biology. In 2005 the physics class of KNUST comprised 12 (14%) female students as compared to 28 (33%) and 46 (53%) female students who pursued chemistry and biology programmes respectively. Furthermore, out of a total of 75 female students who were admitted into physics, chemistry and biology at KNUST in 2006, only 8 (11%) pursued physics programme while 37 (49%) pursued chemistry and 30 (40%) pursued biology programmes.

Again in 2007 only 10 (13%) female students enrolled in the physics class whereas there were 39 (51%) in chemistry and 27 (36%) in the biology. Moreover, since the inception of KNUST, from 1960 to 2008, out of 804 physics graduates who have passed through the university only 67 representing 8.3% were females (KNUST, 2008).

The Need to Study Physics

The study of physics is crucial to understanding the world around us, the world inside us, and the world beyond us. In many respects, physics is the most basic and fundamental natural science - it involves universal laws and the study of the behaviour and relationships among a wide range of important physical phenomena (Cutnell & Johnson, 2006). Physics challenges our imaginations with concepts like relativity and string theory, and it leads to great discoveries, like computers and lasers, that change our lives. It encompasses the study of the universe from the largest galaxies to the smallest subatomic particles. Moreover, it's the basis of many other sciences, including chemistry, oceanography, seismology, and astronomy. All are easily accessible with a bachelor's degree in physics (American Physics Society [APS], 2008). Physics also leads to an understanding of many practical applications and ideas in other areas of science.

The importance of physics is not limited to the "hard sciences." Increasingly, physicists are turning their talents to molecular biology, biochemistry, and biology itself. Even medicine has a niche for physicists, and since medical physicists are hard to come by, they are much in demand. Physics also undergirds many new technologies. Cell phones, the Internet, and Magnetic Resonance Imaging (MRI) are only a few examples of the physics-based technological developments that have revolutionized our world. Many theoretical and experimental physicists work as engineers, and many electrical and mechanical engineers have physics degrees (APS, 2008).

Physics extends into the realm of technology and applied sciences. Many important technological developments can be appreciated through a solid foundation in physics. Applications in engineering, medicine and a wide variety of other fields can be grasped by someone who has a good basic understanding of physics. In an information-based society, with widespread public concerns relating to issues as complex as the protection of the environment, new developments in space exploration, low level electromagnetic radiation from high tension power lines, the action of technologically advanced weapons systems, and various other serious and often controversial issues, a scientifically literate society is needed more urgently than ever before.

While solutions to these kinds of issues are indeed difficult to find, physics does provide a way in which these types of problems can be understood and approached. It offers one world view which, when taken in conjunction with other world views, empowers society to make informed, rational decisions based on diverse ways of thinking about problems. Though physics can make no claims to have all of the solutions to such complex human problems, it does provide us with the necessary knowledge, skills, and attitudes to begin to approach these problems in a unique way.

Again the study of physics education equips a person to work in many different and interesting places - in industrial and government laboratories, on college campuses, and in the astronaut corporations. In addition, many physics graduates leave the lab behind and work at newspapers and magazines, in government, and even on Wall Street - places where their problem-solving abilities and analytical skills are great assets (APS, 2008). Physics is therefore relevant, and it can prepare one for great jobs in a wide variety of places. The study of physics will enable students to understand important aspects about the world in which they live, and make rational choices within a social, technological, and environmental context. So it is very important for students to take up physics courses.

Statement of the Problem

Participation of females in the study of physics is an issue of international concern. Of all the sciences, physics is the subject in which the increase in the number of females involved has been particularly low (Barbosa, 2003). Studies have shown that many of the females who do take physics opt out from the course (Barbosa, 2003; Donnellan, 2003). In fact, statistics indicate that a higher proportion of women leave physics at each stage of their career - a phenomenon that is often dubbed the "leaky pipeline" (European Commission Directorate-General for Research [ECDGR], 2006). The percentage of degrees awarded to women in physics world-wide is also reported as being much lower (Donnellan, 2003).

In Ghana, only few females choose to study physics at the university compared to chemistry and biology. For example at the University of Cape Coast (UCC) female enrolment figures in physics, chemistry and biology reveal a low trend of female participation in physics. Basic statistics produced by the Student Record and Information Management Unit (SRIMU) on females' participation in physics for 2005 to 2008 show that in 2005 out of a total of 171 females who were admitted into the science programmes only 10 (7%) pursued physics to the final year. The remaining 160 pursued chemistry, biology or mathematics. In 2006, only 6 (4%) out of 135 females offered physics at the final year while in 2007, 11 (7%) females out of a total of 157 pursued physics at the final year. In 2008, out of a total of 143 females who read physics in the first and second years only 13 (9%) females pursued physics at the final year. In all cases majority of the female students pursued biology followed by chemistry and mathematics in that order.

Many educational researchers have explored the attitudes of students to science as a whole – their views about the science curriculum, their opinions of how science is taught and their perceptions of scientists. However, such researchers have not often distinguished between the different subjects within science (Woolnough, 1995; Christopher, Martin, Katie, Eddie, & Dominic, 2003). Nevertheless, many studies in the western world have attributed low females' participation in physics to a number of reasons some of which are given as: females have a natural tendency to be more concerned with 'people science' (e.g. biology); females do not see physics as able to contribute to solutions of environmental or medical problems, but rather see physics as requiring a lot of mathematical ability; females do not succeed in physics because of prejudice, discrimination and unfriendly attitudes towards them; females greatly perceive biology as interesting and physics as boring among others (Baker, 2002; Christopher, Martin, Katie, Eddie, & Dominic, 2003; Hazari & Potvin, 2005).

Although these reasons among many others are believed to be the cause of low females' participation and achievement in physics in the western world, they might not necessarily be the cause of the low females' participation in physics in Ghana. Hence there is the need to investigate what account for the low females' participation in physics at University of Cape Coast.

Purpose of the Study

The main purpose of the study was to investigate why the proportion of females who pursue physics at the University of Cape Coast is not comparable with those who pursue chemistry and biology. The study also sought to find out whether Senior Secondary School (SSS) female science students would choose to study physics at the university or not and the reasons for their choice. In addition, the study sought insight into students' views about physics. Differences between undergraduate female non-physics students and physics students' views about physics were investigated.

Finally, the study sought to look for some practical methods or ways that could be employed to encourage more females to study physics at the university level. These practical methods or ways were ascertained through questionnaire on low female participation in physics and interview protocols for female students and physics lecturers and teachers.

Research Questions

The following research questions were formulated to guide the study:

1. What accounts for female students' preference for biology and chemistry courses to physics course at the University of Cape Coast?
2. What accounts for SSS female students' preference for physics as a course of study at the university level?

3. What practical methods/ways could be employed to make physics more appealing to female students?
4. Are there any differences in views about physics between undergraduate female non-physics and physics students?

Hypothesis

To investigate whether or not the differences in Research Question 4, if they really exist, are statistically significant, the following null hypothesis was formulated for the study:

‘H_0: There is no significant difference in views about physics between undergraduate female non-physics and physics students.

Significance of the Study

The study has revealed reasons underlying the low proportion of females in physics compared to the proportion of females pursuing biology and chemistry at Ghana university level, specifically at University of Cape Coast. It will therefore inform educational policy makers, university authorities and authorities of second cycle institutions about why higher proportion of females does not pursue physics at the university level.

The study has also identified and documented practical ways that could be employed to make physics courses more appealing to female students. This study will therefore, not only make important contribution to enhance greater female participation in the study of physics, but will also contribute to improving the teaching and learning of the subject from the SSS level through to the university level.

Even though the study was confined to University of Cape Coast and some selected SSS in the Central Region of Ghana, the findings will serve as indicators of what may be happening in other universities and SSS in Ghana.

The findings from this study also add to the existing knowledge on female disparity issues in the study of physics. It also serves as a resource material for students/researchers who may take a similar study in the future.

Delimitation

The study limited itself to one public university out of six public universities offering physics courses in Ghana at the time of this study. This study also confined itself to only two female SSS and two co-education (mixed) SSS within Cape Coast Municipality which were offering Elective Science Programme as the population of interest. Only final year female science students were used in this study since these students had done the three science elective subjects (biology, chemistry and physics) for a period of almost three years and where therefore in position to share their views on whether they would pursue physics further as a course of study at the university.

The study focused on low female participation in physics at the university level and what practical methods needed to be employed to encourage greater female participation in the subject.

Limitations

In spite of the clear advantages of incorporating quantitative and qualitative data by the use of different methods, the two methodologies are based on different assumptions, thus it is possible that different techniques could produce different results.

The focus on one case study University and four SSS in Central Region of Ghana places a limitation on the study. This was due to the limited time at the researcher's disposal. Also, the purposive sampling technique used to select case study institutions decreases the generalisability of the findings. The findings will therefore not be generalisable to all universities and SSS in Ghana. However, findings will serve as indicators of what may be happening in other universities and SSS in the other regions.

Additionally, the study used biology, chemistry and physics female undergraduate students and SSS final year female science students. However, it is possible that other undergraduate female students in School of Agriculture, Department of Mathematics and Statistics, Computer Science, Information and Technology, Nursing, and SSS second year science students may have offered important information which would have been relevant to the study.

Organisation of the Rest of the Thesis

The remaining chapters of the thesis are organized as follows:

Chapter two discusses the literature related to the study. The review involves theoretical and empirical studies related to the problem under study.

The third chapter describes the methodology used in the study. Specifically, the research design, the research instrument, sample and sampling technique, the procedure for data collection and the data analysis are discussed.

In chapter four, the main focus is the presentation, analysis and discussion of data collected. Finally, summary, recommendations and areas for further research are presented in chapter five.

CHAPTER 2

REVIEW OF RELATED LITERATURE

The review is made up of both theoretical and empirical review and is intended to present a broad overview of the literature related to the study of physics by females.

Theoretical Review

This aspect of the literature covers sex-based differences in brain function, the concept of inherent differences, socialized differences and culture bias of physics.

Sex-based differences in brain function

Sex-based differences in brain function were once thought to be the key to alleged differences in intelligence, which influence the choice of programmes of study by females. However, the theoretical and research work in this area has been largely abandoned (Baird 1997). Sex-based brain differences are now reviewed only in this study to provide a historical context for the larger issue of low female participation in physics.

Brain-based sex difference theories assert that male and female brains function differently and thus give rise to varying levels of success for females in a variety of pursuits. In the seventeenth and eighteenth centuries, western scientists began to develop biological theories to explain the superiority of the male intellect. One early theory was that males were more variable than females (Shields, as cited in Baird 1997). This, according to Shields meant that while males and females might have the same average intelligence, males were given to a broader range of intelligence while females remained huddled around some average value. As a result, the most intelligent males were far superior to the most intelligent females and the least intelligent males were far inferior to the least intelligent females.

Interestingly, the theory of greater male variability arose after Darwin's findings that variability is an asset in the process of evolution (Baird, 1997). The theoretical work moved from the abstraction of variability to the physical characteristics of brain. Baird (1997) offers a brief historical analysis of brain research and its connection to theories of intelligence. Early researchers asserted that males were more intelligent than females due to their greater brain size. This argument was abandoned when it was determined that animals with larger brains (elephants and whales, for example) should have greater intelligence than humans of either gender. The brain size theory was then modified to place importance on the ratio of brain mass to body mass; this was abandoned when it was found that females came out with a higher ratio (Baird, 1997).

As brain research became more sophisticated, so did the arguments for the superiority of male intelligence. First, the frontal lobe was thought to be the seat of intelligence, and researchers observed that the frontal lobe was larger and better developed in males while the parietal lobe was larger and better developed in females (Fausto-Sterling, as cited in Baird 1997). But later research suggested that the parietal lobe was a better indicator of intelligence than the frontal lobe, and around that time researchers came out to say that the parietal lobe was larger and better developed in males while the frontal lobe was larger and better developed in females. Eventually, the theories revolving around the physical size or characteristics of the brain died out; none are considered valid in modern brain research (Restak, 1984). Accordingly, they were replaced by a host of theories revolving around the genetic differences between males and females.

Genes are the cellular material known to determine a number of traits and characteristics passed from parents to offspring via chromosomes (Barnhart & Steinmetz, 1986). Since males and females have different chromosomal make-ups, it seemed natural for researchers to look for a genetic rationale for male superiority. One of the most high profile examples is the work of Benbow and Stanley who claimed to have found the male mathematics gene (Benbow & Stanley as cited in Baird, 1997). They administered the mathematics portion of the Scholastic Aptitude Test to mathematically precocious Junior High School students in USA. The result was that males consistently outperformed females. Since males and females are exposed to the same level of instruction in mathematics from elementary school through Junior High, Benbow and Stanley concluded that the difference was due to genetically inherited ability. Critics were quick to point out that girls and boys undergo different experiences with mathematics in the classroom and are given different kinds of encouragement outside the classroom. The parents of the children in the study were found to have given boys more mathematics and science toys than girls (American Association of University Women [AAUM], 1989). Moreover, the parents also had higher educational expectations for their boys than they did for their girls (AAUM, 1989).

Critically looking at the literature, one is left to wonder why nearly all of the brain and genetic research was directed toward scientifically proving male superiority. Students of sociology and Western civilization have suggested it is a result of the male-dominated society in which we live (Baird, 1997). Arguments supporting brain-based sex differences remain relevant in the current literature. Kimura's (1992) research on ‘Sex differences in the brain’ conducted in USA suggests that hormones affect brain function and lead to differences in ways individuals go about solving problems.

The Concept of Inherent Differences

The inherent differences viewpoint suggests that inherent differences between males and females lead them to have different interests. In other words, females are less inclined towards physics than males due to some natural tendency. Inherent differences in males and females are transmitted through genes and those genetic differences result in males and females responding differently to the same external conditions, for example, enjoying physics and opting to study it. To better understand this viewpoint, it is important to review and understand the arguments for genetic links to human behaviour.

According to sociobiologists who are interested in studying the biological basis of animal behaviour, human beings are born with a number of inherited behaviour patterns, such as those associated with sex. According to them, such inherited behavior patterns are generally unaltered by the environment because they are evolutionary adaptations through natural selection (Lorenzen, 2001). Hence, sociobiologists may describe ‘instinctive’ elements in male and female behavioural dispositions. For example, boys' competitiveness and dominance strivings are seen as preparation for adult male competition over mates, whereas girls' greater social responsiveness and cooperativeness with other girls can be seen as preparation for participation in the kin-based social groups of females in which most rearing of the young ones occurs (Maccoby, 2000). In order words Maccoby is saying that for the purposes of survival and continuation, males have evolved a naturally competitive and aggressive side whereas females have developed a cooperative side. As a results, females are always seen with life sciences rather than those that are naturally seen as competitive and aggressive.

The physicist or science educator who assigns weight to the inherent differences argument believes that, similar to the sociobiologist, females have genetic influences that make them not interested in physics. These people (those who assign weight to inherent differences) often believe that females have a natural tendency to be more concerned with 'people science'. This would be their (those who assign weight to inherent differences) explanation for why there has been consistent evidence across the world for girls being more interested in biology programmes more than in physical science programmes. As Lie and Bryhni (1983) noted, "…females' interests are characterized by a close connection of science to the human being, to society, and to ethic and aesthetic aspects" (p. 209). Holden (2000), a social scientist also noted, "Wherever you go, you will find females far less likely than males to see what is so fascinating about ohms, carburetors, or quarks' " (p. 380).

A careful examination of the literature shows that the inherent differences viewpoint clearly exists (Summers, 2005). Summers found that sociobiologists have been criticized for propagating biological determinism which sometimes upholds racist and sexist practices over egalitarian ones. Accordingly, the same criticism applies researchers who believe in the inherent differences viewpoint. Moreover, they often offer no solution to the problem of under-representation of females in physics because they argue that a solution is unnecessary and irrelevant since females should not be forced to participate if they are not interested in the first place. As Holden (2000) noted "if you insist on using parity as your measure of social justice, it means you will have to keep many men and women out of the work they like best and push them into work they don't like" (p. 380).

Many of the holders of inherent differences viewpoint feel no change is necessary or that they have no power to change the natural interests of females. For instance, Urry (2003) writes, "…women simply don't like physics and there is nothing he can do to change their minds, they are simply more interested in other fields, like biology and chemistry" (p. 12).

Although many of the proponents of the inherent differences viewpoint would argue for no intervention, there are physicists and science education researchers who hold the inherent viewpoint but feel intervention is necessary for other reasons. These are the very ones who do not give the inherent differences viewpoint as much weight as some of the other viewpoints and subsequently have different perspectives from those who give the most weight to inherent differences, hence given rise to the concept of socialized differences viewpoint.

The Concept of Socialized Differences

The socialized differences viewpoint suggests that males and females are socialized to have different interests. In this case, females are less inclined towards physics than males due to values and behavioural dispositions that are transmitted by society, family, education, and other influences surrounding them. Early in the study of socialized behaviour, researchers believed that these patterns may be transmitted through direct socialization where children adopt actions that are typical or valued for their own sex when sex-appropriate actions are positively reinforced by parents, teachers, or other children and when actions associated with the opposite sex are negatively reinforced (Maccoby, 2000). Later it was also shown that socialized behaviours may be transmitted through indirect socialization by children who choose to imitate gender appropriate behaviour after observing those behaviours being positively reinforced when others of their own sex displayed them (Maccoby, 2000).

Once again to help understand the socialized differences viewpoint better, it is important to consider behaviourism, a contrasting school of thought to sociobiology. Behaviorists believe that animal behaviour is mostly dictated by environmental trial-and-error conditioning (Lorenzen, 2001). Thus, people behaviours are governed by the environmental influences surrounding them. Most studies find that children begin to label themselves (and others) as males and females and associate traits with genders around the age of two (Golombok & Fivush, 1994). So adoption of gendered behaviours starts at a very young age and is reinforced throughout the years of schooling when children interact.

Those who give weight to the socialized differences viewpoint believe that females are either trained directly to feel that physics is not for them or are trained toward behaviours that indirectly lead them away from interest in studying physics. This training occurs through the influence of two major social arenas: the education system (teachers, professors, peers, curriculum, etc.) and everything else outside the education system (such as parents, television, or society) (Hazari & Potvin, 2005). One example of direct training from the non-educational arena, according to Hazari and Potvin, is the social stereotype which deters females from the physical sciences particularly physics by portraying the physicist as male. Kahle and Meece (1994) found that both male and female students rated physics as a masculine subject. One physicist writes, "The popular image of success, of competence, of science, is male. We are almost all prejudiced in the sense that we have absorbed the gender and race stereotypes that prevail in our society" (Urry, 2003, p. 12). In addition, those characters that are portrayed as the super-human examples of what a physicist is and should be, often hold views that greatly underestimated female capabilities. For example, Wertheim, quoted Einstein as saying that "…where you females are concerned, your production center is not in the brain, and elsewhere, it is conceivable that Nature may have created a sex without brain!" (Wertheim, 1995 p.187-188). Although such stark stereotypes are no longer acceptable, stereotypes undermining the capabilities and interests of females in physics still permeate society and the educational system.

Similar to the supporters of inherent differences, socialized differences supporters do not deny that females are found to be more interested in 'life science' or science that has direct social relevance. However, they believe that those interests are trained rather than passed on genetically, and that the teaching and learning practices of physics can be modified to neutralize these socialized differences. The socialized differences proponents are far more optimistic in that they feel there are, in principle, ways to get females interested by utilizing or countering their socialization, at least in the education system arena, whereas the inherent differences proponents often feel that there are no ways to counter genetic predisposition. Thus, the socialized differences proponents can be recognized by their desire to intercede to improve female interest in the study of physics. Dawson (2000) demonstrated this by calling for intervention after studying the interest of upper primary boys' and girls' in some physical concepts. He writes "…boys' interest in physics items exceeds that of girls, and the difference is large enough to continue to argue for intervention" (p. 566).

The existence of the socialized differences viewpoint amongst physicists and science education researchers is evident when the literature is examined (Parker, 2002). Examples of the ways in which the socialization viewpoint emerges in the literature include:

- gender stereotypes (Barman, 1997; Yoder & Schleicher, 1996; Steele, James & Barnett, 2002)
- the effect of less 'prior experience' in physics for females (Chambers & Andre, 1996; Jones, Howe, & Rua, 2000)
- lack of equitable assessment (Hazel, Logan, & Gallagher, 1997; Bell, 2001)

- lack of broader world/human perspectives in physics teaching and learning (Stadler, Duit, & Benke, 2000)
- lack of encouragement of females (Jones & Wheatley, 1990; Taber, 1992; Alexakos & Antoine, 2003)
- lack of female self-confidence in studying physics (Gillibrand, Robinson, Brawn, & Osborn, 1999)
- lack of relevance/interest of physics to females (Jones, Howe, & Rua, 2000; Alexakos & Antoine, 2003; Reid & Skryabina, 2003; Williams, Stanisstreet, Spall, Boyes, & Dickson, 2003).

Another piece of evidence supporting the socialized differences viewpoint is the diminishing self-confidence of females as they progress to higher levels of physics education despite the fact that they perform equally well (DeBacker & Nelson, 2000; Haussler & Hoffmann, 2002). The reason might be because women are not encouraged in physics and the fact that they are socialized to question their abilities far more than men. Many studies have found that females tend to attribute their success to hard work whereas males attribute their success to ability (DeBacker & Nelson, 2000; Golombok & Fivush, 1994). The diminishing self-confidence of females as they continue through the educational stages definitely contributes to their early departure from the field.

The physicists and science education researchers who give weight to the socialized differences viewpoint have many suggestions for improving female interest and participation in the subject. For them, there are two areas to contend with: - social barriers that prevent females from studying physics and socialization that influences females away from physics. Since society and socialization cannot be changed by the science education community alone, the way to address the issue is to promote teaching methodologies that counter the barriers and influences. For example, one barrier that females may face is lack of encouragement. This can easily be countered by teachers and parents taking it upon themselves to encourage girls. Other solutions suggested from the socialized differences perspective include using female friendly contexts and a broader world perspective in physics teaching (Kenway & Gough, 1998; Jones, Howe, & Rua, 2000), more equitable assessment practices (Hazel, Logan, & Gallagher, 1997; Bell, 2001), employing well designed cooperative learning strategies (Pearson, 1992; Rosser, 1993), and having single-sex classrooms (which have been found to increase female confidence and persistence) (Gillibrand, Robinson, Brawn, & Osborn, 1999) among others.

Many physicists and physics educators agree that a combination of inherent and socialized influences affect female interest in physics (Hazari & Potvin, 2005). Some give more weight to inherent differences as being the source while others feel that it is socialization that is the dominant factor. Conflict between the two viewpoints arises because one viewpoint is less open to strategies leading to change while the other is forthcoming with solutions. However, both viewpoints have a major limitation in that they focus on what is different about females (either in their biology or socialization) which leads them away from physics rather than asking what is wrong with the physics community (structure, content and pedagogy) that blocks the participation of diverse and able minds. In other words, the problem of female and physics may have more to do with the nature of the field of physics than with the nature of girls (Baker, 2002). This assertion by Baker forms the foundation of the third viewpoint, culture bias of physics.

The Concept of Culture Bias of Physics

The culture bias viewpoint is different from the inherent and socialized differences viewpoints in the sense that it focuses on problems in the community of physics that causes females to lose interest or opt out rather than the differences between sexes that cause their interest in physics to be different. The culture bias viewpoint suggests that physics is not a gender neutral subject but rather is tightly bound by masculine tendencies and preferences. Females and/or males that lack such tendencies might feel disinclined to the subject and/or alienated within the field (Baker, 2002). In contributing to this issue of culture bias of physics, Hazari and Potvin (2005) asserted that culture bias of physics is transmitted in three ways:- pedagogically, by transmitting a narrow message about what it means to do physics rather than allowing for individuals to define it for themselves; academically, by defining what is acceptable physics research and what is not, primarily through various peer review processes; and socially, through the structure, interactions, and treatment in the field.

An example of the pedagogical transmission of culture bias, according to Hazari and Potvin (2005) is that undergraduate physics is taught in a way that is often more unrealistic and abstract than necessary. Sometimes students must learn to ignore air resistance, friction, and objects with structure when necessary, in contradiction with their daily experiences. This surely will not interest them to study the subject. The idea that physics is attempting to describe the laws by which the natural world operates is not clear to students because they do not understand that the abstractions made to simplify the framework can be easily generalized to include more complicated elements like air resistance and friction. Stadler, Duit, and Benke (2000) in a study conducted on the topic 'Do boys and girls understand physics differently?' write, "girls try to understand the relations of the system of physics to the world as a whole …boys, in contrast, tend to accept physics and technology as valuable in themselves. They appear to be more interested in the internal coherence of physics whereas the girls tend to look for an external coherence…" (p. 420). Unfortunately, physics as a field often focuses on the internal coherence of a theory more than on its application in the real-world.

Moreover, there are real-world sub-fields of physics like biophysics, geophysics, and atmospheric physics but these areas are frequently ignored or minimized in undergraduate physics. If they are discussed at all, it is usually peripheral examples to support theory rather than the basis for introducing and wanting to know the theory. They are also much less glorified within physics culture as well as popular culture. For example, every layperson can identify Albert Einstein but few can identify J. Tuzo Wilson (highly influential pioneer of plate tectonics). Thus, one of the pedagogical concerns of culture bias supporters is that traditional teaching of physics perpetuates elitist elements and does not expose students to all the ways in which physics can be pursued in the world (Hazari & Potvin, 2005).

It must be emphasized that one reason why there are so few women in physics is that physics in many ways is associated with masculinity. Thomas (1990) points out; "Higher education does not reproduce gender inequality by actively discriminating against women. What it does is to make use of culturally available ideas of masculinity and femininity in such a way that women are marginalized and, to some extends, alienated" (p. 181). The female students in Thomas' study had to try hard to be ‘as good as the men’ and to be like men. For the male students, studying physics affirmed their masculinity and also their performance in a reasoning circle. On the other side the female students were much less self-confident than the male.

The social culture bias is noticeable at the lower educational levels in physics classes with the intimidation of girls by boys during lessons (Jones & Mahoney, 1989). Additionally, “in typical classroom activities, boys often dominate and girls receive less experience” (Chambers & Andre, 1997, p. 118). However, when isolated from boys, girls in single-sex physics classes gained more confidence in physics than their co-educational counterparts, improved achievement, and subsequently the likelihood of their studying physics at higher levels was increased (Gillibrand, Robinson, Brawn, & Osborn, 1999).

The culture bias of physics is more pronounced than that of the other sciences but many science education researchers believe culture bias exists for the sciences in general (Lederman, 2003). Among the sciences, physics is the most extreme in the male domineering of its culture. In 1998 in the US, 46% of the bachelor’s degrees in chemistry were earned by females and 55% in biology, whereas in physics it was a mere 19%; women even earned 47% of the bachelor’s degrees in mathematics (National Science Foundation [NSF], 2002). From this fact alone, it is clear that, in America at least, the culture of physics is harder for females to break into than that of the other sciences.

Researchers who assign weight to the culture bias viewpoint believe that females face active and passive discrimination and have little or no role in defining the field. Thus, there is an intrinsic bias in the field favouring males. Lederman (2003) sums it up tenaciously that science is hegemonic and androcentric, two characteristics that proceed from the fact that practitioners of science as we know it have traditionally been white, male, and western. “It is they who define the rules, methods, instrumentation, descriptions of results, and criteria for knowledge production. It is they who define what counts as science, both theoretically and in practice. It is they who are the gatekeepers for access to, and definers of, a life in science” (p. 604). This bias according to Lederman is transmitted when physics is taught and studied at all educational levels and through all other interactions within the field.

The culture bias prevalent in physics needs to be addressed with action-oriented solutions that will help change the system from within. It is physicists, physics educators, and physics education researchers that have to act in order to diversify and create an equitable field of physics. The culture bias supporters, like the socialized differences supporters, also call for pedagogical change. However, the socialized difference perspective calls for pedagogical change at early stages to nurture female interest and it does not require that the field of physics be changed itself. But according to Hazari and Potvin (2005), changing female training in physics so that they fit in to the old mould is not the solution. It is an attempt to remold females so that they satisfy the requirements of the community instead of remolding the requirements so that everyone can fit in. On a long enough time scale, they believe that the solutions offered by the socialized differences camp may help improve the initial number of females enrolling but will not help retain them because it will not change the structure or social bias within the culture at higher levels.

Physicists and science education researchers that give weight to the culture bias viewpoint suggest that more comprehensive solutions are needed in order to address both the pedagogical and social issues. To them, revamping physics curriculum and culture to include broad and diverse worldviews, to make it more accessible to everyone, to change the social climate towards collaboration instead of competition seem to be the first steps along this road (Hazari & Potvin, 2005). However, Hazari and Potvin believe that resistance of physics departments and physicists to change is a formidable barrier, especially since the change must come primarily from within the field. The first step is then to increase awareness within physics departments of these issues and begin sensitizing all current members of the community to the idea of openness to different worldviews and approaches to physics.

Empirical Review

The empirical review of literature for this study involves various research studies on the topic. These studies are reviewed under the headings: attitude of females towards physics, low females' in physics, participation of females in physics studies, enhancing female participation in the study of physics (what parents should do, what schools should do, what teachers should do) and intervention/strategies proposed at International Union of Pure and Applied Physics' 2002 international conference meeting.

Attitude of Females towards Physics

An important part for the success of learning is the students' attitudes and believes about the subject. Redish, Saul, and Steinberg (1998) made a survey of students about expectations, before and after undergraduate physics in six universities and colleges in USA. Cross-sectional survey was employed in this study. They found that many female students do not have interest for physics and learning as an 'expect' would like to see. The most serious part was that fewer female students saw a connection between physics and real life. Almost all the female students thought that physics was to a large extent a matter of finding the right equation and plug in numbers.

Research has also shown that more females are interested in socially relevant work, and they want a job that involves teamwork and offers security. The trouble is that too many females think that a career in Science, Engineering and Technology (SET) particularly physics will not give them any of that (Donnellan, 2003). On top of that females see physics as dull and boring. In addition, females see physicist together with other scientist as a clever middle-aged man working along in a laboratory – perceptions that discourage them from SET careers. Donnellan suggests that if more females are to become engineers, nuclear physicist or computer programmers, then they need a more positive image of the industry.

The poor attitude of females in general towards physics has led to a relatively low proportion of female students and researchers in the field. In the European Union for instance, there are on the average 33% female PhD graduates in the physical sciences, while the percentage of female professors amounts to 9% (ECDGR, 2006). At European Center for Nuclear Research (CERN) the proportion is even less, with only 6.6% of the research staff in experimental and theoretical physics being women (Schinzel, 2006).

The poor attitudes of females towards physics in Ghanaian schools and many African countries seem to have been influenced by cultural practices. Although women are known to handle “tough” and “strenuous” jobs in Africa, there has been a belief that a man must earn a salary and a woman must remain as a housewife, resulting in women choosing or being made to choose less rewarding jobs, and studying courses predominantly perceived to be female areas of study (Baryeh, Obu, Lamprey, & Baryeh, 2000).

Participation of Females in Physics Studies

Of all the sciences, physics is the subject in which the increase in the number of females involved has been particularly low (Barbosa, 2003). Before looking at the findings of various studies, it is worth asking if the low representation of women in physics is a problem – does physics actually need more female physicists? Main (2005) answers this question from three perspectives: the perspective of society, the perspective of science and the perspective of women.

Starting from the viewpoint of society, Main believes that there are several issues to consider. First, physics is a field of innovation. Much technological advancement that have a huge impact on society and everyday life come directly or indirectly from physics. Being a physicist therefore means having access to people and knowledge that set the technological agenda. Second, in many countries research and academic positions are regarded as high-status jobs. Academic staffs are often appointed to committees that fund research projects or advise governments on issues that are closely related to their field of expertise. As such, scientists particularly physicists influence the focus of research and the general development of society.

Finally, Main holds the view that it is a democratic principle that power and influence should be distributed equally and proportionally among different groups in society. According to her an EU average of 9% female physics professors does not even come close to equal representation in this field. The fact that women fund research through tax payments adds to the demand for more female physicists. Moreover, in a society in which technology is increasingly governing our everyday life, exposing women to physics leads to a more scientifically literate public.

From a scientific point of view, Main asserts that lack of women represents a huge waste of talent. For physics to develop further as a science, it needs more people with excellent analytical, communicational and social skills. There are also reports that departments without women suffer in many ways (Main 2005). From the perspective of women, they will of course benefit from increased influence in society, but contributing to physics is not only about struggling for influence and power. Fundamental questions have been asked throughout history by men and women alike. Contributing to physics is to participate in a human project, driven by curiosity and wonder that seeks to understand the world around us (Main 2005). Main concludes by saying that women who have a passion for the subject have the right to make a living from it and have a successful career in the field. What is more, science is changing and becoming more interdisciplinary, requiring a diversity of thought and strategies to solve different types of problems. By excluding female researchers, Main holds the view that the available pool of talented people is being limited to half of humanity and eliminating diversity. Physics therefore needs women to survive.

One of the reasons associated with the low females' participation in the study of physics is attributed to the fact that physics is a mathematics related course. Fennema, Pedro, Wolleat, and Becker (1988) asserted that there is limited participation in mathematics related occupations by females because many of them receive inadequate preparation in mathematics, and therefore are unable to enter educational programmes or careers that are mathematically inclined. Bhatia (1991) has commented that most girls hesitate to go in for physics, as this makes heavy demands, both in matters of time and effort because of the mathematics and this deprives them of other interests and activities. Furthermore, with the additional duties traditionally expected from females at home, they are discouraged from aspiring to study and research into pure sciences. Zietsman and Naidoo (1997) also confirmed that in South Africa girls are less interested in Physics and Mathematics than boys, and fewer choose to study these subjects at high school and universities, which severely restricts their entrance into other disciplines, such as engineering.

Science and especially physics is seen by females as an objective, rational and value free enterprise (Keller, 1992). This image of physics according to Keller does not only hinder women from studying physics, it may also have consequences for physics itself. Keller observed that the high value of objectivity and perhaps a fear of subjectivity can be the reason for the impersonal and detached language and writing in science. For example, one writes, It has been observed… Who has observed? From Keller's point of view observations are always made by human beings living in a society and a culture, and this impersonal language makes this invisible and so the relevance of history, time, place, culture, author and personal responsibility is also denied. Traweek (1988) described the culture of high-energy physics as an extreme culture of objectivity: a culture of no culture. Benckert, (2001) observed that, the high value objectivity and impersonality may also have effect on the teaching in physics. The content of physics courses and physics problems according to Benckert are often idealized and removed from real life context which as a result has hindered many females from studying physics.

It must be noted that the association of physics with masculinity and the connection with the idea of a hard, abstract, value free and pure physics tends to exclude more females. It is therefore important to try to change the learning milieus in physics so that female students can feel comfortable and become confident of their knowledge in physics. Females often appreciate a collaborative working atmosphere and dislike high competitive lectures and evaluation. Tobias (1990) found for example that most females found physics classrooms an "unfriendly" place to be in and that female students, who did not pursue physics at the university level for a variety of reasons, wanted changes in classroom culture, more of context in the presentation of physical models and more of discussions.

Commenting on why females fail to advance to the top levels in physics, Pinker and Spelke (2005) report that it is because females are less likely to give priority to their career, while others cite inferiority in the ability to do physics compared with males or lack of some of the abilities necessary to be successful in physics . For example, one report suggests that males are on average more aggressive than females, and that this characteristic (among others) is necessary to succeed in the field of physics (Lawrence 2006). What these reports have in common according to Lawrence is that they all conclude that there will never be many women in physics because of innate differences between the genders, and also that these differences are the main reason for the low participation of females in the study of physics.

Studies on females and physics have shown that females do not succeed in physics because of prejudice, discrimination and unfriendly attitudes towards them. One of such studies is that of Wenneras and Wold (1997). Wenneras and Wold reported that females need to be twice as productive as men to be considered equally competent. Such statements according to Steele (2004) are too harsh and in his opinion do not motivate the females enough to participate in the field of physics. Rather they discourage them from greater participation. According to Steele, though both men and women rate men's work higher than that of women, researchers and people should be mindful of the psychological mechanism called "stereotype threat", which causes individuals who are made aware of the negative stereotypes connected to the social group to which they belong – such as age, gender, ethnicity and religion – to under perform in a manner consistent with the stereotype. It is important to remember that these prejudices are present in most human beings and the necessary steps should be taken to address these vices in order to arouse the interest of the females and thereby enhance their greater participation in the study of physics.

Literature shows that high school and college teachers are generally aware of low female participation in physics courses and the growth of this low participation at higher levels of study (Baird, 1997; Laura, 2005). According to Baird (1997), high school and college teachers assign a number of reasons to low female participation in physics courses. Among them are:

(a) Societal and cultural influences

(b) Lack of female role models

(c) The “Old Boys Club” aspect of physics

(d) Discouragement from parents, counselors and teachers

(e) Lack of interest in physics

(f) Lack of confidence in physics

(g) Aptitude, ability or brain differences

Baird (1997) findings further revealed that there are three aspects of physics structure, content and pedagogy that discourage females from greater participation in physics. These are:

(a) the emphasis on male-oriented interests and applications

(b) gender imbalance among physics instructors and students

(c) a mismatch between the perceived nature of physics and the perceived nature of female students.

A study conducted by Laura (2006) on “Why Are There So Few Female Physicists” identified some of the problems specific to females in the study of physics. According to Laura, many female students do not receive the same level of mathematics instruction as their male peers, and thus do not have the same foundation to study physics. She stresses that girls are not identified for their abilities in mathematics and science in the same proportion as boys (and boys are not identified for their talents in English, languages or the arts). Laura suggested that counselors should encourage students to pursue a variety of classes and they must encourage females to take a variety of high- level mathematics and science courses.

Accordingly, these females should be supported by providing them with mentors and role models, however limited they may be.

Another problem Laura (2006) identified was the classroom environment which she categorized as follows: The classroom environment – general female involvement; the classroom environment – peers and working groups; the classroom environment – teachers among others. On the issue of general female involvement, Laura lamented strongly about how females' lack of presence in the classroom was evidenced by the absence of their voice in the classroom discussions, their physical seating away from the teacher, their withdrawal from class activity and in some cases, by absenteeism. One female physics student in Laura's study referred to her place in the classroom as "invisibility". Other females also felt mistreated by fellow male students. It should be noted that these interactions which form part of an on-going struggle that female students face on daily basis, affect the level of involvement they are willing to put into the classroom. Thus if females are even thinking that they perceive discrimination in their classroom, they will be less likely to take science courses in future. In line with this Laura suggested that physics lecturers and teachers must examine how male students treat females in the classroom and find ways to encourage females to study physics to the higher level as far as possible.

On peers and working groups, Laura (2006) found that females did not speak more in small groups than they did in discussions with the entire classroom. One physics teacher in response to a question asking if he observed stereotypical gender actions when students work in laboratory groups said that, some of the females will allow a male to take over the equipment and 'run' the activities. The teacher further stated that he has had very few females take over the experiments. Another teacher also responded “sometimes the girls let the guys take charge and just sit passively” (p.178). Based on these observations, Laura concluded that single-sex grouping in small groups is one solution to these disparities. Laura believes that if laboratory groups are arranged according to sex, members of both genders are forced to be the observer, secretary and facilitator.

On teachers, Laura’s study revealed that the teachers’ role in the maintenance of gender roles in the physics classroom is very vital but often unknowingly, their roles tend to support gender biases. Though the teachers may be unaware, the students are not. The students in response to a question asking if there are any policies, practices, including the behaviours of teachers in classroom, that have the effect of treating students differently based on the sex, 100% responded ‘yes’. Most of them stressed that teachers spend more time listening to an answer from male students than from female students. It was also identified that the teaching style an instructor chooses affects female involvement in the classroom. According to Laura, refutational discussions was a common tool in physics classroom; this method asks students to debate each other regarding a concept and a specific student is often asked before the class to have a determined opinion that is wrong. Refutational learning, she said can be powerful because it encouraged the students to support their own opinions and thoughts. However, the study revealed that only 30% of females stated they were likely to argue a point in a physics classroom, so this type of learning can serve to increase gender inequalities.

Other teaching tools that were identified to be useful to assist in overcoming gender stereotypes in the classroom are ‘report talk’ and ‘circle talk’. Report talk is a traditional style where a teacher lectures the student which is very useful tool for teaching difficult physics concept that students need to learn. Nevertheless, this method does not engage all the students or force them to connect to the material. Circle talk is a style where the students sit in a circle and discuss concepts, ideas, and questions they have with the materials. Circle talk can be used to determine the thought processes of students and help them discover concepts for themselves (Laura 2006).

A survey designed to identify issues that are important to female physicists also reported on their negative experiences as a minority group owing to the male domination in the field (Ivie & Guo 2005). In the Ivie and Guo's, survey 80% stated that attitudes towards women in physics need to be improved, while 65% believed discrimination is a problem that needs to be dealt with. The survey also reported on positive experiences among female physicists, in particular their love for their field and the support that they have received from others.

An international conference (IUPAP, 2002) report on women in physics reports that the problems facing women in physics depend on the economy and society in which they work, but that some problems cut across countries and cultures. Among the universal challenges experienced by women physicists are the balancing of career with housework and child rearing, discrimination in the workplace, professional isolation, and a lack of representation at all levels of decision making (IUPAP, 2002).

Enhancing Female Participation in the Study of Physics

In addition to the suggestions made by the socialized differences viewpoint for improving female interest and participation in physics, the following strategies have also been found by other researchers to be beneficial as far the need for more women in physics is concerned.

(a) There should be transparency in selection processes for scholarships, funding and positions, i.e. making all evaluation done by the selection committees' public so that any discriminating mechanism can be unveiled. This will also benefit men, since they are also subjects of discrimination (Wenneras & Wold, 1997).

(b) The hostile attitudes in institutes and laboratories should be investigated. Most often those who discriminate tend not to see how their behaviour affects their environment and those discriminated against are usually reluctant to admit it (Main, 2005).

(c) The physics career path should be made more predictable. Both genders often suffer from the unpredictability and requirement of mobility in an academic physics career, and this can also conflict with the desire to start a family (Ivie and Guo, 2005).

(d) Awareness of discrimination. Nobody wants to discriminate against others; the use of stereotypes and prejudice is a part of the human mind. It is therefore important to be aware of how these properties affect the way that we evaluate and treat others. Awareness of discriminating procedures has caused changes (Carnes, 2006). According to Carnes the Swedish Medical Research Council changed their routines after being made aware that their evaluation and recruitment schemes were prejudiced against women.

Other studies reviewed also offered a wealth of strategies for keeping females in the field of physics. While some focus on what parents should do, others also focus on what schools should do with many of them focusing on what teachers should do.

What Parents Should Do

In making a contribution to what parents should do American Association of University Women (AAUM, 1989) recommends that the most important actions parents can take for their daughters are those that build self-confidence and provide experiences that are traditionally provided only for boys. “Parents must therefore encourage their daughters to be independent, to explore, and to experiment-even if it means they will get dirty or hurt” (AAUW, 1989, p. 6). In addition to traditional girls' toys, girls need to be provided with toys such as building blocks, erector sets, and chemistry sets, which encourage facility with spatial relationships and mechanics (Parsons-Chatman, 1987). Most importantly parents must also value the education of their daughters as they do to the education of their sons.

What Schools Should Do

The AAUW (1989) report advised that schools must not initiate or reinforce gender stereotypes. According to the report schools should provide a variety of role models in everything from faculty and staff hiring to textbook selection to designation of speakers at all forums. Furthermore, counselors must be open to encouraging girls in mathematics and science instead of steering them away from it. In addition, through the counseling program, schools should provide special programs-such as alliances with organizations like Women in Science and Engineering (WISAE), the Society of Women Engineers (SOWE), International Union of Pure and Applied Physics (IUPAP) and the American Association of University Women (AAUW) to help girls make wise career choices.

What Teachers Should Do

To the teachers/lecturers who are interested in keeping females in the field of physics Peltz (1990) offers the following strategies. Some seem to be obvious techniques of effective teaching for students of either gender.

- Maintain well-equipped, well-organized, and stimulating classrooms.
- Use non-sexist language, avoid practices that reinforce gender stereotypes, and confront bias in texts when they find it.
- Provide information on woman scientists and technologists in the classroom.
- Value creativity.
- Present a clear sense of direction in lessons, stress the use of math and encourage students to take further coursework.
- Help girls develop spatial abilities (p. 49).

Pollina (1995) recommended the following strategies for physics lecturers and teachers.

- Connect mathematics, science, and technology to the real world.
- Choose metaphors carefully, and have students develop their own. Presenting images that are comfortable and meaningful for girls.
- Foster an atmosphere of true collaboration.
- Encourage girls to act as experts with the teacher refusing to act as an expert.
- Give girls the opportunity to be in control of technology.
- Portray technology as a way to solve problems as well as a plaything.
- Capitalize on girls' verbal strengths.
- Experiment with testing and evaluation.
- Give frequent feedback, and keep expectations high.
- Experiment with note-taking techniques (p. 2-4).

Smail (1987) offers the following strategies in his paper "Organizing the Curriculum to Fit Girls' Interests."

- Set experiments in context by providing background information about the possible uses and applications of scientific principals. Do this, if possible, before ideas are derived by experiment - tell the pupils where they are going and why.
- Link physical science principals to the human body.
- Stress safety precautions rather than dangers.
- Discuss scientific issues aiming at a balanced view of the benefits and disadvantages of scientific developments.
- Make esthetically appealing exhibitions.
- Use imaginative writing as an aid to assimilating scientific principles and ideas (p.87-88).

Doherty, as cited in Taber (1991) offers specific advice to physics teachers. Some of the strategies echo the work of other authors.

- Change the way topics are taught to capitalize on girls' interests.
- Stress the relevance of science by relating it to social and environmental issues.
- Regular testing on short course units with assessments designed to show positive achievement.
- Career advice relating to science.
- Visits from working scientists and engineers.
- Gradual transition to examination level work.

- Don't allow boys to dominate teacher's attention.
- Don't allow stereotypical gender role behavior in class (boys work with apparatus; girls record and clean up).
- Don't allow boys to dominate lab equipment.
- Don't allow boys to put down girls' abilities in physics.
- Don't allow boys to disrupt girls' work.
- Don't make comments that support gender stereotypes and don't allow others to make such comments unchallenged.
- Don't employ teaching or assessment strategies that predominantly relate to the learning styles of males (for example, girls have been reported to do less well on multiple choice test but better on essay questions) - p. 226.

Labudde, Herzog, Neuenschwander, Violi, and Gerber (2000) offer the following strategies in their joint paper, “Girls and Physics: Teaching and learning strategies tested by classroom interventions.”

- Integration of everyday experiences and interests that is relevant to both genders into the content and context of instruction.
- Assessment and use of students’ prior knowledge to construct new knowledge.
- Interactive environments that enhance cooperation and communication in the classroom among the students and between the students and the instructor.
- Alternation between group discussion and structured teaching. Females perform better when they are able to articulate their thoughts verbally and males perform better when their learning experience is structured.
- Activities that decrease competitiveness.

- Diverse and frequent assessment practices and feedback.
- Activities that foster students understanding.
- Application of physics to a broader world-view (p.156).

While all the strategies listed above were developed and publicized by respected authors and researchers interested in narrowing the disciplinary disparity gap in physics, the strategy that has been best studied is one that appears on none of the lists above - the controversial strategy of single-gender learning environments. Research on the interactions in mixed-gender classes and groups offers compelling evidence in support of single-gender learning environments (Kelly, 1981; Peltz, 1990; Stowe, 1991; Lockwood, 1995), and some have been found to be successful (Pollina, 1995).

But the findings from single-gender classrooms according to Stowe (1991) indicate that there are pitfalls and paradoxes - boys learn best in coeducation classrooms whereas girls learn best in girls-only classrooms. Gierl (1994) reports that while high school girls found a single-gender physics course to have a better environment than a mixed-gender course, they were not sure when asked which type of course (single- or mixed-gender) they preferred. Geisel (1996) offers a heated philosophical argument in opposition to segregating the genders: "The problem is not with women's abilities. In fact the problem is not with women at all. The problem is sexist attitudes which are held mostly by men. Segregation of classes will not solve anything; it will only isolate the problem instead of exposing it" (p. 2).

Whitelegg and Parry (1999) also discussed real-life contexts for learning physics. They concluded that the context can come in as an application of a scientific principle after teaching theory or physics can be taught with the starting point in appropriate contexts. They are of the opinion that to increase females' interests teaching and learning should start with problems from an appropriate context, which is familiar for the students. Rennie & Parker (1996) have investigated the effect of context in physics problems by comparing the performance of physics students on two sets of matched problems, one set included problems embedded in a real-life context and the other set included abstract problems without reference to real-life events or objects. They found that the students performed better on the context-rich problems and therefore advised that physics should be by making reference to real-life situations, events or object to provide better understanding of physics concepts.

Davis and Humphreys (1985) in their book, "Evaluating Intervention Programs, Applications from Women's Programs in Math and Science", discussed and evaluated the effectiveness of some intervention programs/strategies. They group intervention programs/strategies into five types: short-term, audiovisual and printed products, experiential learning, long-term, and teacher education.

Short-term programs serve to raise awareness and change attitudes. They may consist of a speaker's series, one-day conferences, or workshops. Audiovisual and printed products are used as interventions to raise awareness, change attitudes, or increase knowledge. Films, filmstrips, videotapes, books, puzzles, exhibits, videodiscs, and career posters may be used to provide information about science careers in a concise manner. Experiential learning is used to give participants a hands-on experience in science or a science-related field. Long term interventions consist of courses and curricula. They are designed to increase learning as well as to change attitudes. Teacher education intervention programs may consist of summer institutes or in-service programs. Their purpose is to modify teachers' behaviors and improve their skills so that, ultimately, the learning and attitudes of their students are improved (Davis & Humphreys, 1985).

Intervention/strategies Proposed at IUPAP's 2002 International Conference Meeting

At the IUPAP international conference meeting in 2002, the delegates unanimously passed eight resolutions calling for fair treatment of females at every level of physics education, employment, and policy-making. The ideas in these resolutions are aimed at bringing more females into the field and leadership of physics. Some of the IUPAP (2002) resolutions are summarized below:

The delegates proposed that females should be given the same opportunities and encouragement as males to learn physics in schools. Universities were asked to examine their policies and procedures to ensure that female students are given an opportunity for success that equals that of male students. More importantly, lecturers/teachers were challenged to allow the females the opportunity to see ways that physics has a positive impact on society. Scientific and professional societies were also tasked to play a major role in increasing the number and success of women in physics. The societies were tasked to: work with other organizations to collect and make available statistical data on the participation of women in physics at all levels; identify women physicists and publicize them as role models; include women on program committees and as invited speakers for society-sponsored meetings and conferences; and include women on editorial boards of society journals.

The delegates at the IUPAP conference also proposed to National Governments that females should have the same access and chance for success in research and education as males, more importantly physics education. To the granting agencies the delegates proposed that females should have the same access to research funding as males and above all, competitions for funding should be transparent and widely publicized; the criteria for obtaining funds should be clear; and women should be included on all review and decision making committees. A challenge was thrown to the granting agencies to maintain and make available statistical data by gender, including such information as the proportion and qualifications of females and males who apply for funding and who obtain funding.

Summary

This review explored both theoretical and empirical perspectives of literature related to the research topic. The theoretical perspective covered four main areas namely, sex based differences in brain functions, the concept of inherent differences, socialized differences and culture bias of physics. However, sex based differences in brain function was not explored in the field research for the fact that theoretical and research work in this area has largely been abandoned. Its review therefore was just to provide a historical context for the substantial issue of 'low female participation in physics.'

The concept of inherent differences suggests that inherent differences between males and females lead them to have different interests. This means that females are less inclined towards physics than males due to some natural tendency. Furthermore, inherent differences in males and females are transmitted through genes and those genetic differences result in males and females reacting differently to the same external stimuli. The proponents of the inherent differences argument believe that females have genetic influences that lead them to being disinterested in physics. Lie and Bryhni (1983) noted that females' interests in biology topics are characterized by a close connection of science to the human being, to society and to ethic and aesthetic aspects.

Available literature shows that the inherent difference viewpoint exists (Summers, 2005). But their criticisms offer no solution to the problem of female under-representation in physics because their argument is that a solution is unnecessary and irrelevant since females should not be forced to participate if they are not interested. Many of the holders of this viewpoint also feel they have no power to change the natural interests of females. There are however, other physicists and science education researchers who hold the inherent differences viewpoint but feel intervention is necessary for other reasons. This has given rise to the concept of socialized differences.

This concept suggests that males and females are socialized to have different interests. Therefore females are less inclined towards physics than males due to values and behavioural dispositions that are transmitted by society, family, education and other influences surrounding them. The science educator who supports the socialized differences viewpoint believes that females are either trained directly to feel that physics is not for them or are trained toward behaviours that indirectly lead them away from interest in studying physics (Hazari & Potvin, 2005). Hazari and Potvin identify two major arenas through which this training occurs. These are the education system (comprising teachers, processors, peers, curriculum, etc.) and everything else outside the education system (such as parents, television, or society).

Socialized differences supporters like the inherent different supporters do accept the view that females are more interested in "life science" or science that has direct social relevance but believe that those interests are trained rather than passed on genetically and that teaching and learning physics can be modified to neutralize socialized differences.

It is believed that the problem of girls and physics have more to do with the nature of the field of physics than with the nature of girls, an assertion which has led to the emergence of the concept of culture bias of physics. The culture bias viewpoint focuses on problems in the community of physics that causes females to lose interest or opt out rather than the differences between sexes that cause their interest in physics to be different. The cultural bias viewpoint suggests that physics is not a gender neutral subject but rather is highly bound by masculine tendencies and preferences. Females or males that lack such tendencies might feel disinclined to the subject or alienated within the field.

The science educator who assigns weight to culture bias viewpoint believes that females face active and passive discrimination, and there is a bias in the field of physics favouring males. Physicists, physics educators, and physics education researchers have to diversify and create an equitable field of physics by revamping physics curriculum and culture to include broad and diverse worldviews, to make it more accessible to everyone and to change the social climate.

Fewer female students see a connection between physics and real life. More females than males are interested in socially relevant work and want a job that involves teamwork and offers security. As such many females think that a career in Science, Engineering and Technology, most especially physics will not give them any of these realizations. There is also limited participation in mathematics related occupations by females because many of them receive inadequate preparation in mathematics, and are therefore not able to enter educational programmes or careers that are mathematically inclined. The low females' participation in the study of physics is also attributed to the fact that physics is a mathematics related course. However, it is a democratic principle that power and influence should be distributed equally among different groups in society. More so, in a society in which technology is increasingly governing our everyday life, exposing women to physics will therefore lead to a more scientifically literate public. Scientifically, lack of women in the field of physics represents a waste of talent. Main (2005) opines that departments without women suffer in many ways. Hence, physics needs women to survive.

In fact, many people in physics community hold this truth that there should be more women in the field. Some of the common justifications include possible benefits to women, possible benefits to the economy, the possibility to help others and the unfairness of the current low female participation (Sullivan, Reamon, & Louie, 2003; Bouville, 2007). When these justifications are made explicit and seriously scrutinized, they in fact show that there should be mutual attraction between women and physics. However, this attraction is not universal so that there should be more women in physics programmes in as much as women actually want to graduate in these programmes. Many who claim that women are under represented in physics and that, out of fairness, their enrolment should be increased, forget the fact that drawing constantly more women to physics violate their right to choose a career freely.

The question therefore is how to get greater female participation in physics. A popular way out takes the forms of awareness programme. A change of mind, a 'paradigm shift' – from increasing number to increasing self-determination is essential. This means that the problems associated with females and physics need to be uncovered so that appropriate awareness programme can be designed to stir up the interest of females for the subject.

CHAPTER 3

METHODOLOGY

This chapter provides a detailed description of the design, instruments and procedure used to gain insights into female participation in physics at University of Cape Coast (UCC) and Senior Secondary Schools (SSS) in Cape Coast Metropolis. The chapter is therefore organized under following sub-headings: research design; population; sample and sampling technique; instruments for data collection; method of data collection and method of data analysis.

Research Design

In this study, attempts were made to investigate the causes of low proportion of females in physics compared to the proportion of females in biology and chemistry at UCC. Attempts were also made to investigate SSS female students' preference for physics as a programme of study beyond SSS level. This study therefore used cross-sectional survey to investigate why the proportion of females who pursue physics at the university level is not comparable with those who pursue biology and chemistry. The study further identified plausible practical methods/ways that could be employed to encourage more females (both SSS and undergraduate female students) to study physics to the higher level as far as possible.

The design involved two stages in which mixed methods were used to collect data. It has been observed that if a study uses different research methods for example quantitative and qualitative, it has the advantage of helping the researcher to get a deeper understanding of certain issues pertaining to the problem under investigation. (Best & Kahn, 1995; Taylor, 2004).

In the first stage, questionnaires were administered to university female undergraduate students offering physics, biology and chemistry at the university. This was meant to find out why they selected physic, biology, or chemistry as a course of study. A questionnaire was also administered to SSS final year female science students to find out whether they would choose to study physics at the university or not and the reasons for their choice. Another set of questionnaire was administered to university physics lecturers and SSS physics teachers to elicit reasons on low female participation in physics and what could be done to encourage more females to study physics.

The second stage involved individual student interviews with a smaller number of the females to delve deeper into some of the issues that came up from the questionnaire. A similar interview was conducted with physics lecturers and SSS physics teachers for the same purpose.

According to Ampiah (2004), choosing one method or the other for research work should be guided by two main two questions. These are “What kinds of information are relevant?” and “What kinds of methods are relevant for the particular topic under investigation?” (p. 82). Ampiah’s argument is that there is no best method in carrying out any educational research and that the method one uses should be suited to the issue or topic being explored.

The cross-sectional survey was used because it is a type of survey that collects information from a sample of a predetermined population (Fraenkel & Wallen, 2000). According to Cohen, Manion and Morrison (2000), a cross-sectional survey produces a snapshot of a population at a particular point in time and the description of the population is inferred from what is found from the sample. Nworgu (2006) also noted that cross-sectional survey makes it possible for many subjects to be studied at a time. The cross-sectional survey for this study had the advantage of ascertaining reasons that account for females' preference for biology and chemistry to physics from female students in SSS through to the university (level 100 to 400). Fraenkel and Wallen, (2000) have noted that cross- sectional survey has the potential of providing a lot of useful information from the subjects of the study. Mitchell and Jolley (2004) also noted that cross-sectional survey is more economical because it makes it possible for many subjects to be studied at the same time.

However, the difficulties involved in using the cross-sectional survey for this study lied in: ensuring that the questions to be answered were clear and not misleading; getting respondents to answer questions thoughtfully and honest; and getting a sufficient number of questionnaires completed and returned so that meaningful analysis could be made.

Population

The population of the study comprised female undergraduate students offering biology, chemistry and physics, SSS final year female science students, university physics lecturers and SSS physics teachers. The target population for this study was level 100 to 400 female undergraduate students pursuing biology, chemistry and physics at UCC, physics lecturers at UCC, final year female students from four selected SSS offering all three elective science subjects (biology, chemistry and physics) in Cape Coast Metropolis and physics teachers from the four selected SSS in the Metropolis.

Sample and Sample Technique

The sample size for the study comprised 208 undergraduate female students reading biology, chemistry and physics with a mean age range of (22 – 25) years and standard deviation of 0.8 respectively; 201 SSS final year female science students with a mean age of 17 years and standard deviation of 0.7 and 11 physics lecturers and teachers also with a mean age range of (30 – 36) years and standard deviation of 1.0 respectively.

Out of the 208 undergraduate female students, 127 representing 61.1% were biology students, 53 representing 25.5% were chemistry students and 28 representing 13.4% were physics students. The researcher applied for the list of female students reading biology, chemistry and physics from Students Record and Information Management Unit (SRIMU) at UCC. From the list that was provided, the females in their respective subject areas for the various levels were selected accordingly. The female biology and chemistry students were randomly selected using computer generated numbers. In the case of physics, all the females, from level 100 to 400, were selected.

Also, four SSS offering all three elective science subjects (biology, chemistry and physics) in Cape Coast Metropolis were purposively selected from a list of SSS obtained from Cape Coast Metro Educational Office. Purposively sampling technique was used because the other SSS in the Metropolis offering all three elective science subjects were only male institutions. The four schools comprised two female institutions and two co-educational (mixed) institutions respectively. In each of the co-educational schools all the final year female science students were selected. This yielded a total of 60 female students from these two schools, 35 from one and 25 from the other respectively. In the case of the two female institutions, computer generated numbers was used to select 83 (out of 165) and 58 (out of 116) final year science students according to the number of the final year science students in each school, making a total of 141 students from the two female institutions.

In each institution (UCC and SSS), all physics lecturers and physics teachers at post at the time of the research numbering 11 formed the sample of lecturers and teachers for the study. Teaching experience of these lecturers and teachers ranged between 1 to 18 years.

Instruments

The instruments developed for the study were: questionnaire on low female participation in physics (QLFPP); interview protocol for female students (IPFS) and interview protocol for physics lecturers and teachers (IPPLT).

Questionnaire on low female participation in physics (QLFPP)

This questionnaire was in two parts. The first part consisted of open-ended items which elicited respondents' opinions on participation of females in physics studies. The second part, closed-ended items with five-point Likert scale, asked respondents to indicate the extent to which they agree to some general views of students about physics.

In order to develop this instrument to elicit respondents' reasons on low female predication in physics studies, open-ended items (Appendix E) were constructed and administered to a group of Level 400 final year female students offering physics, chemistry and biology at UCC who were not used in the main study, and some selected physics lecturers who were also not used in the main study. In all, 50 female students [29 (58%) biology students, 16 (32%) chemistry students and 5 (10%) physics students] and 4 lecturers responded to the items in an initial pilot study. Their responses were used as a guide to construct the first draft of the QLFPP.

The QLFPP was made available to expects in the field to determine its validity after which it was pilot-tested using a total sample size of 150 subjects in four institutions in Kumasi Metropolis having the same characteristics as the institutions in Cape Coast Metropolis that were used in the main study. The 150 subjects included 91 undergraduate female students offering biology, chemistry and physics, 46 SSS female final year science students and 13 physics lecturers and teachers. The responses indicated that the wording was appropriate to the participants concerned.

In addition, the items with five-point Likert scale were subjected to item analysis in order to identify items whose removal would enhance the internal consistency of the instrument. In view of this, the Statistical Package for Social Sciences (SPSS) was used to determine the Cronbach alpha coefficient values for these five-point semantic differential scale items. An alpha value of 0.87, 0.71 and 0.65 were obtained for responses by undergraduate female students, SSS final year female science students and physics lecturers and teachers respectively. Coefficients ranged from 0.67 to 0.87, exceeding the threshold of 0.60 is given as being acceptable reliability for research purposes (Cohen, Manion & Morrison, 2000; Ampiah, 2004). Items whose inter-item reliability was below 0.3 were however deleted to enhance the internal consistency of the instrument. The final QLFPP was then constructed and labeled as Appendix A, B, C, and D respectively.

Interview Protocols for Female Students (IPFS)

Semi-structured interview protocols were designed for female undergraduate students and SSS female students. The semi-structured interview was used as follow up to gather data in the female students' own words in order to delve deeper into some of the issues that came up from the questionnaire. Issues like difficulty of physics, limited career opportunities in physics, poor tuition of the subject and relevance of the subject among others were discussed further during the interview protocols with the female students (see Appendix K).

Interview Protocols for Physics Lecturers and Teachers (IPPLT)

Another semi-structured interview protocol was designed for physics lecturers and teachers also as follow up to gather data in the lecturers and teachers' own words so that insights could be gained into low female participation in physics studies. The semi-structured interviews also allowed the researcher to raise issues of particular concern to the study (see Appendix L).

Data Collection Procedure

Data collection (fieldwork) was done in two stages: the first one took place between November 2008 and December 2008 whereas the second one took place between January 2009 and February 2009. The second data collection was a follow up to some issues that came up from the analysis of the first fieldwork data. The second data collected gave the researcher additional insights into the survey findings conducted in the first fieldwork.

The first fieldwork involved data collection from female undergraduate students offering biology, chemistry and physics at UCC, female final year science students from four selected SSS in Cape Coast Metropolis, physics lecturers from UCC and physics teachers from the selected SSS. Before data were collected the researcher visited the university lecturers and introduced himself. The purpose of the study was also explained to them. With a letter of introduction from the Head of Science and Mathematics Education Department of the University of Cape Coast, the researcher also visited the selected SSS and introduced himself to the various Heads and physics teachers in the schools. The dates and periods for the data collection were then arranged.

The QLFPP was designed in four different sets (see Appendix A, B, C and D). The researcher met the female undergraduate (biology, chemistry and physics) students in their respective lecture halls to administer the questionnaires. The QLFPP for female undergraduate students was administered to the selected students after the purpose of the study was explained to them. As much as possible, all questionnaire administered to female undergraduate students were collected by the researcher on the same day. However, some students insisted to take questionnaires away and return them the following day. Out of a total of 240 questionnaires distributed to the undergraduate female students, 208 were completed and returned, constituting 86.7% return rate.

The researcher also visited the selected SSS to administer the questionnaires. In each of the school, the purpose of the study was explained to the female students before questionnaires were administered. Questionnaires were administered with assistance from the physics teachers at post at the time of the research. Questionnaires that were administered to female students in the two co-educational (mixed) schools were completed and returned on the same day questionnaires were administered. However, in the case of the other two female institutions, it took the researcher three days each to finish with questionnaire administration. Completed questionnaires for each day were collected by the researcher. QLFPP for physics lecturers and teachers were also given out to them. As much as possible questionnaires administered to physics lecturers and teachers were collected back the third day. However, there were cases of non responses which were abandoned by the researcher after several attempts to get back these questionnaires failed. This resulted in a return rate of 50%. The advantage of using the questionnaires was that, they were administered to a larger number of the female population. This enabled the researcher to obtain wide range of information on the problem under investigation.

In the second stage, the researcher conducted individual interviews with a smaller number of the respondents. The researcher personally conducted the interviews with the selected female students, lecturers and teachers. The purpose of this interview was to delve deeper into issues which came up from analysis of responses to female students' questionnaires and physics lecturers and teachers' questionnaires. It was also meant to allow respondents who might not have had the chance to expand on, or react verbally to a question of particular interest or importance to do so.

All interviews were conducted using semi-structured interview guide. At the beginning of each interview session, interviewees were assured that their responses would be treated confidentially and would be used for research purposes only. All the interviews were recorded with an audio tape-recorder with the permission of interviewees. Notes were also taken to supplement what were recorded.

Data Analysis

Data gathered from the study were analysed based on the research questions and the null hypothesis that were formulated to guide the study. Frequency and percentage tables were used to ascertain students' and teachers' reasons on the low female participation in physics at UCC and what could be done to encourage greater female participation in physics studies. SSS female students' preferences for physics programmes at the university level were also ascertained by using frequency and percentage tables. In order to analyse the data on differences between undergraduate female non-physics and physics students' views about physics, responses obtained from the questionnaires on students' common views about physics were organised and shown in tabular forms containing frequencies/percentages, mean and standard deviations. Apart from these descriptive statistics, inferential analyses were also done. An independent samples t-test was carried out to test the null hypothesis that 'there is no significant difference between undergraduate female non-physics students and physics students' views about physics.

Qualitative data gathered during interviews were used to substantiate findings from the survey data. All responses were transcribed and interpreted as presented by the respondents. Though this was tedious and time consuming it helped the researcher to create familiarity with the data and hence aided the process of analysis.

CHAPTER 4

RESULTS AND DISCUSSION

Introduction

In this chapter, the findings from the study into female students' preferences for physics courses at the University of Cape Coast and selected Senior Secondary Schools in Cape Coast are presented and discussed in relation to the three research questions and the null hypothesis that were formulated to guide the study. The research questions are discussed based on quantitative and qualitative data that compared the responses of female biology, chemistry and physics undergraduate students; SSS final year female science students and physics lecturers and teachers. The data gathered during interviews with female students and teachers are used to complement and substantiate the survey findings.

Female Undergraduate Students' Preference for Biology, Chemistry and Physics Courses

Research question one was formulated to find out what accounts for UCC female students' preference for biology and chemistry courses to physics course. In order to answer this question, data were obtained from female biology and chemistry undergraduate students, female physics undergraduate students and physics lecturers and teachers.

Female biology and chemistry undergraduate students were, first of all, asked to offer at least three reasons why they chose to offer biology or chemistry but not physics. The responses for not offering physics were put into the following categories:

a) nature of physics

b) difficulty of the subject (physics)

c) limited career opportunities in physics

d) lack of motivation to study physics

e) limited usefulness of physics

f) lecturer factor

g) weak mathematics background

Table 1 shows cross tabulation of category and reasons by subject area of the students. It can be seen from Table 1 that the main reason why biology and chemistry students did not select physics was lack of career opportunities in physics. Majority of the biology students (79%) and all the chemistry students stated this as the major reason. Difficulty of the subject (physics) was the next popular reason chosen by 30 % of the biology students and 38% of the chemistry students. Issues of weak mathematics background, lecturer factor, and lack of motivation among others did not matter to most of the students.

Table 1

Female Undergraduate Students' Reasons for choosing Biology and Chemistry instead of Physics (N = 180)

	Non-Physics Students					
	Biology (N=127)		Chemistry (N=53)		Total (N=180)	
Reasons/category	N	%	N	%	N	%
Nature of physics	26	20	8	15	34	19
Lack of career opportunities in physics	100	79	53	100	153	85
Difficulty of physics	38	30	20	38	58	32
Limited usefulness of physics	28	22	9	17	37	21
Lack of motivation to study physics	28	22	6	11	34	19
Lecturer factor	25	20	3	6	28	16
Weak mathematics background	8	6	1	2	9	5

Examples of responses offered by female biology and chemistry undergraduate students in relation to the categories are presented in Table 2. Biology and chemistry female undergraduate students who were later interviewed believed that there were more job opportunities in their subject areas compared to those in physics. In order words, they thought they were familiar with career opportunities in biology and chemistry but not physics. For example, some of the female students said:

> I know little about career opportunities available for people who pursue physics. Besides, career opportunities in biology and chemistry are more human and easier to find compared to physics (Female chemistry student).

Another also said:

> I have interest in becoming a medical doctor. I want to be in the health sector and biology is the only course that I have to pursue in order to achieve my aim (Female biology student).

Table 2

Category and Example of Responses by Biology and Chemistry Female Undergraduate Students

Category	Example of responses
Nature of physics	Physics is too abstract, is more of principles and assumptions.
Limited career opportunities in physics	Little is known about job opportunities in physics.
Difficulty of physics	Physics concepts are difficult to comprehend.
Lack of motivation	There are more encouragement from lecturers to study biology and chemistry than physics.
Limited usefulness of physics	Life is about biology and chemistry but not physics.
Lecturer factor	I was discouraged in Level 100 by the physics lecturers.
Weak mathematics background	I am not very good in mathematics.

About the difficulty of physics, the females responded that biology and chemistry were much easier to understand compared to physics. Female biology students interviewed lamented that biology was much easier to ‘chew’ and reproduce but this can never be done for physics. When asked to explain further why they think physics was difficult, one biology female student responded:

> One has to understand everything, I mean all the principles
> and concepts and at the end your reward is D+, this is not
> fair (Female biology student).

These females seem to suggest that physics course work is full of principles and concept and since one has to understand these concepts and principles, it makes the course difficult.

Even though background in mathematics was not a major issue which influenced females’ preference for biology and chemistry, female biology and chemistry undergraduate students who were interviewed mentioned that physics involved a lot of calculations (mathematics) and formulas which made the study of the subject more difficult. According to them, their mathematics background was not strong for the university physics hence their choice for biology and chemistry. Female biology students who expressed this sentiment shared a similar view that biology was a reading subject and that they preferred reading to calculations. It was clear in their statements and comments during the interviews that to pursue physics in the university, one need to have a good background in mathematics which to them was a great worry. One female chemistry students responded:

> I opted out of physics at Level 300 because my mathematics
> was weak (Female chemistry student).

On lecturer factor, female biology and chemistry undergraduate students interviewed expressed similar concerns that some physics lecturers in the university had made the course so complex and difficult that students did not have the enthusiasm to pursue it any longer. Some of them further reported that statements and comments made by these lecturers in the lecture room were discouraging enough for them to continue pursue further courses in physics. Some of these statements by lecturers were given as follows: “physics is difficult, is not like your biology; some of you have made wrong choices for been here; physics is not your field you better go and drop physics for something else.” Indeed such utterances by physics lecturers will definitely kill the interest of students especially the females who in one way or the other have decided to pursue physics.

Female physics undergraduate students were also asked to offer at least three reasons why they offered physics but not biology or chemistry. It can be seen from Table 3 that 68% of the physics students indicated ‘career avenues in physics’ and ‘usefulness of physics’ as the major reasons underlying female physics undergraduate students’ choice for physics as a course of study at the university. Even though parent factor and good performance were mentioned, they were not really the main reasons.

Table 3

Female Physics Undergraduate Students Reasons for Choosing to offer Physics but Not Biology or Chemistry (N=28)

	Physics Student (N=28)	
Reasons/categories	N	%
Career opportunities in physics	19	68
Mathematics factor	6	21
Usefulness of physics	19	68
Parents factor	3	11
Good performance	4	14

Example offered by female physics undergraduate students in relation to the categories are shown in Table 4.

Table 4

Category and Example of Responses by Physics Female Undergraduate Students

Category	Example of reasons
Career opportunities in physics	I intended to go into the medical aspect of physics especially into X-rays.
Mathematics factor	Physics blends with mathematics and because I love math I chose physics.
Usefulness of physics	Physics is the basis of all technologies e.g. mobile phone service.
Parents factor	My parents asked me to do it.
Good performance	Easy to understand and perform ones you follow the principles.

Female physics undergraduate students who were later interviewed were very optimistic about job opportunities in physics after first degree. According to them they were aware of the job opportunities available for female physics student. For example, two female physics students said:

> I was motivated by my brother about the career opportunities for female physics students (Female physics student A).

Another also said:

> For me I intend to go into the medical aspect of physics, precisely into X-rays, because I understand is one of the high paid jobs in the health sector (Female physics student B).

Even though career is a motivating factor for physics female undergraduate students and their counterparts in biology and chemistry, there seem to be a conviction among biology and chemistry female students that there are more or better job/career opportunities in their subject areas than physics. This gives an indication that students pursuing biology and chemistry are ignorant of job avenues open to students pursuing courses in physics. Physicists may work in many fields like medical physics, computing, communication, environmental physics, geophysics and meteorology among others. Each field has many sub areas as indicated below: Medical physics (health service, instrumentation, health physics); Computing (computing design, system design, microprocessor design, robotic); Communications (fibre optics, satellites, telecommunications); Environmental physics (radiation protection, conservation, noise control, pollution control); Geophysics (mineralogy, petrology, prospection, mineral processing); meteorology (oceanography, weather forecasts) among others.

With regards to the usefulness of the subjects (biology, chemistry and physics), physics female undergraduate students contended that physics was most useful subject among the three subjects. All the female physics students interviewed held a similar view that physics is life and without it life is meaningless. They also said that physics was the basis of all sciences. In fact, all the six students who gave a third reason argued that physics was the chief corner stone of all technologies we see in this world. Interestingly, biology and chemistry undergraduate female students argued in favour of their respective subject saying that life depends on biology and chemistry but not physics.

To really understand the reasons underlying female students' preferences for biology and chemistry over physics, additional questions were posed to both biology and chemistry undergraduate female students as well their counterparts in physics. Answers to an item which sought to find out if the females have any regrets for choosing to study their respective subjects revealed that majority of female biology and chemistry students (95%) had no regrets for studying biology or chemistry. As indicated in Table 5, out of the 180 female biology and chemistry students, only 5% responded 'yes', implying that they had some regrets for choosing to study biology or chemistry.

Table 5

Proportion of Biology and Chemistry Undergraduate Students who Expressed Regrets for Studying Biology or Chemistry (N = 180)

Item	Response	Biology		Chemistry		Total	
		N	%	N	%	N	%
Do have any regrets for choosing to study biology or chemistry?	Yes	7	5.5	2	3.8	9	5.0
	No	120	94.5	51	96.2	71	95.0

Similarly, majority of female physics students, 23 (82.1%), indicated they had no regrets for choosing to study physics. Only 5 (17.7%) of them stated they had regretted for choosing to study the subject (physics).

When asked to give reasons for their responses, the 171 biology and chemistry female students who had no regrets for choosing to study biology or chemistry cited availability of career opportunities, good performance, and practicality, usefulness of the subjects and among others. As indicated in Table 6, majority of the biology and chemistry students (45.6%) stated that they were on the way to their future dreams considering the numerous career avenues waiting them. It was clear in their statements that with biology and chemistry they were very optimistic in the sense that their future career aspirations were not dicey. They were certain about where their future lies.

Second to career was performance level in relation to the three subjects as 37.5% of the students indicated that biology and chemistry concepts were not difficult to grasp or understand compared to physics. “Our performance is excellent and we are always getting the As and B+s,” stated by one biology student. Another student also indicated, “…how many physics students obtain first class in this university, physics is very difficult to come by the grades let alone first class.” Again, the believe that biology and chemistry are the most useful subjects gained another boost as 5.8% of the students asserted that the two subjects, biology and chemistry, were far better and more useful than physics because, according to them, biology and chemistry are the science of the body and the environment which every individual must be educated upon. Lecturer factor was ones again not left out. About 4.7% of them maintained that physics lecturers had hands in the females’ rejection for physics at the university.

Table 6

Reasons offered by Biology and Chemistry Undergraduate Students who Expressed no Regrets of Studying Biology or Chemistry (N = 171)

Category	Biology		Chemistry		Total	
	No	%	No	%	No	%
Availability of career opportunities	54	45.0	24	47.1	78	45.6
Good performance	46	38.3	18	35.3	64	37.5
Practical nature of the subjects	9	7.5	2	3.9	11	6.4
Usefulness of the subjects	6	5.0	4	7.8	10	5.8
Tutor factor	5	4.2	3	5.9	8	4.7

Three of the five female physics students who indicated they had regretted studying physics gave reasons that the subject was difficult. Below are the views expressed by these students:

> Physics is very difficult and demanding. It is difficult and very challenging too. Physics is very difficult for one to even have the passion to read it (Female physics student).

Another also offered multiple reasons:

> The lecturers are not teaching well. I am weak in mathematics. The lecturers are mean. The course is two abstract and not practical oriented (Female physics student).

About (61%) of the female physics undergraduate students (60.9%) who indicated they had no regret for studying physics stated that there were many prospects and avenues in physics after first degree. The others believed that physics was more practical oriented compared to biology or chemistry. One student stated, "…from what I have learnt so far everything around us is made up of physics."

A follow up question was asked to find out if biology, chemistry and physics female undergraduate students would like to offer physics at the university level when given another opportunity. The responses showed that majority of biology and chemistry female students would not like to offer physics if given another opportunity. Table 7 shows that out of 180 biology and chemistry female undergraduate students, only 11.1% indicated their intention to pursue physics should they be given another opportunity. Greater proportion of them (88.9%) responded negative to the question.

Table 7

Proportion of Biology and Chemistry Undergraduate Students who would like to offer Physics at the University when given another Opportunity (N = 180)

Item		Biology		Chemistry		Total	
		N	%	N	%	N	%
If you are given another opportunity, would you like to offer physics at the university?	Yes	13	10.2	7	13.2	20	11.1
	No	114	89.8	46	86.8	160	88.9

When asked to explain the reasons behind their choice, biology and chemistry female students who would not like to offer physics cited the abstract nature of physics, low interest level, the use of mathematics in physics, poor performance among others as reasons why they would not like to pursue physics should they be given another opportunity. Table 8 shows details of these reasons.

Table 8

Reasons offered by Biology and Chemistry Undergraduate Students who do not want to offer Physics if given another Opportunity (N = 160)

Category	Biology		Chemistry		Total	
	No	%	No	%	No	%
Abstract nature of physics	9	7.9	6	13.0	15	9.4
The use of mathematics in physics	13	11.4	4	8.7	17	10.6
Lac of motivation to study physics	5	4.4	6	13.0	11	6.9
Low interest level	41	36.0	17	37.0	58	36.2
Poor performance	35	30.7	9	19.6	44	27.5
Lecturer factor	11	9.6	4	8.7	15	9.4

It can be seen from Table 8 that the main reasons why biology and chemistry students would not like to pursue physics should they be given another opportunity had to do with low interest level in the subject, poor performance and perhaps the use of mathematics in physics. Lack of motivation was not a major issue even though it was mentioned among the reasons offered. Examples of reasons given by these biology and chemistry undergraduate female students in relation to the categories are indicated in Table 9.

Table 9

Example of Reasons offered by Biology and Chemistry Undergraduate Students who do not want to offer Physics if given another Opportunity (N = 160)

Category	Example of reason
Abstract nature of physics	Physics is more theoretical rather than being practical and this makes it difficult to understand.
The use of mathematics in physics	I am not good at mathematics hence cannot do physics.
Lack of motivation	There is no motivation to study physics, besides, students offering it are always complaining.
Low interest level	I don't have any interest in physics at all, is very boring, besides what I want to do in future has nothing to with physics.
Poor performance	My two years of physics was like a hell to me, it nearly sent me home
Lecturer factor	Lecturers have made physics very scary, difficult and boring.

The few biology and chemistry female students who would like to offer physics if they were given another opportunity indicated they were good in mathematics, had interest in the subject and that physics is the backbone of modern technology. As shown in Table 10, their main reason was that physics was the backbone of modern technology.

Table 10

Reasons offered by Biology and Chemistry Undergraduate Students who would like to offer Physics if given another Opportunity (N = 20)

Category	Biology		Chemistry		Total	
	No	%	No	%	No	%
Good in mathematics	4	30.8	1	14.2	5	25.0
Interest in physics	2	15.4	3	42.9	5	25.0
Technology based	7	53.8	3	42.9	10	50.0

Surprisingly, half of the female physics undergraduate students indicated they would not like to offer physics should they be given another opportunity. When asked to give reasons as to why they would not like to offer physics should they be given another opportunity, 35.7%, as shown in Table 11, stated that physics was too abstract and as a result understanding the fundamental concepts had not been easy for them. They added that the practical aspect of the course was not given the due attention by lecturers. One of them indicated:

> We always learn by imagination, assumptions and beliefs
> But we don't know where they originated from. We would
> have loved to see these things happening (Female physics student).

Similar to the views expressed by biology and chemistry students, 35.7% of female physics students hinted that physics course was difficult. It came out during interviews with these students that physics lecturers could have made physics more understandable by taking time to explain concepts and principles as well as the mathematics aspects very well for them to understand, but this was not been the case. According to them, lecturers have rather made physics scarier. The students blamed their physics lecturers for not teaching the course the way they felt it should be taught.

Table 11

Reason offered by Female Undergraduate Physics Students who would not want to offer Physics if given another Opportunity (N = 14)

Category	No.	%
Abstract nature of physics	4	28.6
Limited career opportunities	3	21.4
Lack of motivation	2	14.3
Poor performance	5	35.7

Furthermore, 21.4% revealed that with only first degree in physics, career opportunity was limited to only teaching. However, they were quick to add that with a master's degree in physics one would be exposed to more job opportunities. About 14% however mentioned that there was no motivation for them to pursue the course as one student lamented:

> The encouragement is not there and the worse of it all is
> that some lecturers keep on mentioning that after school
> there is no offer out there for you except teaching
> (Female physics student).

Reasons given by physics female undergraduate students who would not like to offer physics should they be given another opportunity were similar to those given by female biology and chemistry students. This means that biology and chemistry female students may have a genuine cause for not pursuing physics as a course of study at the university.

On the other hand, the other 50% who indicated their willingness to pursue physics should they be given another opportunity cited interest (35.7%), recipe of knowledge (21.4%) and usefulness of physics (42.9%) as their main reason. Examples of these are shown in Table 12.

Table 12

Example of Reasons offered by Physics Students who would still want to offer Physics if given another Opportunity (N = 14)

Category	Example of reason
Interest	I personally like physics, it makes you think.
Knowledge based	Learning physics makes you more knowledgeable and abreast with current issue in the technological world.
Usefulness of physics	The global world wouldn’t have been possible without physicists.

Physics Lecturers and Teachers’ Contributions on what Accounts for Females’ Preferences for Physics Courses

The previous section dealt with female biology, chemistry and physics undergraduate students on what accounts for female students’ preference for biology and chemistry courses to physics at the university. What about physics lecturers and teachers, a lot were said about them by the females, what do they also have to say?

Items 6 and 7 on physics lecturers and teachers' questionnaire sought to find out from lecturers and teachers if females show interest in physics lessons and how often they actively participate in physics lessons. Majority response by lecturers and teachers (90.9%) was that females show interest and actively participate in physics lessons. If this is so what then accounts for low female participation in physics compared to biology and chemistry? The lecturers and teachers had these to say. According to physics lecturers and teachers, low female participation in physics compared to biology and chemistry could be attributed to the following reasons: poor tuition; mathematics factor; negative perception about the subject and low interest level.

Poor Tuition

About 37% of physics lecturers and teachers who participated in the study admitted that physics was not well taught in a way to apply it in everyday life; as a result, students could not really see the subject as a life science. According to them most students did not get good basic explanation in the subject right from the secondary school level. This to them had not helped to develop students' interest for the subject. They also pointed out that insufficient skilled labour in the secondary institutions had caused many females to withdraw from physics studies. They however accused themselves by saying that students were not taught well to see the link between physics and mathematics at the SSS level so studying physics at the university appeared to be difficult. One lecturer stated:

> The first teacher who taught the ladies [females] physics could
> not make the subject attractive but rather boring
> (Physics lecturer).

Mathematics Factor

On mathematics component of physics, 27% of the lecturers and teachers stated that physics involves mathematics (calculations) and proofs which mean that one cannot succeed in physics without having strong background in mathematics. They indicated that most females had low concepts in mathematics topics hence they failed to appreciate the relationship between physics and mathematics. According to them, the females' low concept in mathematics topics was one of the main reasons why majority of females did not select physics courses at the university. One physics lecturer stated:

> Since physics is mathematics based at higher levels, weak
> background in mathematics makes the subject difficult
> to study/learn (Physics lecturer).

Another also offered,

> Lack of certain basic mathematics concepts compelled
> many females to opt out of physics at the university
> (SSS physics tutor).

Perception

There is a perception that physics like mathematics, is difficult and also for men. About 20% of the physics lecturers and teachers believed that this perception had done more harm than good to the physics society to the extent that greater number of female potentials who could have contributed to the development of physics had been lost due the perception they conceded as far back their secondary education. Comments by this lecturers and teachers suggested that, most female students had an impression that physics was a difficult subject and therefore they did not spend much time to study it. The lecturers believed that the females had conceded the notion that whether or not they study physics; they would not perform well in it. Some female students, as reported by the lecturers and teachers had also perceived physics to be very technical hence only males could do it whereas others had the mentality that physics was a programme designed for only males. One teacher stated:

> As there is a general idea that physics is for men,
> females from the word go associate the subject to
> males (SSS physics tutor).

Interest

On interest, 16% of the physics lecturers and teachers believed that there had been low interest level in the subject by female students right from the secondary school level. The lecturers and teachers were of the view that due to lack of personal interest in the subject on the part female students, they did not see the beauty in the physics let alone career opportunities associated with the study of physics.

Reasons given by female undergraduates' students about their preferences for biology and chemistry courses to physics course and reasons by physics lecturers and teachers – abstract nature of physics; limited/unknown career opportunities in the subject; difficulty level of the subject; the use of mathematics in physics; lack of encouragement; tuition etc are in line with most of the findings in the literature. NSF (2002) for example reported that the culture of physics is harder for females to break into than that of other sciences. Bhatia (1991) has lamented that most females hesitate to go into physics because of the mathematics aspect of the subject as this makes heavy demands of them both in matters of time and effort. On career opportunities, Ivie and Guo (2005) asserted that student (both genders) suffer from the unpredictability in an academic physics career. A prejudice (discriminations), which has been largely reported in the literature (Urry, 2003; Hazari & Potvin, 2005), was not found in this study to be an important reason that discourages greater female participation in physics at University of Cape Coast.

In summary, research question one was aimed at guiding the study in such a manner as would help answer the question why female students at UCC prefer biology and chemistry to physics. Both qualitative and quantitative data were used for the analysis of the findings. The females' responses for not offering physics were categorised as follows: nature of physics; difficulty of the subject; limited career opportunities in physics; limited usefulness of physics; lecturer factor and weak mathematics background.

It was revealed that majority of the female undergraduate students offering chemistry and biology with hindsight would not like to offer physics, even when given the opportunity. Their reasons for rejecting physics among others were low interest level, poor performance and the mathematics component of physics. Even a significant number of female physics students indicated that the physics course is difficult.

Differences between Undergraduate Female Non-Physics Students (Biology and Chemistry) and Physics Students' Views about Physics

After given reasons for selecting their respective subjects, female biology, chemistry and physics students indicated the extent to which they agree with some general view of students about physics. Table 13 shows the mean, standard deviation and percentage responses by female biology students.

Table 13

Mean, Standard Deviation and Percentage Responses of Biology Undergraduate Students' Views about Physics (N = 127)

No	Statements	Percentage responses					Mean	Std dev.
		SA	A	U	D	SD		
8	Females naturally like biology.	65.4	28.3	3.9	2.4	0	4.6	0.7
9	I simply don't like physics.	33.1	15.7	9.4	29.1	12.6	3.3	1.5
10	There is nothing that can be done to change my mind to study physics.	25.2	11.8	17.3	31.5	14.2	3.0	1.4
11	Physics is not an appealing subject for females.	13.4	12.6	13.4	34.6	26.0	2.5	1.4
12	I had a diminishing self-confidence as I progressed to higher levels of physics studies.	15.7	27.6	13.4	26.8	16.5	3.0	1.4
13	I was not encouraged enough (e.g. by peer, teachers and parents) to study physics.	27.6	22.8	3.5	29.1	15.0	3.2	1.5
14	Physics is naturally difficult.	13.4	26.8	11.0	33.1	15.7	2. 9	1.3

Table 13 cont'd

No	Statements	Percentage responses					Mean	Std dev.
		SA	A	U	D	SD		
15	I am not good at physics.	11.8	26.0	9.4	34.6	18.1	2.8	1.3
16	I am not good at mathematics.	9.4	15.0	5.5	35.4	34.6	2.3	1.3
17	Physics is taught in a way that is often theoretical.	44.1	28.3	7.1	11.0	9.4	3.9	1.3
18	I have little information on areas where physics can lead me to.	33.1	24.4	7.1	22.0	13.4	3.4	1.5

SA-strongly agree A-agree U-undecided D-disagree

SD-strongly disagree

It can be seen from the Table 13 that majority of the female biology undergraduate students (93.7%) agreed to the statement 'females naturally like biology.' However, they were hesitant about the statement 'females simply don't like physics' as 48.8% agreed while 41.7% disagree with 9.4% undecided. Even though the biology students agreed that the content of physics is more difficult to understand compared to biology or chemistry (67.8%), they refuted the assertion that females are not good at mathematics (70.0%) and physics (42.7). Moreover, about 72.4% indicated that the teaching of physics had been more of theory than practical.

The responses by female chemistry undergraduate students on students' views about physics were generally not different from those by female biology students. As indicated in Table 14, 94.3% of the female chemistry students agreed to the statement 'females naturally like biology.' Similar to the biology students, the chemistry students also refuted the assertion that females are not good at mathematics (73.6%) and physics (39.0%). Majority of them (62.3%) also agreed that the content of physics is more difficult to understand compared to biology or chemistry. The responses as presented in Table 13, by female biology students, and female chemistry students, Table 14, show that both female biology and chemistry students had similar views about physics.

Table 14

Mean, Standard Deviation and Percentage Responses of Chemistry Undergraduate Students' Views about Physics (N = 53)

No	Statements	Percentage responses					Mean	Std dev.
		SA	A	U	D	SD		
8	Females naturally like biology.	41.5	52.8	0	3.8	1.9	2.3	0.8
9	I simply don't like physics.	24.5	22.6	13.2	24.5	15.1	3.2	1.4
10	There is that can be to change my mind to study physics.	26.4	11.3	24.5	24.4	13.2	3.1	1.4
11	Physics is not an appealing subject for females.	3.8	26.4	9.4	34.0	26.4	2.5	1.3

Table 14 cont'd

No	Statements	Percentage responses					Mean	Std dev.
		SA	A	U	D	SD		
12	I was not encouraged enough (e.g. by peer, teachers and parents) to study physics.	22.6	43.4	5.7	20.8	7.5	3.5	1.3
13	Physics is naturally difficult.	17.0	28.3	18.9	28.3	7.5	3.2	1.2
14	The content of physics is more difficult to understand compared to biology or chemistry.	30.2	32.1	11.3	20.8	5.7	3.6	1.3
15	I am not good at physics.	9.4	18.9	22.6	37.7	1.3	2.8	1.2
16	I am not good at mathematics.	9.4	11.3	5.7	45.3	28.3	2.3	1.3
17	Physics is taught in a way that is often theoretical.	32.1	47.2	5.7	7.5	7.5	3.9	1.2
18	I have little information on areas where physics can lead me to.	32.1	35.8	3.8	17.0	11.3	3.6	1.4

SA-strongly agree A-agree U-undecided D-disagree

SD-strongly disagree

Responses by female physics undergraduate students on students' views about physics are shown in Table 15. It can be seen from Table 15 that even though 60.8% of the female physics students agreed to the statement 'females naturally like biology', there was no majority decision on whether females simply do not like physics as 42.9% agreed and 42.9% also disagreed with 14.3% indecisive. Female physics students also refuted the assertion that females are not good at physics as 75.0% disagreed to the statement. However, majority of them admitted that physics is more mathematical (85.7%) and their weak background in mathematics was affecting their performance in physics (92.8%).

Table 15

Mean, Standard Deviation and Percentage Responses of Physics Undergraduate Students' Views about Physics (N = 28)

No	Statement	Percentage responses					Mean	Std dev.
		SA	A	U	D	SD		
8	Females naturally like biology.	17.9	42.9	3.6	17.9	17.9	3.3	1.4
9	Females simply do not like physics.	7.1	35.7	14.3	25.0	17.9	2.9	1.3
10	Physics is not an appealing subject for females.	7.1	28.6	7.1	35.7	21.4	2.6	1.3
11	Females are not encouraged enough (e.g. by peer, teachers and parents) to study physics.	39.3	35.7	0	10.7	14.3	3.8	1.5
12	Physics is naturally difficult.	17.9	32.1	0	35.7	14.3	3.0	1.4

Table 15 cont'd

No	Statement	Percentage responses					Mean	Std dev.
		SA	A	U	D	SD		
13	The content of physics is more difficult for me to understand compared to biology/chemistry	10.7	32.1	14.3	28.6	14.3	2.96	1.3
14	Females are not good at physics.	0	10.7	14.3	39.3	35.7	2.0	1.0
15	Physics is more mathematical.	53.6	32.1	3.6	7.1	3.6	4.3	1.1
16	My mathematics background influences my achievement in physics.	46.4	46.4	3.6	3.6	0	4.4	0.7
17	Physics is taught in a way that is often more practical and relevant to everyday life situations.	7.1	14.3	0	25.0	53.6	3.0	1.7
18	Many females have little information on areas where physics can lead them to.	32.1	42.9	0	10.7	14.3	3.7	1.4

It can also be observed from Table 15 that, 57.1% of female physics students refuted the assertion that physics is not an appealing subject for females. It came during interviews with these students that methods lecturers used during their presentation or teaching did not make physics appealing and interesting to them. One physics female student responded,

> Due to poor presentation by some lecturers most females
> do not see physics to be practical and relevant to their
> everyday life situations (female physics student).

In addition, about 75.0% of female physics students had little information or knowledge on areas where physics can lead them to. This goes to buttress the point made by biology and chemistry female students about the limited career opportunities in physics.

A null hypothesis was tested to find out if any significant difference exists between undergraduate female non-physics students (biology and chemistry) and physics students' views about physics. As shown in Figure 1, the difference between responses of undergraduate female non-physics students (biology and chemistry) and physics students' views about physics was much closed.

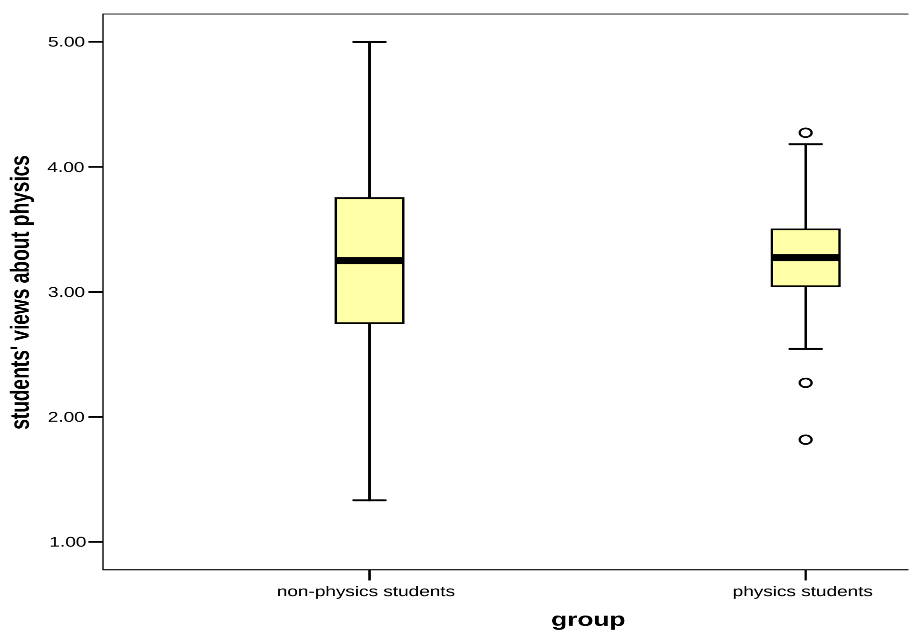

Figure 1: **Boxplot showing the distribution pattern of undergraduate female physics and non-physics students' views about physics**

When an independent samples t-test was conducted to test the null hypothesis that no significant difference exists between undergraduate female non-physics and physics students' views about physics, Table 16 shows that the results of the test were not significant, t (206) = -0.19, p = 0.85. Undergraduate female non-physics students (M = 3.2, SD = 0.71) and physics students (M = 3.3, SD = 0.54) do not differ in their views about physics. The null hypothesis was therefore not rejected.

Table 16

Independent Samples t-test on differences between Undergraduate Female Non-Physics Students and Physics Students Views about Physics

	Group	Mean	Std dev.	t	p-value
Students views about physics	Non-physics students	3.2	0.71	-0.19	0.85*
	Physics students	3.3	.54		

*Not significant, p > 0.05 degree of freedom (df) = 206

In Table 17, responses by physics lecturers and teachers on students' views about physics are presented. It can be observed from Table 17 that 54.5% of the lecturers and teachers agreed to the statement 'females naturally like biology' whereas 27.7% disagreed and 18.2% were undecided. In addition, 72.7% could not tell whether females simply do not like physics. Only 18.2% agreed that females simply do not like physics. Even though most of the lecturers and teachers agreed that females naturally like biology, 90.9% disagreed to the statement that there is noting that can be done to change the minds of females to study physics. The lecturers and teachers were rather optimistic that there were ways that could be employed to develop the interest of females to study physics. By this view, physics lecturers and teachers who participated in the study disagree with holders of inherent differences viewpoint who feel that no change is necessary because they have no power to change the natural interest of females. Urry (2003), a proponent of the inherent differences viewpoint asserts that females simply don't like physics and there is nothing he could do to change their minds.

Table 17

Mean, Standard Deviation and Percentage Responses of Physics Lecturers and Teachers' Views about Physics (N = 11)

No	Statement	Percentage Responses					Mean	Std dev.
		SA	A	U	D	SD		
10	Females naturally like biology	0	54.5	18.2	27.3	0	3.3	0.9
11	Females simply do not like physics.	0	18.2	72.7	0	9.1	3.3	0.5
12	There is nothing that can be done change the minds of females to study physics.	9.1	0	0	36.4	54.5	1.7	1.2
13	Physics is not an appealing subject for females.	0	0	9.1	72.7	18.2	1.9	0.5
14	Females have diminishing self- confidence as they progress to higher levels of physics studies.	9.1	18.2	9.1	45.5	18.2	2.6	1. 3

Table 17 cont'd

No	Statement	Percentage Responses					Mean	Std dev.
		SA	A	U	D	SD		
15	Physics is naturally difficult.	9.1	36.4	0	36.4	18.2	2.8	1.4
16	The content of physics is harder more difficult for many females to understand compared to biology/chemistry.	0	18.2	9.1	72.7	0	2.6	0.8
17	Physics is taught in a way that is often more theoretical.	9.1	72.7	0	18.2	0	3.7	0.9
18	Many females have little information on areas where. physics can lead them to	18.2	63.6	9.1	9.1	0	3.9	0.8

The lecturers and teachers also debunked the impression that physics is not an appealing subject for females as 90.9% disagreed to this statement. 63.7% of the lecturers/teachers also disagreed to the statement 'females have diminishing self-confidence as they progress to higher level of physics studies. This view is not in line with the assertion by Gellibrand, Robison, Brown and Osborn (1999), DeBacker and Nelson (2000) and Haussler and Hoffmann (2002) that females lack self-confidence in studying physics as they progress to higher levels of physics education. On the other hand, 72.7% agree with Haussler and Hoffmann (2002) that females are not encouraged enough, especially by peers, teachers and parents, to study physics.

It can also be seen from Table 17 that 45.5% of the lecturers and teachers agreed that physics is naturally difficult. Even though majority of them (54.2%) disagreed, the difference is not so much to believe that physics is naturally difficult or not. Interestingly, majority (81.8%) agreed that physics is taught in a way that is often more theoretical. This discovery is in line with Hazari and Potvin's (2005) assertion that undergraduate physics is taught in way that is often more unrealistic and abstract than necessary. It also confirms that of Benkert (1997) who claims that content of physics courses and physics problems are often idealized and removed from real life context.

It is interesting to note also that 81.8% of the lecturers and teachers agreed to the statement 'female have little information on areas where physics can lead them to.' This creates the impression that lecturers and teachers are not doing much to promote physics studies among females.

Senior Secondary School Female Science Students' Preference for Physics as a Course of Study beyond Senior Secondary School Level

Research question two was formulated with the aim of finding out the reasons which accounts for SSS female students' preference for physics as a course of study at the university. Data were obtained from 201 SSS female final year science students to answer this question. Prior to giving their responses, the 201 SSS female students stated the programme they would like to pursue at the university. Table 18 shows the first choice programme of preference of these females.

As indicated in Table 18, two-thirds of the SSS females (67.2%) would like to pursue medicine as their first choice programme at the university, followed by pharmacy (6.0%) and nursing (5.5%). Only 1.5% of SSS female final year students would like to pursue physics as their first choice programme. Programmes that had less than three frequency counts were categorized as others. These included Psychology, Statistics, Information Technology, Marine Engineering etc.

Table 18

First Choice Programme of Preference of SSS Female Final Year Science Students

Programme	No	Percentage
Agricultural Science	5	2.5
Biological Science	6	3.0
Chemistry	4	2.0
Medicine	135	67.2
Nursing	11	5.5
Pharmacy	12	6.0
Physics	3	1.5
Yet to decide	5	2.5
Others	20	10.0
Total	201	100

Furthermore, when they were asked to indicate their second, third and forth preferences should they not be admitted into their first choice programmes, the proportion of SSS female students who preferred physics as second, third or fouth choice was still far below that of biology and chemistry (see Appendices H, I and J). These results indicate that female science students at the SSS level in Cape Coast

Metropolis had much interest in biology and chemistry and their related course than physics because when asked to select among biology, chemistry and physics as a course of study at the university, physics was the least chosen subject. Majority of the SSS female students (82.6%) indicated they would not like to offer physics at the university as shown in Table 19.

Table 19

Proportion of SSS Female Students who would choose to offer Physics at the University instead of Biology or Chemistry (N = 201)

Programme	No	Percentage
Biology	119	59.2
Chemistry	47	23.4
Physics	35	17.4
Total	201	100.0

The SSS female respondents however cited abstract nature of physics, limited career opportunities in physics, poor performance due to difficulty of the subject and mathematics aspect of physics as reasons why they would not like to pursue physics at the university. It can be seen from Table 20 that the main reasons why SSS female students would not like to pursue physics at the university had to do with limited career opportunities in physics (43.4%) and poor performance due to difficulty of physics (27.7%). Mathematics component of physics was really not a major issue to them.

Table 20

Reason offered by SSS Female Students who would not want to Pursue Physics as a Course of Study at the University (N = 166)

Category	No.	%
Limited career opportunities in physics	72	43.4
Poor performance in physics	46	27.7
Abstract nature of physics	32	19.3
Mathematics factor	16	9.6

SSS female students who were later interviewed stated that physics was not related to the fields they aspire to pursue. They also believed that there were no job opportunities for physics students after graduation, apart from teaching. One female student responded:

> Most people I had known as physics students in the universities came out as teachers. I do not want to limit myself to teaching (SSS female student, mixed school).

The SSS female students also reported that among the three subjects (biology, chemistry and physics) physics was the most difficult one. This according to them confirmed what they had been hearing from people, friends and even teachers that physics was difficult at the university. Some of them were simply convinced that what they were going through at the SSS level clearly demonstrated the nature of physics at the university. They therefore preferred not to enter into this "hell" again. One female responded:

> Physics at the SSS level is too complicated, difficult and bulky. I would not have to go through this again at the university (SSS female student, single sex school).

Another also offered:

> Physics at this level (SSS) is really difficult for me hence I really don't know how I am going to cope with it at the university (SSS female student, mixed school).

The females who would not like to offer physics because they described the subject as abstract, further explained that it required one lot of time to think in order to remember as many assumptions and principles as far as possible, and making deductions. This according to them made physics boring to study. One female student from a single sex school (girls only) complained:

> The principles and laws seem unreal, everything seems to be an assumption and that studying it confuses me as I try to compare it to reality (SSS female student, single sex school).

Another female student from a mixed school also said:

> The theories, laws and formulas are too many to be memorized for solving a typical physics questions (SSS student, mixed school).

On the other hand, the 35 SSS females who indicated they would like to offer physics at university also gave reasons for their choice. As shown in Table 21, to most of them (40.0%), physics was more useful. They indicated that physics was the subject that could offer explanation to all natural occurrences under the universe and beyond so to them, physics was more useful. They further explained that if physicists were able to predict things like eclipse of the sun (one of the natural occurrences) for it to happen as predicted, then, no matter the difficult level of the subject, it should be studied. One student stated:

> Physics offers explanation to earthquake, tsunami and others and almost always their occurrences are predicted. Physicists are just great thinkers; I would like to be one among the few".

About one-forth of these females also indicated they were good at mathematics so understanding the concepts would not be difficult for them. According to them, once you understand the mathematics behind the concepts you can easily pass physics with distinction. They also expressed mixed-feelings about biology and chemistry that they are more of reading than calculation.

Table 21

Reason offered by SSS Female Students who indicated they would like to Pursue Physics as a Course of Study at the University (N = 35)

Category	No.	%
More useful subject	14	40.0
Career opportunities in physics	9	25.7
Good at mathematics	7	20.0
Good performance	5	14.3

The study also revealed that some SSS females would only offer physics if they had no other option. When the 166 females (who had indicated their preferences for biology and chemistry) were asked to indicate whether they would like to offer physics should they not be admitted into biology or chemistry, quite a good number of them (45.2%) responded ‘yes,’ meaning that they would offer physics should they missed their programme of choice. This gives an indication that should they be lucky to be admitted into their preferred programmes, they would have nothing to do with physics. The remaining 54.8% however, responded that they were not interested to pursue any course in physics at the university even if do not get admission into their preferred programmes.

When the SSS female students were asked to describe some conditions that could encourage them to study physics beyond SSS level, Table 22 shows that job opportunities in physics, practicality of the subject, good tuition, motivation and role models and mentors were among the pertinent issues that must to be addressed so as to develop and sustain the interest of these females to study physics beyond SSS level. These concerns by the SSS females support the concerns raised by their colleagues in the University of Cape Coast pursuing biology, chemistry and physics programmes.

Table 22

Responses by SSS Female Students of ways to encourage them to Study Physics beyond SSS Level (N = 201)

Category	No.	%
Good tuition	46	22.9
Career opportunities made known	44	22.0
Practicality of physics	42	20.9
Given more motivation	23	11.4
No option	21	10.4
Role model and mentors	13	6.5
Change of perception	12	6.0

Examples of the categories given by the students are listed in Table 23.

Table 23

Category and Examples by SSS Female Students of ways to encourage them to Study Physics beyond SSS Level (N = 201)

Category	Example of category
Career opportunities in physics	If I am convinced that I'll easily find employment other than teaching after graduation.
Given motivation	If I get more encouragement from teachers, parents and friends.
Change of perception	If people stop making the pronouncements that physics is difficult at the university.
Practicality of physics	When physics made more practical than just the theory and the assumptions.
Role model and mentors	If I see females in physics who are known to be doing well in life.
Good tuition	If physics teachers will adopt new strategies of teaching the subject to enhance better understanding.
No option	I'll only study physics if I have no other option

In addition to the ways suggested, when all the 201 SSS females were asked to rank some practical methods that were provided, Table 24 shows that they ranked medium/high for knowing the importance of physics and parents support (see Appendix F for the basis for the ranks). This explains further, the need for awareness programmes to sensitize students, especially female students about the numerous opportunities in physics and the need to study the subject. By this way, students will be psychologically prepared to pursue physics at higher level.

Table 24

SSS Female Students' Ranking for Reasons for Studying Physics Beyond SSS Level (N = 201)

Statement	Rank
a. If my parents support me	Medium/high
b. If my teachers encourage me	Medium
c. If I am given special attention in class by my physics teachers	Medium
d. If I see female scientists in physics as role models	Medium/low
e. If I know the importance of physics	Medium/high
f. If the study of physics will raise my social status	Low/medium

In conclusion, research question two was framed with the purpose of finding out reasons which accounts for SSS female students' choice of physics as a course of study at the university. Prior to giving their responses, 201 SSS female students used for the study were asked to indicate the programme they would like to pursue at the university. Physics was the least chosen option while medicine, pharmacy and nursing assumed prominence. When the students were made to indicate their second choice programmes in case they missed their first choice programmes, physics was still given a low profile.

The respondents gave such reasons as physics is abstract, there are limited career opportunities in the subject, poor performance due to the difficulty level of the subject and that the subject has a mathematics component. The SSS female students observed that their experiences in the physics class have confirmed the stories they have heard from their friends and teachers about how difficult physics is at the university. Hence, they will not like to enter what they called "hell" by going in for physics. They however suggested among other things that if they get good tuition from their teachers and also made known about career opportunities in physics, they will be encouraged to pursue the subject beyond SSS level.

Practical Ways to Make Physics More Appealing to Females

Research question three sought to find out practical methods or ways that could be employed to make physics more appealing to female students as a programme to pursue in higher institutions. Practical methods identified are presented in three perspectives: in the views of female undergraduate non-physics students (biology and chemistry); female physics undergraduate students and physics lecturers and teachers. Responses offered by female non-physics students and physics students are shown in Table 25.

It can be seen from Table 25 that good tuition and career awareness in physics were the main concerns of biology and chemistry female students. In fact, these were the main reasons why biology and chemistry female undergraduate students did not select physics. It is therefore in line for biology and chemistry female students to suggest that, job opportunities in physics should be made known to students together with good tuition of the subject in order to make the subject (physics) more appealing to female students.

About 9% of the biology and chemistry female students also indicated that scholarship schemes should be instituted in the universities for females who pursue physics to motivate and encourage others to pursue the subject to the higher level as far as possible. Very few of them (3.9%) indicated that regular counseling services should be instituted to help clarify misconceptions and perceptions most females had conceded about the subject.

Table 25

Non-Physics and Physics Students' Suggestions of Practical Ways to make Physics more appealing to Female Students (N = 208)

	Non-Physics Students (N=180)		Physics Students (N=28)	
Practical way	No.	%	No	%
Good tuition	57	31.7	8	28.6
Career awareness in physics	49	27.2	10	35.7
Making physics more practical	18	10. 0	3	10.7
Scholarship schemes	16	8.9	5	17.9
Change of perception about the subject	13	7.2	0	0
Restructure of content	12	6.7	0	0
Role models and mentors	8	4.4	2	7.1
Counseling services	7	3.9	0	0

Practical ways suggested by female physics undergraduate students were not different from those given by female biology and chemistry undergraduate students since they were also much concerned about career awareness in physics and good tuition as shown in Table 25 above.

It an undeniable fact that females in general would not like to be found in a limited job opportunity environment, and since to them little is known about job/career avenues in physics, female students especially, should be exposed to the job avenues in physics so that physics would be seen as equally important as biology or chemistry. Indeed, majority of females pursuing biology, chemistry and physics at University of Cape Coast are not aware of the many prospects in the subject. Physics lecturers are therefore entreated to disseminate amongst students, especially female students, information on job avenues in physics. By this way, females' perception about limited job opportunities in physics will be a thing of the past.

As indicated in Table 26, 45.5% of physics lecturers and teachers were also concerned about good tuition as a major tool for making physics more appealing to female student.

Table 26

Physics Lecturers and Teachers' Suggestions of Practical Ways to make Physics more appealing to Female Students (N = 11)

Practical way	No.	%
Good tuition	5	45.5
Counseling services	4	36.4
Role models and mentors	2	18.1

When asked to throw more light on good tuition as a way to make physics more attractive to females, physics lecturers who were interviewed mentioned that physics should be taught by using practical examples to explain physics concepts and phenomena. They also advised that, lecturers and teachers must take their time to ensure that students, especially female students grasp the concepts being presented. In addition, they emphasized on special attention which should be given to female students after lectures to help them clarify some of the concepts they couldn’t understand in the lecture room.

SSS physics teachers who were also interviewed added that mathematics and physics concepts should be taught well at JSS level in order to encourage more females to study both mathematics and physics at SSS. To them if basic terminologies and concepts are explained very well with examples and involving females during class discussion when the subject is being taught, more females would be interested to pursue physics to the higher level.

Another strategy which physics lecturers and teachers placed much emphasize on was counseling. They suggested that counseling services should be provided for female students for two main reasons: one, to renew their minds and dispel the notion that physics was a difficult subject and two, to bring to their knowledge the many prospects in the subject which cuts across all fields. The lecturers who were interviewed conceded that much had not been done to project the subject in terms of its numerous job opportunities hence there was the need therefore to educate students on job opportunities in the subject. One lecturer stated:

> As a matter of fact, most physics tutors only teach the subject without discussing its numerous careers with their students (Physics lecturer).

Practical ways which have been suggested by both biology and chemistry female students, physics female students and lectures/teachers are in line with the strategies offered in the literature. For example, Doherty, as cited in Taber (1991) suggested that physics teachers should provide good teaching by changing the way topics and concepts are taught to capitalize on girls' interest. Ivie and Guo (2000) indicated that physics career path should be made more predictable to students. Also in IUPAP's (2002) resolution directed to National Government and Granting Agencies, proposed that female physics education should be supported with grants and scholarship schemes.

However, single-sex classroom environment which has been tested and reported in the literature as a successful strategy (Kelly, 1981; Peltz, 1990; Stowe, 1991; Lockwood, 1995; Pollina, 1995) was not found in this study to be an important strategy that could encourage greater female participation in physics. Nevertheless, physics lecturers and teachers suggested that female students should be given special attention after lectures to help clarify issues that did not go down well with them in the classroom. It is however; believe that if the above strategies are accepted and implemented, low female participation in physics at University of Cape Coast will be a thing of the past.

In a similar situation, when all the female undergraduate students and teachers were asked to rank other methods that were provided, Table 27 shows that, methods related to career opportunities in physics and relevance of physics, among other methods were ranked medium/high (see Appendix G for the basis for the ranks). This goes to buttress the need for physics educators to create awareness of job/career avenues in physics so as to make physics more appealing to female students in particular.

Table 27

Female Undergraduate Students and Physics Teachers' Ranking for Practical Ways to make Physics more Appealing to Females (N = 219)

Statement	Rank
a. Career opportunities in physics should be made known to students in the lecture room.	Medium/high
b. Lecturers should stress the relevance of physics by relating it to social and environmental issues.	Medium/high
c. Counselors should be encouraging girls in mathematics and science.	Medium/high
d. Lecturers must find ways to encourage females to study physics to highest level as far as possible.	Medium
e. Females should be supported by providing them with mentors and role models.	Medium/high
f. Lecturers should occasionally invite female scientists and technologists into the lecture room.	Medium/Low
g. Lecturers should provide information on female scientists and technologists in the lecture room.	Low/medium

Research question three was designed with the aim of determining methods/ways by which physics can be made more appealing to female students. The methods were evolved based on some inputs of three significant stakeholders of the study: biology and chemistry female undergraduate students, female undergraduate students and physics lecturers and teachers. Good tuition, job opportunity awareness, making the subject more practical oriented, scholarship schemes, change of perception and among others were mentioned as some of the ways that could be employed to make physics more appealing to female students.

The practical strategies suggested by the stakeholder-respondents are in perfect consonance with the strategies offered in various works 1991, 2000, and 2002 among others by experts in the field.

CHAPTER 5

SUMMARY, CONCLUSION AND RECOMMENDATIONS

Summary

Overview of Research Problem and Methodology

In this concluding chapter, the most important findings are highlighted, and some recommendations are offered to draw attention to the low proportion of females in physics compared to the proportion of females in biology and chemistry at University of Cape Coast (UCC).

This study sought insight into the low female participation in physics compared to biology and chemistry at University of Cape Coast and what could be done to increase greater female participation in physics studies. The study also sought insight into SSS female science students' preference for physics as a programme of study at the university level. These were done by providing descriptive and explanatory information on respondents' reasons about the low female participation in physics studies.

The study was conducted in two stages. Stage one involved the administration of questionnaires to biology, chemistry and physics female undergraduate students, and SSS female final year science students, which gathered information on females' preferences for physics courses. At this stage information was also gathered on physics lecturers' and teachers' views on low female participation in physics. A cross-sectional survey was employed for this purpose. After analysis of the data gathered in stage one, stage two involved individual interviews with a smaller number of the female respondents and physics lecturers and teachers to gain deeper insight into some of the issues that came up.

Key Findings

1. It was found in this study that several reasons accounted for female students' preferences for biology and chemistry courses at the University of Cape Coast. From the study, it can be deduced that some of the reasons that underlie the low proportion of females in physics compared to the proportion of females in biology and chemistry at the University of Cape Coast are:

    (a) nature of physics (abstractness of the subject)

    (b) limited job opportunities in the subject

    (c) difficulty of the subject

    (d) weak mathematics background

    (e) lack of motivation to study physics

    (f) limited usefulness of physics

    (g) poor tuition by lecturers and teachers

    (h) absence of role models and mentors

2. The study revealed that both undergraduate female non-physics students (biology and chemistry) and female physics students do not differ in their views about physics as the differences in their mean responses were statistically insignificant.

3. The study also revealed that among female SSS science students in Cape Coast Metropolis, physics was the least chosen subject as a course of study at the university level whereas medicine, pharmacy and nursing were given much prominence. The SSS students observed that their performance in physics was poor due to the difficult of the subject. Besides, their experiences in the physics class have confirmed the stories they have heard from their friends and teachers about how difficult physics is at the university. Hence, they will not like to enter what they called "hell" by going in for physics.

4. The respondents offered a variety of practical ways or strategies that could be employed to encourage greater female participation in physics. These strategies ranked in terms of priority are:

a) Exposing females to career opportunities in physics through counseling, educational forms and seminars.

b) Good tuition of the subject by physics lecturers and teachers.

c) Making the subject more practical.

d) Using audio-visual materials to explain concepts etc.

Conclusion

The findings from the study lead to a number of conclusions about female participation in physics at the University of Cape Coast and Senior Secondary Schools. The findings suggest that female students do not prefer physics as a course of study at the university level. Moreover, the low female participation in physics at UCC has a root course, and that it shouldn't be taken for granted that females just don't like physics. In the first place, there are views that the subject is not presented well for students to understand and develop the interest for it both at the University and SSS levels. Secondly, students are not made to appreciate the relationship between mathematics and physics at both levels because lecturers/teachers do not take time to explain the mathematics aspect of the subject for students to appreciate it, especially female students who are believed to be scared of mathematics. Female students' participation in physics can be enhanced if proper foundation in the subject is ensured by carefully examining the way physics is taught at the SSS level.

Although a good foundation of the subject is important, some physics lecturers at the university also seem to have neglected their role of making the subject more appealing to female students. Either they do not communicate well with students in the lecture rooms or do not have the zeal for teaching the subject. Female students' reactions to comments made by some lecturers in the lecture halls and the way presentations are done (as reported by the female students), seem to suggest that lecturers are rather discouraging females from greater participation.

The perception that, limited career opportunities in physics, play an important role in female students' preferences for biology and chemistry courses suggest that little is known by female students about career opportunities in physics. Female science students seem to know more about job avenues in biology and chemistry than physics. It is quite unfortunate that for many female students the only job physics offers is teaching which many female students do not want to associate themselves with. The question therefore is what have physics lecturers and teachers done and/or are doing to create awareness of the numerous career opportunities in physics to their students.

There is a reason to believe that physics lecturers and teachers are not doing much to encourage greater female participation in physics studies because when asked in the questionnaire and also during interviews, all the lecturers and teachers appeared to be suggesting strategies rather than reporting strategies they have been using. Physics lecturers/teachers and science educators will agree that female students are not 'ill-assorted' with physics. This study has discussed in some details female students' views about low female participation in physics. It is logical that they will tend to be less interested in the subject if the strategies suggested for enhancing greater female participation are not adopted and implemented. Thus physics lecturers and teachers as well as science educators who are interested in greater female participation in physics studies should seek to understand the views of the females and incorporate these views in the interventions/strategies they develop.

Recommendations

From the findings of this study the following recommendations are offered:

(a) Serious efforts must be made by physics lecturers and teachers as well as the various physics departments to create awareness of career opportunities in physics so as to make the subject more appealing to female students. Particular attention should be paid to physics-related technologies which most advanced countries have embarked upon to reach where they are now. Medical physics should also be stressed upon because most females believe that biology and chemistry are the only subjects that can lead them to the health sector where most females are interested to work.

(b) Physics lecturers and teachers have the potential to make a significant (positive or negative) impact on greater female participation in physics. They do have a responsibility to provide an environment in which female students can learn and appreciate the beauty of the subject. Physics lecturers and teachers must therefore discontinue any practices or behaviours (especially in the lecture halls or classrooms) that discourage greater female participation in the study of physics. They must instead take actions directed towards greater female participation in the study of the subject.

(c) The use of audio-visual aids to present certain concepts in physics has been emphasized by both students and lecturers. Heads of Departments should therefore collaborate with school authorities to acquire computer simulated practical materials for teaching some of the abstract topics in the subject.

(d) Effort should be made physics tutors to give female students extra tuition in mathematics and physics in secondary schools to raise their abilities and interest in the subject (physics).

Suggestions for Further Research

The following suggestions are provided for further studies:

(a) The present study focused on female biology, chemistry and physics undergraduate students at University of Cape of Coast and SSS final year female science students in four selected SSS in Cape Coast Metropolis in Central Region. Further studies will be required to elicit reasons of students from other sister universities and SSS in the country to collaborate the findings of the present study and to ensure their generalisability.

(b) There is a perception among female students that physics is poorly taught at both SSS and the University levels. For example, female undergraduate students used in the present study observed that physics lecturers could have made physics more understandable by taking time to explain concepts and principles as well as the mathematics aspects very well for them to understand, but this was not been the case. The female students blamed their physics lecturers for not teaching the course the way they felt it should be taught. Further studies can be conducted to examine the way physics is taught at both the University and SSS levels in the country.

REFERENCES

Alexakos, K. & Antoine, W. (2003). The gender gap in science education: Strategies to encourage female participation in science. *The Science Teacher*, *70*(3), 30-33.

American Association of University Women. (1989). *Equitable treatment of girls and boys in the classroom*. Washington, DC: Author. Retrieved April 10, 2008, from http://nces.ed.gov/programs/digest/d02/index.asp.

American Physics Society (2008). *Why study physics*? Retrieved July 25, 2008 from http://www.aps.org/programs/education/whystudy.cfm

Ampiah, G. J. (2004). *An investigation into science practical work in senior secondary schools: Attitudes and perceptions* (PhD thesis). Cape Coast: Department of Science Education of the Faculty of Education, University of Cape Coast.

Baird, D. (1996). The blowgun as a teaching tool. *The Physics Teacher*, *34*(2), 98-100.

Baird, D. (1997). *Is physics classroom any place for girls*? (MPhil thesis). Faculty of National University. University of Michigan.

Baker, D. (2002). Where is gender and equity in science education? *Journal of Research in Science Teaching, 39*(8), 659-663.

Barbosa, M. (2003). Equity for women in physics. *Physics World*, *34*, 45-46.

Barman, C. (1997). Students' views of scientists and science: Results from a national study. *Science and Children*, *35*, 18-23.

Barnhart, R. K. & Steinmetz, S. (1986). *Hammond barnhart dictionary of science* (1st ed.). New Jersey: Hammond Incorporated.

Baryeh, E. A., Obu, R. Y., Lamprey D. L., & Baryeh, N. Y. (2000). Ghanaian women and the engineering profession. IJMEE, 28(4) (2000), 334-346.

Bell, J. (2001). Investigating gender differences in the science performance of 16-year-old pupils in the UK. *International Journal of Science Education, 23*(5), 469-486.

Benckert, S. (2001). "Context and conversation - a way to create more gender-inclusive physics education?" Contribution to GASAT-conference 2001, World Wide Wisdom - socially responsible and gender inclusive science and technology. *GASAT10 July 1-6 2001*. Copenhagen.

Best, J. W. & Kahn, J. V. (1995). *Research in education*. New Delhi: Prentice-Hall of India of Private Limited.

Bhatia, K. T. (1991). Girls and science education in developing countries. *Contributions to the 6th International GASAT Conference, 1* 19-26. National Key Centre for School Science and Mathematics, Perth, Australia.

Bouville, M. (2007). Should we enroll more female students in physics? *Physics World, 20*(4), 18-19

Carnes, M. (2006). Gender: Macho language and other deterrents. *Nature, 442*, 868-875.

Chambers, S. & Andre, T. (1996). Gender, prior knowledge, interest, and experience in electricity and conceptual change text manipulations in learning about direct current. *Journal of Research in Science Teaching, 34*, 107-123.

Christopher, W., Martin, S., Katie., Eddie., B., & Dominic., D (2003). Why aren't secondary students interested in physics? *Physics Education 38*(4), 324-329.

Cohen, L, Manion, L & Morrison, K (2000). *Research methods in education* (5th ed.). London: RoutledgeFalmer publishers.

Cutnell, J. D., & Johnson, K. W. (2007). *Physics* (7th ed.). New Jersey: John Willey & Sons Inc.

Davis, B. G., & Humphreys, S. (1985). *Evaluating intervention programs: Teachers* New York: College Press.

Dawson, C. (2000). Upper primary boys' and girls' interests in science: have they changed since 1980? *International Journal of Science Education, 22*(6), 557-570.

DeBacker, T., & Nelson, R. (2000). Motivation to learn science: Differences related to gender, class type, and ability. *Journal of Educational Research, 93*(4), 245-255.

Donnellan, C. (2003). Does sex make a difference? An equalities peak for young people on international women's day. *The Gender Issues 64,* 14-17.

European Commission Directorate-General for Research (ECDGR) (2006). *Women and science: Statistics and Indicators. She Figures 2006*. ISSN 1018-5593. Retrieved March 25, 2008, from http://ec.europa.eu/research/science-society/pdf/she_figures_2006_en.pdf.

Fennema, E., Pedro, J. D., Wolleat P. L., & Becker, A. B. (1988). Increasing women's participation in mathematics an intervention study. *Journal of Research in Mathematics Education, 12*(1), 3-11.

Fraenkel, J. R., & Wallen, N. E. (2000). *How to design and evaluate research in education*_ (4th ed.). New York: McGraw-Hill, Inc.

Gibbs, K. (2003). *Advanced physics* (2nd ed.). Cambrige, United Kingdom: Cambridge University press.

Gierl, M. J. (1994). A student's perspective on the intrinsic characteristics of the single-sex physics class. *Paper presented at the annual meeting of the American Educational Research Association*, New Orleans, LA.

Gillibrand, E., Robinson, P., Brawn, R., & Osborn, A. (1999). Girls' participation in physics in single sex classes in mixed schools in relation to confidence and achievement. *International Journal of Science Education, 21*(4), 349-362.

Golombok, S. & Fivush, R. (1994). *Gender development*. Cambridge: Cambridge University Press.

Haussler, P., & Hoffmann, L. (2002) an intervention study to enhance girls' interest, self-concept and achievement in physics classes. *Journal of Research in Science Teaching, 39*(9), 870-888.

Hazari, Z. & Potvin, G. (2005) Views on female under-representation in physics: Retraining women or reinventing physics? *Electronic Journal of Science Education, 10*(1). Retrieved June 20, 2008 from http://wolfweb.unr.edu/homepage/crowther/ejse/potvin.pdf

Hazel, E., Logan, P., & Gallagher, P. (1997). Equitable assessment of students in physics: importance of gender and language background. *International Journal of Science Education, 19*(4), 381-392.

Holden, C. (2000). Parity as a goal sparks bitter battle. *Science, 289*(5478), 380.

International Union of Pure and Applied Physics (2002). *Why women don't flock to physic: A report on the IUPAP international conference on women in physics*. Paris, 7-9 March 2002.

Ivie, R., & Guo, S. (2005). *Proceedings from the 2nd IUPAP international conference on women in physics***.** Retrieved June 10, from, www.if.ufrgs.br/iupap

Jones, C. & Mahony, P. (Eds.) (1989). *Learning our lines: Sexuality and social control in education*. London: The Women's Press.

Jones, G., Howe, A., & Rua, M.. (2000). Gender Differences in Students' Experiences, Interests, and Attitudes toward Science and Scientists. *Science Education, 84*, 180-192.

Jones, M. & Wheatley, J. (1990). Gender differences in teacher-student interactions in science classrooms. *Journal of Research in Science Teaching, 27*, 861-874.

Kahle, J. & Meece, J. (1994). Research on gender issues in the classroom. In D. Gable (Ed.), *Handbook of research on science teaching and learning* (pp. 542-557). New York: Macmillan.

Keller, E.F. (1992). *Secrets of life, secrets of death, essays on language, gender and science*. New York: Routledge.

Kelly, A. (1981). Girls and science education: Is there a problem? In Kelly, A. (Ed.), *The missing half: Girls and science education* (p. 1-19). Manchester, England: Manchester University Press.

Kenway, J. & Gough, A. (1998). Gender and science education in schools: A review 'with attitude'. *Studies in Science Education, 31*, 1-30.

Kimura, D. (1992). Sex differences in the brain. *Scientific American, 267*(3), 118-125.

KNUST (2008). *College of science handbook*. Kumasi: University press

Labudde, P., Herzog, W., Neuenschwander, M. P., Violi, E., & Gerber, C (2000). "Girls and physics: Teaching and learning strategies tested by classroom interventions." *International Journal, Science Education*, *22*(2), 143–157.

Laura, A. R. (2006). Why are there so few female physicists? *The Physics Teacher, 44*, 177-180

Lawrence, P. (2006). Men, women and ghost in science. *PLoS Biology, 4* (1), e19.

Lederman, M. (2003). Gender/inequity in science education: A response. *Journal of Research in Science Teaching, 40*(6), 604-606.

Lie, S., & Bryhni, E. (1983). Girls and physics: Attitudes, experiences and under achievement. *Contributions to the Second GASAT Conference.* London: Chelsea College, 202-211.

Lockwood, J. (1994). Creating gender-friendly astronomy classrooms. *Mercury, 23*. Available: Electric Library.

Lorenzen, E. (2001). Issues in sociobiology. *The Science Teacher, 68*(6), 44-48.

Maccoby, E. (2000). Perspectives on gender development. *International Journal of Behavioral Development, 24*(4), 398-406.

Main, P. (2005). Does physics actually needs more female physicists? *Talk at the Nordic Conference for Women in Physics, Bergen*. Retrieved June 10, 2008, from http://web.ift.uib.no/nwip2005/DOCS/SESSION_1/PeterMain.ppt.

Mitchell, M. L., & Jolley, J. M. (2004). *Research Design Explained* (5th ed.). Wadsworth: Thompson Learning Inc.

National Science Foundation (NSF). (2002). *Women, minorities, and persons with disabilities in science and engineering: 2002*. Report NSF 03-312. Retrieved May 25, 2008, from http://www.nsf.gov/sbe/srs/nsf03312/start.htm.

Nworgu, B.G (2006). *Educational research: Basic issues and methodology*. Ibadan: Wisdom Publishers Limited.

Parker, K. (2002). Men are not from mars. *Physics Education, 37*(1), 12-17.

Pearson, C. (1992). Women as Learners: Diversity and Educational Quality. *Journal of Developmental Education, 16*(2), 2-10.

Peltz, W. (1990). Can girls + science - stereotypes = success? (Subtle sexism in science studies). *The Science Teacher, 57*(9), 44-49.

Pinker, S. & Spelke, E. (2005). *The science of gender and science*. Pinker vs. Spelke. Retrieved April 10, 2008 from, www.edge.org/3rd_culture/debate05/debate05_index.html.

Pollina, A. (1995). Gender balance: Lessons from girls in science and mathematics. *Educational Leadership, 53*, 30-33.

Redish, E. F., Saul, J. M., & Steinberg, R. N. (1998) "Students expectations in introductory physics". *American Journal of Physics. 66* (3), 212-224.

Reid, N. & Skryabina, E. (2003). Gender and Physics. *International Journal of Science Education, 25*(4), 509-536.

Rennie, L. J. & Parker, L. H. (1996) "Placing physics problems in real-life context: Students' reactions and performance". *Australian Science Teachers Journal, 42* (1), 55-59.

Restak, R. M. (1984). *The Brain*. New York: Bantam Books.

Rosser, S. (1993). Female friendly science: Including women in curricular content and pedagogy in science. *Journal of General Education, 42*(3), 191-220.

Schinzel, J. (2006). *"Statistics for Equal Opportunities 2005"* (Draft), CERN 2006.

Smail, B. (1981). Organizing the curriculum to fit girls' interests. In Kelly, A. (Ed.), *The missing half: Girls and science education* (pp. 80-88). Manchester, England: Manchester University Press.

Stadler, H., Duit, R., & Benke, G. (2000). Do boys and girls understand physics differently? *Physics Education, 35(6),* 417-422.

Steele, C. (2004). *Steele Discusses "Stereotype Threat"*. Retrieved June 10, 2008, from www.mtholyoke.edu/offices/comm/csj/092404/steele.shtml.

Steele, J., James, J., & Barnett, R. (2002). Learning in a man's world: Examining the perceptions of undergraduate women in male-dominated academic areas. *Psychology of Women Quarterly, 26,* 46-50.

Stowe, L. G. (1991). Should physics classes be single sex? *The Physics Teacher 29*(6), 380-381.

Sullivan, J. F., Reamon, D., & Louie, B. (2003). Girls embrace technology: A summer internship for high school girls. *Frontiers in Education Conference*.

Retrieved April 15, 2008, from http://fie.engrng.pitt.edu/fie2003/

Summers, L. (2005). *Remarks at NBER Conference on Diversifying the Science & Engineering Workforce*. Retrieved April 10, 2008, from http://www.president.harvard.edu/speeches/2005/nber.html.

Taber, K. (1992). Girls' interaction with teachers in mixed physics classes: results of classroom observation. *International Journal of Science Education, 14*(2), 163-180.

Taylor, B. A. (2004). *The influence of classroom environment on high school students mathematics, anxiety and attitudes*. (Unpublished PhD), Curtin: Curtin University of Technology.

Thomas, K. (1990). *Gender and subject in higher education*. Milton Keynes: Open University Press.

Tobias, S. (1990). *They're not dumb, they're different. Stalking the second tier*. Tucson, Arizona: Research Corporation.

Traweek, S. (1988). *Beamtimes and lifetimes. The world of high energy physicists*. Cambridge, Massachusetts: Harvard University Press.

UNDP (1993). *Human development report 1997*. New York: Oxford University Press.

UNESCO (1993). *World educational report 1993*. New York: Oxford University Press.

UNICEF & Ghana Government (1990). *Children and women of Ghana: Situation Analysis*. Accra.

UNICEF (1996). *World children report of UNICEF*.

Urry, M. (2003). Speeding up the Long Slow Path to Change. *APS News*, February, 12.

Wenneras, C. & Wold, A. (1997). Gender and physics, *Nature, 387*, 341-347.

Wertheim, M. (1995). *Pythagoras' trousers: God, physics, and the gender wars*. New York: Times Books/Random House.

Whitelegg, E. & Parry, M. (1999). "Real-life contexts for learning physics: Meanings, issues and practice". *Physics Education, 34* (2), 68-72.

Williams, C., Stanisstreet, M., Spall, K., Boyes, E., & Dickson, D. (2003). Why aren't secondary students interested in physics*? Physics Education*, *38*(4), 324-329.

Woolnough, B. (1995). School Effectiveness for Different Types of Potential Scientists and Engineers. *Research in Science Technological Education 13*(1), 54-61.

Yoder, J. & Scheicher, T. (1996). Undergraduates regard deviation from occupational gender stereotypes as costly for women. *Sex Roles: A Journal of Research, 34*, 171-188.

Zietsman, A., & Naidoo, S. (1997). *Girls' understanding of concepts of thermal properties of matter*. Nairobi: Academy Science Publishers.

APPENDIX A

QUESTIONNAIRE FOR FEMALE BIOLOGY AND CHEMISTRY UNDERGRADUATE STUDENTS

INTRODUCTION

This questionnaire seeks information about female students' preference for biology and chemistry courses to physics course. Your responses will be treated confidentially and will be used for research purposes only. It is therefore hoped that you will give your maximum co-operation.

Please make a tick [√] in the box against your response. Where there are no boxes, write your response as demanded by the question.

SECTION A

1. Age:
   - 18-21 yrs [ ]
   - 22-25 yrs [ ]
   - 26-29 yrs [ ]
   - 30 + [ ]

2. Level: 100 [ ] 200 [ ] 300 [ ] 400 [ ]

3. What is your major area of study?
   - Biology [ ]
   - Chemistry [ ]

4. Why did you choose to offer biology or chemistry but not physics?

   i) ……………………………………………………………………………………
   ……………………………………………………………………………………
   ……………………………………………………………………………………

   ii) ……………………………………………………………………………………
   ……………………………………………………………………………………

…………………………………………………………………………………
………………………………………..

iii) …………………………………………………………………………………
…………………………………………………………………………………
…………………………………………………………………………………

5a. Do you have any regrets for choosing to study biology or chemistry but not physics?

Yes ☐ No ☐

5b. Give reasons for your answer.

…………………………………………………………………………………
…………………………………………………………………………………
…………………………………………………………………………………

6a. If you are given another opportunity, would you like to offer physics at the university?

Yes ☐ No ☐

6b. Give reasons for your answer.

…………………………………………………………………………………
…………………………………………………………………………………
…………………………………………………………………………………

7. What do you think could be done to make physics more appealing to female students?

i)…………………………………………………………………………………
…………………………………………………………………………………
…………………………………………………………………………………

ii)…………………………………………………………………………………
…………………………………………………………………………………
…………………………………………………………………………………
……………………………………….

SECTION B

To what extent do you agree with the following statements?

	STATEMENTS	**STONGLY AGREE**	**AGREE**	**UNDECIDED**	**DISAGREE**	**STRONGLY DISAGREE**
8	Females naturally like biology.					
9	I simply don't like physics.					
10	There is nothing that can be done to change my mind to study physics.					
11	Physics is not an appealing subject for females.					
12	I had diminishing self-confidence as I progressed to higher levels of physics studies.					
13	I was not encouraged enough (e.g. by peers, teacher and parents) to study physics.					
14	Physics is naturally difficult.					
15	I am not good at physics.					
16	I am not good at mathematics.					
17	Physics is taught in a way that is often more theoretical.					
18	I have little information on areas where physics can lead me to.					

SECTION C

20a. The following statements describe some of the practical ways that could be employed to encourage more females to study physics. **TICK FOUR (4)** most important ones that could make physics more appealing to females.

STATEMENT	**Tick [√] only 4**
a. Females should be supported by providing them with mentors and role models.	
b. Counselors should be encouraging girls in mathematics and science.	
c. Lecturers must find ways to encourage females to study physics to highest level as far as possible.	
d. Career opportunities in physics should be made known to students in the lecture room.	
e. Lecturers should stress the relevance of physics by relating it to social and environmental issues.	
f. Lecturers should provide information on female scientists and technologists in the lecture room.	
g. Lecturers should occasionally invite female scientists and technologists into the lecture room.	

20b. Rank **the four (4)** that you have ticked in order of priority. Write the **letters** in front of the statements you have ticked below:

1st Priority ……………………………..

2nd Priority …………………………….

3rd Priority ……………………………..

4th Priority ……………………………..

THANK YOU

APPENDIX B

QUESTIONNAIRE FOR FEMALE UNDERGRADUATE PHYSICS STUDENTS

INTRODUCTION

This questionnaire seeks information about female students' preference for physics courses. Your responses will be treated confidentially and will be used for research purposes only. It is therefore hoped that you will give maximum co-operation and as much as possible provide accurate responses.

Please make a tick [√] in the box against your response. Where there are no boxes, write your response as demanded by the question.

SECTION A

1 Age:
- 18-21 yrs [ ]
- 22-25 yrs [ ]
- 26-29 yrs [ ]
- 30 + [ ]

2 Level: 100 [ ] 200 [ ] 300 [ ] 400 [ ]

3 Why did you choose to offer physics but not biology or chemistry?

i)…………………………………………………………………………………
…………………………………………………………………………………
………………………… ……………………………………………………

ii)…………………………………………………………………………………
…………………………………………………………………………………
…………………………………………………………………………………

4a. Do you have any regrets now for choosing to study physics?

Yes ☐ No ☐

4b. Give reasons for your answer.

…………………………………………………………………………………
…………………………………………………………………………………
…………………………………………………………………………………

5a. If you are given another opportunity, would you rather NOT like to offer physics at the university?

Yes ☐ No ☐

5b. Give reasons for your answer.

…………………………………………………………………………………
…………………………………………………………………………………
…………………………………………………………………………………

6. What do you think could be done to make physics more appealing to female students?

i)……………………………………………………………………………
……………………………………………………………………………
……………………………………………………………………………

ii)……………………………………………………………………………
……………………………………………………………………………
……………………………………………………………………………
……………………………………….

SECTION B

To what extent do you agree with the following statements?

	STATEMENTS	STONG LY AGREE	AGREE	UNDEC IDED	DISAG REE	STRON GLY DISAG REE
8	Females naturally like biology.					
9	Females simply do not like physics.					
10	Physics is not an appealing subject for females.					
11	Females are not encouraged enough (e.g. by peers, teacher and parents) to study physics.					
12	Physics is naturally difficult.					
13	The content of physics is more difficult for many females to understand compared to biology/ chemistry.					
14	Females are not good at physics.					
15	Physics is more mathematical.					
16	My mathematics background influences my achievement in physics.					
17	Physics is taught in a way that is often more practical and relevant to everyday life situations.					
18	Many females have little information on areas where physics can lead them to.					

SECTION C

19a. The following statements describe some of the practical ways that could be employed to encourage more females to study physics. **TICK FOUR (4)** most important ones that could be employed to encourage most females to study physics.

STATEMENT	**Tick [√] only 4**
a. Females should be supported by providing them with mentors and role models.	
b. Counselors should be encouraging girls in mathematics and science.	
c. Lecturers must find ways to encourage females to study physics to highest level as far as possible.	
d. Career opportunities in physics should be made known to students in the lecture room.	
e. Lecturers should stress the relevance of physics by relating it to social and environmental issues.	
f. Lecturers should provide information on female scientists and technologists in the lecture room.	
g. Lecturers should occasionally invite female scientists and technologists into the lecture room.	

19b. Rank **the four (4)** that you have ticked in order of priority. Write the **letters** in front of the statements you have ticked below:

1st Priority ……………………………..

2nd Priority …………………………….

3rd Priority ……………………………..

4th Priority ……………………………..

THANK YOU

APPENDIX C

QUESTIONNAIRE FOR SENIOR SECONDARY SCHOOL FEMALE FINAL YEAR SCIENCE STUDENTS

INTRODUCTION

This questionnaire seeks information about Senior Secondary School final year female students' preference for physics as a course of study at the university. Your response will be treated confidentially and will be used for research purposes only. It is therefore hoped that you will give maximum co-operation provide accurate responses.

Please make a tick [√] in the box against your response. Where there are no boxes, write your response as demanded by the question.

SECTIO A

1 Age: …………………….. years.

2 School type: Co-educational (Mixed) ☐

Girls only ☐

3a. What programme would like to pursue at the university?

……………………………………………..

3b. If you don't get your first choice programme, what will be your other preferences?

2nd Preference …………………………………………….

3rd Preference ……………………………………………..

4th Preference …………………………………………….

4. If you are to choose between Biology, Chemistry or Physics at the university, which one will you go for?

Biology ☐

Chemistry ☐

Physics ☐

5. Give reason(s) for you answer in 4.

i)……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………
………………………………………

ii)……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………
………………………………………

Answer question 6 if your response in question 4 is <u>NOT</u> physics.

6a. Would you like to study physics at the university should you **<u>NOT</u>** get your choice in
Question 4?

Yes ☐ No ☐

6b. Give reason(s) for your answer.

i) ……………………………………………………………………………
……………………………………………………………………………
……………………………………………………………………………
………………………………………

ii) ……………………………………………………………………………
……………………………………………………………………………
……………………………………………………………………………
………………………………………

iii) ……………………………………………………………………………
……………………………………………………………………………
……………………………………………………………………………
………………………………………

SECTION B To what extent do you agree with the following statements?

	STATEMENT	STONG LY AGREE	AGREE	UNDECI DED	DISAGR EE	STRON GLY DISAGR EE
7	Physics is not an appealing subject for females.					
8	Physics is naturally difficult subject.					
9	I fear physics as a science subject.					
10	Physics is an interesting subject.					
11	I find physics assignments difficult.					
12	I am not good at physics.					
13	I am not good at mathematics.					
14	Physics is too mathematical and scares me.					
15	Physics helps me to understand some natural events.					
16	I can easily be employed when I study physics.					
17	Physics not a useful subject.					
18	I don’t know any female physicist who can serve as a role model me.					

SECTION C

19 a. Which of the following could encourage you most to study physics beyond Senior Secondary School level? **TICK THREE (3)** most important ones.

STATEMENT	**Tick [√] only 3**
a. If my parents support me.	
b. If my teachers encourage me.	
c. If I am given special attention in class by my physics teachers.	
d. If I see female scientists in physics as role models.	
e. If I know the importance of physics.	
f. If the study of physics will raise my social status	

19 b. Rank **the three (3)** that you have ticked in order of priority. Write the **letters** in front of the statements you have ticked below:

1st Priority ……………………………..

2nd Priority …………………………….

3rd Priority ……………………………..

20. What other ways could encourage you to study physics beyond Senior Secondary School level.

i) …………………………………………………………………………… ……………………………………………………………………………

ii) …………………………………………………………………………… …………………………………………………………………………

THANK YOU

APPENDIX D

QUESTIONNAIRE FOR PHYSICS LECTURERS AND SSS SCIENCE TEACHERS

INTRODUCTION

This questionnaire seeks information about the low females' participation in physics as compared to biology and chemistry. Your responses will be used for research purposes only. Your confidentiality is therefore assured.

Please make a tick [√] in the box against your response. Where there are no boxes, write your response as demanded by the question.

SECTION A

1. Sex: Male [ ] Female [ ]

2. Age: 23-29 yrs [ ]

   30-36 yrs [ ]

   37-43 yrs [ ]

   44-50 yrs [ ]

   51 + [ ]

3. Highest level of educational attainment:

   PhD [ ]

   MPhil [ ]

   1st Degree [ ]

   Diploma [ ]

   Other (s), specify ………………………………..

4. Indicate where you teach (but do not mention your institution by name):

   University [ ] SHS [ ]

5. For how long have you been teaching physics? ……………………………

6. Do females show interest during physics lessons?

Yes ☐ No ☐

7. How often do females participate actively in physics lessons?

Almost always ☐ Always ☐ Sometimes ☐ Almost never ☐

Not at all ☐

8. What do you think could be the reason(s) for the low female participation in physics at the university compared to biology and chemistry?

i) …………………………………………………………………………
…………………………………………………………………………
………………………………………………………………………..

ii) …………………………………………………………………………
…………………………………………………………………………
…………………………………………………………………………

iii) …………………………………………………………………………
…………………………………………………………………………
…………………………………………………………………………

9a. Do you have any practical way(s) in mind that could help sustain and encourage females to study physics?

Yes ☐ No ☐

9b. If yes, what are some of these practical ways?

i) …………………………………………………………………………
…………………………………………………………………………
…………………………………………………………………………

ii) …………………………………………………………………………
…………………………………………………………………………
…………………………………………………………………………

iii) …………………………………………………………………………
…………………………………………………………………………
…………………………………………………………………………

SECTION B

To what extent do you agree with the following statements?

	STATEMENTS	STON GLY AGRE	AGRE E	UNDE CIDED	DISAG REE	STRO NGLY DISAG REE
10	Females naturally like biology.					
11	Females simply do not like physics.					
12	There is nothing that can be done to change the minds of females to study physics.					
13	Physics is not an appealing subject for females.					
14	Females have diminishing self-confidence as they progress to higher levels of physics studies.					
15	Females are not encouraged enough (e.g. by peers, teacher and parents) to study physics.					
16	Physics is naturally difficult.					
17	The content of physics is more difficult for many females to understand compared to biology/ chemistry.					
18	Physics is taught in a way that is often more theoretical.					
19	Many females have little information on areas where physics can lead them to.					

SECTION C

20a. The following statements describe some of the practical ways that could be employed to encourage more females to study physics. **TICK FOUR (4)** most appropriate ones.

STATEMENT	**Tick [√] only 4**
a. Females should be supported by providing them with mentors and role models.	
b. Counselors should be encouraging girls in mathematics and science.	
c. Lecturers/teachers must find ways to encourage females to study physics to the highest level as far as possible.	
d. Career opportunities in physics should be made known to students in the classroom.	
e. Lecturers/teachers should stress the relevance of physics by relating it to social and environmental issues.	
f. Lecturers/teachers should provide information on female scientists and technologists in the lecture room.	
g. Lecturers/teachers should occasionally invite female scientists and technologists into the lecture room.	

20b. Rank **the four (4)** that you have ticked in order of priority. Write the **letters** in front of the statements you have ticked below:

1st Priority ……………………………..

2nd Priority …………………………….

3rd Priority ……………………………..

4th Priority ……………………………..

THANK YOU

APPENDIX E

OPPINIONNAIRE ON FEMALES' PARTICIPATION IN THE STUDY OF PHYSICS

Please kindly share your opinion with me on the above issue by responding to the following opinionnaire. Be objective as far as possible.

1. What reasons do you feel are responsible for low female participation in physics at the university? Offer as many reasons as you think are applicable.

2. What reasons specifically involving the structure, content, or methodology of physics instruction that discourages female students from greater participation?

3. Please describe any practical methods/ways you think can help address this problem.

4. What is your personal assessment of the issue of gender equity in physics?

5. Is there anyone you know who would be willing to share expertise and/or experience relating to issues of gender disparity in physics? Please provide his/her name and contact address/telephone number.

APPENDIX F

RESULTS OF FEMALES SSS STUDENTS' RANKING FOR REASONS FOR STUDYING PHYSICS BEYOND SSS LEVEL

Statement	Mean	Median	Mode	Rank
a. If my parents support me	2	2	1	Medium/high
b. If my teachers encourage me	2	2	2	Medium
c. If I am given special attention in class by my physics teachers	2	2	2	Medium
d. If I see female scientists in physics as role models	2	2	3	Medium/low
e. If I know the importance of physics	2	2	1	Medium/high
f. If the study of physics will raise my social status	2	3	3	Low/medium

In compiling this table all the responses were brought together and average values were worked out. Mean, mode and median values for each of the statement were compared, since each of the methods had a tendency to obscure some aspect of the data. The values were placed as an order (order of mean, order of modes, and order of medians). All three orders were then considered in allocating a high (1), medium (2) or low (3) rank for each statement. Thus high denotes that all three averaging methods gave a higher rank, medium/high that there were two medium and one high and so on.

APPENDIX G

RESULTS OF FEMALE UNDERGRADUATE STUDENTS AND TEACHERS' RANKING OF WAYS TO MAKE PHYSICS MORE APPEALING TO FEMALES

Statement	Mean	Median	Mode	Rank
a. Females should be supported by providing them with mentors and role models.	2	2	1	Medium/high
b. Counselors should be encouraging girls in mathematics and science.	2	2	1	Mediun/high
c. Lecturers must find ways to encourage females to study physics to highest level as far as possible.	3	3	3	Medium
d. Career opportunities in physics should be made known to students in the lecture room.	2	2	1	Medium/high
e. Lecturers should stress the relevance of physics by relating it to social and environmental issues.	2	2	1	Medium/high

Appendix G cont'd

f.	Lecturers should provide information on female scientists and technologists in the lecture room.	3	4	4	Medium/low
g.	Lecturers should occasionally invite female scientists and technologists into the lecture room.	3	3	4	Medium/low

In compiling this table all the responses were brought together and average values were worked out. Mean, mode and median values for each of the statement were compared, since each of the methods had a tendency to obscure some aspect of the data. The values were placed as an order (order of mean, order of modes, and order of medians). All three orders were then considered in allocating a high (1), medium (2-3) or low (4) rank for each statement. Thus medium high denotes that all three averaging methods gave a higher rank, medium/high that there were two medium and one high and so on.

APPENDIX H

SECOND CHOICE PROGRAMME TO PURSUE AT THE UNIVERSITY BY SSS FEMALE FINAL YEAR SCIENCE STUDENTS

Programme	No	Percentage (%)
Agric Science	5	2.7
Actuarial Science	6	3.1
Biochemistry	13	6.7
Biological Science	10	5.1
Computer Science	7	3.6
Medicine	7	3.6
Nursing	8	4.1
Petroleum Engineering	14	7.0
Pharmacy	67	34.4
Physics	6	3.1
Others	52	26.7
Total	195	100.1

APPENDIX I

THIRD CHOICE PROGRAMME TO PURSUE AT THE UNIVERSITY BY SSS FEMALE FINAL YEAR SCIENCE STUDENTS

Programme	No	Percentage (%)
Agric Science	4	2.2
Architecture	5	2.7
B Com	9	5.0
Biochemistry	14	7.6
Biological Science	7	3.8
Chemical Engineering	7	3.8
Chemistry	4	2.2
Civil Engineering	6	3.3
Computer Science	7	3.8
Dentistry	13	7.1
Law	8	4.3
Nursing	14	7.6
Petroleum Engineering	22	12.0
Pharmacy	21	11.4
Physics	5	2.7
Psychology	13	7.1
Others	25	13.6
Total	184	100.2

APPENDIX J

FOURTH CHOICE PROGRAMME TO PURSUE AT THE UNIVERSITY BY SSS FEMALE FINAL YEAR SCIENCE STUDENTS

Programme	No	Percentage (%)
Agric Science	8	6.1
B Com	16	12.1
Biochemistry	5	3.8
Biological Science	9	6.8
Chemical Engineering	9	6.8
Chemistry	3	2.3
Civil Engineering	3	2.3
Computer Science	4	3.0
Law	9	6.8
Nursing	10	7.6
Optometry	4	3.0
Petroleum Engineering	10	7.6
Pharmacy	9	6.8
Psychology	9	6.8
Others	24	18.2
Total	132	100

APPENDIX K

SEMI-INTERVIEW PROTOCOL USED TO INTERVIEW FEMALE UNDERGRADUATE STUDENTS AND SSS STUDENTS

1. (a) Do you enjoy physics lectures/lessons?

   (b) What makes you enjoy or not enjoy physics lectures/lessons?
2. If you don't do well in physics test, what will you attribute it to?
3. What motivated you to select biology, chemistry or physics?
4. Is physics really difficult?
5. What career opportunities in physics are you familiar with?
6. Biology, chemistry and physics, which one will you say is more relevant and why?
7. (a) What is about physics that you like?

   (b) Is there any thing about physics lecturers/teachers that you don't like?
8. Do you think physics can be made more attractive to female students? Explain.

APPENDIX L

SEMI-INTERVIEW PROTOCOL USED TO INTERVIEW PHYSICS LECTURERS AND TEACHERS

1. What is the female students' attitude towards physics lectures/lessons?
2. What problems do you have with female students in your class when it comes to physics lectures/lessons?
3. What is the performance of female students in your physics class?
4. How often do you give special attention to female students in your physics class?
5. Your female students say physics is difficult. What do you say about it?
6. What is about physics that deters many females from studying it?
7. Some of the female students have complained about poor tuition of the subject. In most cases they said teaching had been more of abstract than practical. What is your reaction?
8. Most female students seem to know little about where physics can lead them to. Do you have any reaction to that?
9. What career opportunities are available for physics students?
10. Do you think physics can be made more attractive to female students than it is now? Please explain.

APPENDIX M

CAREER AVENUES IN PHYSICS

Field	Sub-area	Field	Sub-area
Medical Physics -	Health Service	Env. Physics -	Radiation Protection
	Instrumentation		Conservation
	Health physics		Noise control
			Pollution control
Computing -	Computing design	Alt. Energy -	Geothermal
	System design		Solar
	Microprocessor design		Wave
	Robotic		Wind
Communications -	Fibre optics	Industry -	Aerospace
	Satellites		Electronics
	Telecommunications		Petroleum
Meteorology -	Oceanography	Geophysics -	Mineralogy
	Weather forecasts		Petrology
	Radio		Prospecting
	Travel		Mineral processing
Education -	Schools	Industry -	Aerospace
	Colleges		Elecronics
	Polytechnics		Petroleum
	Universities		Food
			Semiconductor