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ABSTRACT

Many Commonwealth countries are concerned about gender factors in mathematics and science education. Labor market statistics in many developing countries show greater participation rates for men in science in general and in numerically-based disciplines in particular. Available evidence indicates that gender biases account for the difficulties girls experience in learning mathematics and for the barriers to their later entry into, and good performance in, science and technology education. This report is the product of a two-day conference which addressed the issue of mathematics as a barrier to learning science and technology amongst girls. It was organized as a follow-up to the 8th International Conference of Gender and Science and Technology (GASAT). The conference was convened to explore the interrelationships between the teaching of mathematics and of science and technology in the context of gender and to identify those areas worthy of further study in Commonwealth countries. This report provides the perspectives of many distinguished researchers and practitioners from the Commonwealth with diverse cultural, linguistic, and ethnic backgrounds which play an important role in the choices that girls and boys make in school and in the way that schools and teaching are organized. Teachers, teacher educators, researchers and other interested readers are provided with an overview of the influence of mathematics on gender differences in participation and achievement in science and technology teaching. It also points to directions for further investigation. Chapters include: (1) "Mathematics as a Barrier To the Learning of Science by Females" (Leone Burton); (2) "Mathematics Performance in Botswana Public Examinations: Implications for Girls' Participation in Science-Oriented Careers" (K.G. Garekwe); (3) "Mathematics as a Barrier To Learning Science and Technology among Girls in Dominica (Eastern Caribbean)" (Ezra Blondel); (4) "Participation of Boys and Girls in Mathematics and Science at Secondary School Level in India" (A. Vasantha); (5) "Enhancing Women's Participation in Mathematics Education" (G.C. Vora); (6) "Girls, Mathematics, Science and Technology Education in Kenya" (Esther N. Kioko); (7) "Mathematics and the Learning of Science and Technology amongst Girls in Malawi" (Onesmo Joseph); (8) "Mathematics as a Barrier To Learning Science and Technology amongst Girls in Papua New Guinea" (Neela Sukthankar); (9) "Mathematics as a Barrier To Learning Science and Technology amongst Girls" (V.G. Masanja); (10) "Mathematics as a Barrier To Learning Science and Technology amongst Girls in Uganda" (Janet Kaahwa); and (11) "The Relationship between the Learning of

Mathematics and the Learning of Science and Technology amongst Girls in Zambia" (Bentry Nkhata). (Author/ASK)

Mathematics as a Barrier to the Learning of Science and Technology by Girls

Report of a Conference

Ahmedabad, India
11-12 January 1996

Commonwealth Secretariat

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Foreword

Many Commonwealth countries are concerned about gender factors in mathematics and science education. Labour market statistics in many developing countries show greater participation rates for men in science in general and in numerically-based disciplines in particular. Available evidence indicates that gender biases account for difficulties that girls experience in learning mathematics, and for barriers to their later entry into, and good performance in, science and technology education.

This report is the product of a two day conference which addressed the issue of "Mathematics as a Barrier to Learning Science and Technology amongst Girls". It was organised by the Commonwealth Secretariat and held at Ahmedabad, India in January 1996 as a follow-up to the 8th International Conference of Gender and Science and Technology (GASAT). The conference was convened to explore the inter-relationships between the teaching of mathematics and of science and technology in the context of gender and to identify those areas worthy of further study in Commonwealth countries.

The report provides the perspectives of many distinguished researchers and practitioners from the Commonwealth with diverse cultural, linguistic and ethnic backgrounds which play an important role in the choices that girls and boys make in school and in the way that schools and teaching are organised. The report will provide teachers, teacher educators, researchers and other interested readers with an overview of the influence of mathematics on gender differences in participation and achievement in science and technology teaching. It also points to directions for further investigation.

The Commonwealth Secretariat is grateful for the support received from the Rockefeller Foundation, New York; the British Council, Lusaka; the Norwegian Agency for International Development (NORAD) and GASAT. On behalf of the Commonwealth Secretariat, I also wish to express our sincere gratitude to all the participants for their contributions to the success of the workshop and to Professor Leone Burton of the University of Birmingham, UK, for preparing this report.

Professor Stephen A Matlin
Director
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Conference report

This two-day conference was organised by the Commonwealth Secretariat and took place at the Hotel Inder Residency, Ahmedabad, India on 11–12 January 1996 as a follow-up to the annual international Gender and Science and Technology conference (GASAT). The conference was led and facilitated by Professor Leone Burton, with the assistance of Dr Ved Goel of the Commonwealth Secretariat. The Commonwealth Secretariat wishes to express its thanks to the Rockefeller Foundation, New York, for providing the financial support which enabled some participants from Africa to attend the conference. Gratitude must also be expressed to the British Council, Lusaka, Zambia for partially supporting one participant, and to the Norwegian Agency for International Development (NORAD) for supporting another. Finally, the Commonwealth Secretariat is grateful to Professor Leone Burton of the University of Birmingham, Birmingham, UK for running the conference and preparing the report.

Participation

Participants consisted of those who had attended the GASAT conference and had been invited to, or signified their interest in, the two-day event. This interest had been aroused by a Round Table at the GASAT conference which had overviewed the work of the two-day conference and given a flavour of what was intended. The presenters at the Round Table, which was chaired by Dr Goel, were Professor Burton, Dr Aletta Zeitsman and Mrs Janet Kaahwa.

The 25 participants in the two-day conference were:

Dr Arsanipalani Vasantha, Jawaharlal Nehru University, India
Ms Ezra Blondel, Dominica
Professor Leone Burton, University of Birmingham, UK
Mrs Padma K. de Silva, University of Peradeniya, Sri Lanka
Mrs K. Garegae Garekwe, University of Botswana
Dr Hina Gokhale, Defence Metallurgical Research Laboratory, Hyderabad, India
Mrs Janet Kaahwa, Makerere University, Uganda
Ms Esther Kioko, National Museum of Kenya
Ms Vasudha Kulsheshtha, North Gujarat University, India
Mr O. J. Manda, Likuni Girls' Secondary School, Malawi
Dr Verdiana Masanja, University of Dar-es-Salaam, Tanzania
Dr Md. Sahajahan Mian, University of Dhaka, Bangladesh
Dr Jane Mulemwa, Makerere University, Uganda
Mr Bentry Nkhata, University of Zambia
Mrs Georgina Quaisie, Ghana Education Service, Accra
Dr Neela Sukthankar, University of Technology, Papua New Guinea
Prof. Darshan Singh Bassan, North Gujarat University, India
Prof. Man Mohan Singh, Northern Eastern Hill University, Meghalaya, India
Dr Gira C. Vora, Smn. K. Dalal Edu. College for Women, Ahmedabad, India. Dr Aletta Zeitsman, Witswatersrand University, South Africa
Representing the Commonwealth Secretariat: Dr Ved Goel
A full list of names and addresses is given at the end of this report.

Format and agenda for the conference

Invited participation in the conference was contingent on the submission of a relevant paper. Eleven papers were received. Professor Burton introduced the conference with a situation paper on the topic. The other ten papers were grouped into pairs, each pair being allotted one and a half hours for the presentation of their main arguments and for general discussion. Each presenter was asked to confine their introductory remarks to 20 minutes to be used in outlining their position and arguments, thus providing necessary contextual information. Thus, each session had 50 minutes for discussion.

The agenda submitted to and agreed by the participants was:

11 January 1996

9.00 a.m. – 9.15 a.m.	Ved Goel, welcome, background and purpose
9.15 a.m. – 10.30 a.m.	Leone Burton, Setting the scene
11.00 a.m. – 12.30 p.m.	K. G. Garegae Garekwe, Md. Sahajahan Mian
2.00 p.m. – 3.30 p.m.	Bentry Nkhata, Vasantha Arsanipalani
4.00 p.m. – 5.30 p.m.	Janet Kaahwa, Verdiana Masanja

12 January 1996

9.00 a.m. – 10.30 a.m.	Ezra Blondel, Neela Sukhantar
11.00 a.m. – 12.30 p.m.	Georgiana Quaisie, Esther Kioko
2.00 p.m. – 3.30 p.m.	Strategies and recommendations for action
4.00 p.m. – 5.00 p.m.	Implications and summing up

In his welcome and introduction, Dr Goel pointed out that the papers from particular countries would explore, for each country, whether mathematics is a barrier to learning science and technology amongst girls and, if it is, to what extent and in what manner. He emphasised that the purpose of the two-day conference was to move us all into a position where we could identify action strategies which we would like to implement in our own contexts.

Outcomes

The depth of engagement and discussion during the two days certainly provided evidence that the participants recognised a cluster of issues that were worthy of attention and welcomed the opportunity to concentrate upon them. At the end of the two days, participants divided into two groups for the session on strategies and recommendations for action.

The reports of the two groups made the following points:

Group 1

1 There is need for a comparative study in different countries (contexts), using qualitative methods.

2 Approaches to changes are necessary at different levels of the system: teacher education, classrooms/schools, community groups, policy makers.

3 Different perceptions of mathematics should inform the construction of curricula.
4 Changes in pedagogy are necessary from teachers 'giving' to teachers facilitating the learning process and inculcating respect in pupils for their own learning.
5 Responses to questionnaires do not necessarily bring to the surface the feelings of the respondents.
6 Does the sex of the teacher affect the learning of girls and boys?

Group 2

1 Teaching should be improved. Girls need more time in schools.
2 Teaching activity should be reinforced by members of the community.
3 How sensitive are the examination questions to the learning of girls?
4 There should be a breadth of styles of assessment and, in particular, more continuous assessment.
5 Career guidance and counselling should be increased so that boys and girls are aware of the uses of mathematics both for future studies and adult life.
6 Mathematical content should be interrogated for its relationship to the needs of girls as well as boys and, in particular, its relevance to daily life.
7 Teachers need to know what, and how much, mathematics is needed for different purposes and the mathematics should be connected to the needs of daily living.
8 In-service education of teachers is inadequate.
9 Gender issues should be made part of the curriculum of teacher education courses.
10 Teacher educators themselves need educating.
11 Instructional materials should be researched, in particular from the point of view of individual differences and diagnostic functioning.
12 Teachers and teaching materials should make use of research findings on how children construct knowledge in science.
13 Members of society needs sensitisation, particularly those like policy makers who are in a position to influence.
14 The mathematics curriculum lacks female role models.

A number of participants committed themselves to future activities in their own settings. Examples were:

1 The use of ethnographic methods within small communities, with their involvement, to sensitise for gender bias.
2 Introducing and encouraging development of the teacher as researcher in her or his own classroom.
3 A small-scale study of changing understanding of mathematics and science in one class within one school.
4 An investigation of school policies towards mathematics in the curriculum. Is mathematics compulsory? If so, for whom? Are there options? Why/why not? Are the curricula in high schools and universities related? Do these school policies have any impact (negative or positive) on further/higher education?
5 What is the effect of anchoring formal science and mathematics in indigenous knowledge/practices?
6 What exactly stops girls continuing into mathematics/science courses at university?

7 How is the non-formal system (e.g. museums) used by the formal educational system?
8 An extensive qualitative study to confirm or dispute the assertion that mathematics is a barrier to the learning of science and technology by girls.
9 A programme to develop teaching aids and encourage teachers to use them.

Additionally, participants were asked to provide a written reflection upon the conference and these have been used in order to gather information for this report. Amongst the comments included in these reflections were the following:

- Mathematics may not be the only barrier to girls' participation in science. Science itself should be researched. But boys, too, find mathematics difficult.
- Other barriers operate including socio-cultural ones.
- Insofar as mathematics does present one barrier, it does so by acting as a critical filter, by appearing to be necessary to success in science, especially the physical sciences, and by appearing to be different from the mathematics used in the sciences.
- Indigenous knowledge and practices should be a part of the teaching and learning of science and mathematics in schools.
- Teacher education needs to be addressed from epistemological, pedagogical and socio-cultural perspectives.
- The meeting was not long enough to enable all of the issues to be given the attention that they warranted. In particular, more time was needed to discuss strategies to improve the situation. None the less, fruitful discussions took place.
- There is a need for policymakers to be made aware of the problematics which informed our discussions.
- The conference was excellent, providing a lot of information regarding the teaching of mathematics and physics at school level. It was useful to me as a lecturer at the university.
- The conference was very useful to teacher educators and provided an opportunity to develop international contacts and compare situations in different countries.
- The time has come to shift from gender deficiency studies using statistical models to more explanatory ways of investigating gender disparities.
- Society has need of a shift from science/mathematics as 'immutable facts' to the contribution of these disciplines to socio-cultural knowledge/understanding, especially through the use of indigenous knowledge.

Short list of helpful references

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Mathematics as a barrier to the learning of science by females

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Introduction

In setting the scene for the forthcoming two days, I think that it is important that we all hold three questions in mind and use those questions to interrogate what we hear and help us reflect upon it. The three questions are:

> *How does this thinking apply to my context?*
> *Can I, should I, make use of it?*
> *How does my thinking apply to these ideas?*

I want to begin by looking at pupil attitudes to mathematics and science and using one particular study to trigger reflections about what we know and what we do not.

In a meta-analysis of studies that looked at the links between interest in mathematics and choice of a scientific career, Lantz, Carlberg and Eaton (1981) said *'Women choosing science were differentiated from other women by their high intellectual ability, their strong career commitment, and their general patterns of interests, especially interest in mathematics.'* (from Chipman and Thomas, 1987: 412). In addition, Alison Kelly found that *'pupils taking physics performed approximately half a grade better in mathematics than equally able pupils who did not take physics'* (1987: 310; see also Fennema and Sherman, 1977). While these results confirm that studying a package of numerically based disciplines is especially helpful to the learning of mathematics, they do not imply that students are failing to choose to study science *because of* its links with mathematics.

Studies of pupils' attitudes to science have identified many socio-economic and cultural factors alongside those of school and classroom which influence academic preferences and performance. Wendy Duncan (1989) investigated Botswanan students' attitudes and achievement in science. She developed a model which *'has as its basis the idea that it is student attitudes to the gender of science as a school subject which foster gender differences in science achievement and participation'* (p.56). She said:

> *'The societal context has a major impact upon gender differences in the recruitment to, and achievement in, the forms of education which lead to a potential career in science. Of special importance are the level of economic development (and, hence, a country's ability to invest in education generally and science in particular), the availability of scientific and technological jobs, the sexual division of labour in the traditional and modern sectors, and the gender ideology. The school organisation, the structure of the curriculum, the expectations of teachers and school personnel and the gender ideology of the school also form important constraints which perpetuate discrimination in the educational system and mould the gender role socialisation process.'* (1989: 47)

As is so often the case with studies that result from the administration of questionnaires, this one begs many questions. When girls and boys were asked to identify the subjects they believed to be most important, only the boys included mathematics in their top four. Of note is that between girls and boys there was little disagreement about the importance of mathematics to girls. The average rating by girls of the importance of the subject to girls was 1.4 and to boys, 1.6. The average ratings by boys of the importance of mathematics were 1.2 to girls and 1.7 to boys. What does this tell us? Girls appeared to think that mathematics was almost as important for girls as for boys while boys rated it of significantly greater importance for them.

	Importance for girls		**Importance for boys**	
	Girls	Boys	Girls	Boys
English	2.2	2.0	1.2	1.7
Mathematics	1.4	1.6	1.2	1.7
Science	1.5	1.3	1.5	2.4
Agriculture	0.6	0.4	2.3	1.9
Domestic Science	3.2	3.0	0.0	0.0
Woodwork	0.0	0.0	1.7	0.9

Source: Table 8.1, Duncan, 1989: 146

What can we learn from these figures? Boys considerably diminished the importance of science for girls as compared with themselves. They dismissed domestic science as unimportant for both girls and boys, probably a function of perceiving the exercise of rating school subjects for their importance as academic. But girls seemed to think science more important for them than for boys, and domestic science equally important to both. We have no information as to how girls and boys perceived the relationship between their school subjects and their future aspirations or social possibilities. What is understood as 'important' within this context?

Let us look, however, at the agreement between the boys and girls. They agree on the relative importance of science for girls, and come close to agreement on the slightly greater importance of mathematics for boys. Their areas of disagreement are considerable. While girls think domestic science is important for both sexes, the boys discount its importance completely, as do the girls for woodwork, while the boys think woodwork is considerably more important for girls. In an economy dependent upon agriculture, the girls discount it while the boys acknowledge its importance to both sexes, but more so to girls.

How can we interpret these numbers? I think it is foolish to take them at face value. The data were collected from a nationwide survey of secondary school students in Form 3 by means of a questionnaire comprising three- or five-point Likert scale items and administered in the schools. Importance is contextually understood. Something that is important in school might well be very unimportant in other contexts and vice versa. From this perspective, the figures begin to make more sense. School is a gateway to opportunities which themselves are constrained by gender, society and economics. Seen in this way, it is not mathematics that is acting as a barrier to learning science. On the contrary, mathematics was the only subject of the 12 listed which was not gender-stereotyped by the pupils when the differences between mean scores for 'importance for girls' and 'importance for boys' were tested for statistical significance. This, perhaps, is testimony to the degree to which mathematics is perceived by all as acting as a critical filter to employment, whether that employment is science-based or not. It also helps to explain the importance of mathematics perceived by girls and boys when asked to comment on why subjects were important. 'Job preparation', although not seen as equally important for both sexes, was none the less top of the reasons given by boys and second only to 'Preparation for family life' of the reasons given by girls. Indeed, the dominance of 'Preparation for family life' in the explanations given by girls of which subjects are important and why, goes some way towards explaining why domestic science scores so highly in importance for girls, whether they are rating it for themselves, or for boys. And the dominance of 'Job preparation' for boys helps to explain the importance with which agriculture is rated by the boys, whether they are considering girls or themselves. It would appear that far more is going on in the minds of these children than the simple tables and figures would indicate.

Is mathematics a barrier to the learning of science by females?

Is mathematics a barrier to the learning of science? Anecdotally, we believe it to be so but we do not have consistent evidence obtained from young people in many different settings in a manner which enables them to share their feelings and expectations with the researchers. Scientific thinking has dominated much of the research that has been done in science education. I will discuss the problematics of our conceptions of science in a moment. However, here I want to point out that so-called 'scientific' research, that is research built upon a quantitative paradigm which *assumes* 'objectivity' has been of limited, although supportive, value. We now need qualitatively rich data from a number of different sites comparing teachers' expectations with those of pupils and parents, and with pupil attitudes to the learning of mathematics and science, before we can assert this connection unequivocally. In the meantime, it is noticeable that in much of the literature, this connection, while assumed, is not explored. It is an example of what Eileen Byrne calls the 'Snark effect' which:

> *'operates when two things are simultaneously found. Firstly, that the assertion is based merely on the educator, teacher or policymaker having internalized it from hearing it repeated many times ('What I tell you three times is true'), and despite the widely cited ubiquity of the belief or principle it proves to be either unfounded, or only occasionally and contextually true. Secondly, at the same time the internalized belief is used to justify and implement major policies (for example, the creation or retention of single-sex schools or classes.)'* (1993: 3)

In the case of the influence of mathematics on the learning of science by girls, the belief, supported by research, that success at mathematics is closely implicated in success at science remains. This has led to policies such as making both mathematics and science compulsory at school level. Take for example the National Curriculum in England and Wales where two things happened. First, pupils were declared as entitled to a curriculum which included both mathematics and science. Then, a recognition that many pupils found science difficult, led to an introduction of two levels of science, only one of which admits to higher studies. The barrier then operates against the perceived weaker pupils, often seen by schools and pupils themselves as being the females. The policy decision, therefore, is based upon belief and partial evidence about links in *successful* study. It has led inexorably to a bias in entrants to further scientific studies who are required to provide proof of achievement in mathematics as well as in higher levels of science. Just because aggregation of studies is helpful to those who are already succeeding, this does not validate the converse, that is, that those who are failing to succeed would be helped by aggregation of studies. Nor does it provide any evidence that linking disciplines in this way is, or is not, a disincentive to some pupils who might otherwise choose to study some of them.

Is mathematics a barrier to the learning of science by girls? I am suggesting that we have little in the way of substantiated evidence to support any response to this question. We do, however, have a growing recognition that the issues which demand investigation are embedded in a scenario of great complexity and that there are many of them. Also such research requires the use of methods which are sensitive to complexity. This complexity resides in the socio-cultural environment, and the roles available, and adopted, within it by teachers, pupils and parents. There are researchable questions about policy-making and its reliance, or otherwise, on context and evidence or beliefs, prejudices and stereotypes. There are questions about the relationships between the social definition of roles and responsibilities and the educational and occupational opportunities available to girls and boys. There are also questions about the perceptions which girls and boys have of the relationship between their schooling and their expected life-style trajectories.

Should mathematics be perceived as a barrier to learning science?

In this section, I wish to deal with three questions and finally sum up with a section on 'Science as power'. The three questions are:

- Is the barrier mathematics, or is it how schooling is structured?
- How are school mathematics and school physics understood?
- Is the mathematics necessary to learning science of equivalent difficulty to the science?

Is the barrier mathematics, or is it how schooling is structured?

The most frequently cited reasons for mathematics impeding learning in science are not about the sciences generally but about physics. However, *'among young school children, girls are nearly as interested in physics topics as are boys. Gender differences increase with age.'* (Beyer, 1995: 47). Many explanations for this have been offered including values, motivations and belief systems (Fennema and Peterson, 1985; Kloosterman, 1990) and educational structures, subject cultures and pedagogical styles (Beyer, 1995). A major difference between the USA and Europe is that mathematics becomes optional in early adolescence in the USA, remaining compulsory in most European countries until 16 years. As Karin Beyer points out: *'the greater the number of electives and the earlier the choices have to be made, the more profound are the patterns of gender differences to be found.'* (1995: 47). Consequently, while mathematics acts as a critical filter in the USA, it is physics which may play this role in some European countries such as Denmark (1995: 48). It is not clear, therefore, that it is mathematics which is blocking entry to study of the sciences. It may rather be a result of the ways in which passage through the educational system is constructed and who benefits from this structuring. This observation leaves that structure unquestioned as well as failing to deconstruct the ways in which authority is allocated.

How are school mathematics and school physics understood?

The distinctions between mathematics and physics are often considerably blurred but there is little agreement between those teaching the two subjects about their synchronisation, in terms of techniques to be applied or even nomenclature. Philip Davis and Reuben Hersh reported in their book, *The mathematical experience*, upon an interview with a physicist who placed himself at the intersection of physics, chemistry and materials science *'When asked whether he thought of himself as a creator or a consumer of mathematics, he answered that he was a consumer'* (1981: 45). Unlike mathematicians, who tend to be looking for, and claiming, universality, this physicist said that *'The best one can hope for is a model which is a partial truth ... Ideally, a model should have predictive value ... But one has to be in a position to derive mathematical and hence physical consequences from the model.'* (1981: 46/7). Further, *'to him, proofs were relatively uninteresting and they were largely unnecessary.'* (1981: 48). I think that there are important questions to be asked here. Is this the way in which teachers and pupils view, and encounter, physics and mathematics? In what ways would a view consistent with this approach change pupils' experiences and possibly their attitudes towards mathematics and physics?

As Karin Beyer makes clear (1995: 50–52), difficulties are introduced through the subject construction as well as the teaching and learning styles. The mathematisation of a physics problem is emphasised often without siting this mathematisation in the context of the physical model in such a way as to make the whole thing more meaningful. However, when mathematics is taught in such a way as to explore the meaning of both the model and the outcomes of its application, it is learnt more effectively. But Mary Barnes, who was responsible for developing and evaluating an innovative, and gender-fair, programme to teach calculus, points out:

> *'If innovative curricula are to be more widely implemented, teachers need support in making the necessary changes in teaching style and in working out how to organise their teaching so as to make the time for exploratory activities.'* (1995: 86)

Perhaps we are not so much talking of mathematics as a barrier to learning science as the methods that we use to teach mathematics and the ways in which we prepare teachers of mathematics and science. I will return to this below.

Is the mathematics necessary to learning science of equivalent difficulty to the science?

Pupils who have had difficulties with learning mathematics are likely to find the application of mathematical techniques to their physics problematic and, consequently, to be antagonised by connections. However, it is worth remembering that the learning of new mathematics, and its applications in physical situations, are likely to be targetted at very different levels of sophistication. In other words, the mathematics needed to solve physics problems is not as difficult as that mathematics being learnt at the same time nor, conceptually, as difficult as the science being taught. In some research which I did in the 1980s, I found that there was something like a two year gap between learning new mathematics and drawing upon that same mathematics in a problem-solving situation. Such a gap is usually built in to the mathematical techniques expected to be applied in scientific situations. That is, the demands of the science are likely to require the application of mathematics learned some time earlier. Mathematics ability and achievement are implicated in the selection of physical sciences as an area of study (see Dunteman *et al.*, 1979). However, I would expect pupils whose mathematics and physics is embedded in a coherent philosophy which is supportive of both disciplines to be more likely to be positive about both.

Furthermore, mathematics, until recently, has not blocked, in a major way, female entry to the study of biology. As the so-called female science, biology did, in the past, gain better entry statistics from a female perspective than either physics or chemistry. However, even with a greater number of female entrants at Advanced level in England and Wales, *'more males than females attained a grade A or B'* (Gipps and Murphy, 1994: 242). This result is replicated in most subjects, including those which have a predominantly female entry such as English Literature. *'Preliminary analyses of the 1992 results by gender ... show that one in eight males had the equivalent of three A grades compared with one in eleven females ... What these A-level results show is a quite dramatic reversal of the trend at GCSE (and national assessment at 7 and 14 years thus far).'* (1994: 243) So, it is not the case that earlier achievement ensures later gains. Between GCSE and A-level there is a major reversal which I would ascribe to the watershed of A-level providing entry to higher education. I believe that this is about power.

Science as power

Biology and physics are excellent examples of the way in which the distribution of power is central to the genderisation of disciplines. I would argue that the question of who studies physics has been more about the power of the discipline and less about its content. As Hilary Rose points out:

> *'It was with the professionalization and industrialization of the sciences, and the steady transfer of the production of scientific knowledge from within to outside the home – first chemistry in nineteenth-century Germany, later physics and most recently biology – that women came to be systematically and sequentially excluded from the new occupational structures which, at their apex, were linked to new forms of economic and social power... Women were increasingly confined to those areas of more contemplative, less interventive science which were not yet industrialized (such as botany or nature study in the nineteenth century) or to newly developing areas (biochemistry in the 1930s, crystallography in the 1940s and 1950s, computing in the 1960s and 1970s). Women were able to gain a foothold in these new fields of science, which lacked fully elaborated career structures.'* (1994: 100/101)

The position which physics has occupied in recent times as the most influential of the scientific disciplines is now being challenged by the biological sciences.

> *'As happened for chemistry in the nineteenth century and physics in the mid-twentieth, it has now become the turn of significant sections of the life sciences to enter the process of industrialization. Changes in the production system of the life sciences which had been foreshadowed in the sixties with the advent of automatic analysers in biochemical pathology were extended in the eighties, particularly in genetics, as the techniques of molecular biology gathered strength and showed increasing potential application to medicine, agriculture, crime detection, the military and the food industry.'* (1994: 174)

With the shift in power, a changing proportion of males and females entering the discipline can be noted as well as the inability of many women to break through into senior positions. All learning is dependent upon the socio-political context within which it is situated, the discourse which defines and supports the discipline, and the consequent 'persona' which it acquires. It is not, therefore, surprising that in each new set of conditions, power is differentially allocated to disciplines, and the patterns of successful learning change.

Should mathematics be seen as a barrier to the learning of science? I have argued that mathematics has not, in the past, acted as a barrier to biology so much as it has appeared to block entry to physics. However, as a result of shifting patterns of power within the scientific disciplines, parallel shifting gender patterns are to be observed. I have suggested that an assumption of a simple relationship between the learning of mathematics and physics or biology is misguided. Also, this apparent relationship between mathematics and scientific disciplines such as physics is actually less influential than a more powerful socio-economic positioning which creates the preconditions for the genderisation of disciplines. This process, I have indicated, is subject to changing social conditions which themselves project different dispositions of power. At least one interesting research question suggests itself in this context. It would require the charting of the shifting patterns of power within scientific disciplines, cross-referenced to the perceived gender dispositions. Would mathematics contribute to this scenario and, if so, in what ways?

Do mathematics and science differ as disciplines?

Is it mathematics which is a barrier to the learning of science or their shared epistemology and consequent pedagogy which makes them appear intricately interlocked? What is shared between mathematics and science is the power which they are accorded in late twentieth century social and intellectual organisation. This power is not only evident in the social positioning of 'scientists' as compared, for example, with priests or members of the aristocracy in former times. It is also evident in the genderisation of the role of 'scientist' and in the consequent adoption of disciplinary perspectives which assume that scientific knowledge must be 'objective', depersonalise the procedures of knowledge searching and gaining, and treat science and mathematics classrooms as places where one 'correct' understanding is transmitted to learners perceived as homogeneous. It is my view that this socio-cultural pattern, which conveys an image of uniform and unchallengeable knowledge, fits comfortably in the context of an expected uniformity of those who are active and respected in the disciplines. That is, the epistemology associated with the disciplines, by which I mean the conception of what it means to know science, itself provokes an expected homogeneity of learners and practitioners. To be male, and in many cases white and middle class, therefore, matches appropriately!

> *'The halls of academe have always been too narrow, so it is no surprise that they still do not easily accommodate the press of those who were once completely excluded from academic spaces. The shape of the hallways must be changed, not the shape of those whose different demands draw attention to the limits of Western knowledge systems.'*
> (Taylor and McWilliams, 1995: 579/580)

I would therefore claim that, from this perspective, a shared barrier to the study of mathematics *and* science does exist in the epistemology which defines them. This makes these disciplines appear as unchallengeable and constrained bodies of knowledge which must be learnt as they are offered, not questioned or reinterpreted by the learner. The shared blight of 'objective' knowledge seems to me to be more powerful than the potential interaction of one discipline on the study of another.

Implicated in this preferred epistemology is a definition of knowledge which arises from the historical development of both mathematics and science such that they have been responsive to the needs, interests and procedures of male Western Europe. More importantly , they have been seen to create and contribute to an improving social environment. Unfortunately, they have also created and contributed to a world which is being polluted and, in parts, destroyed. And the resources which are the focus of the perceived 'improvements' are severely maldistributed. The science which has thus been derived is, in my view, mistakenly perceived as universal and through that perception has been imposed, often with their connivance and involvement, on other communities. Thus, for example some of those European females who, in the process of becoming scientists, have been socialised into scientific culture, understand 'real' science as the only possible product of the process they have been taught. They can sometimes adopt the strongest positions of antagonism to arguments suggesting in-built bias, culture-centricness or any other challenge to their 'reality'. They make the claim that it is absurd to consider that there could be any other science or mathematics than that which is respected and admired in developed societies. In itself this claim cannot be substantiated. At the same time, many less developed countries feel that a new form of colonialism is operating when it is suggested that they might take a scientific path different from that of the developed world. For some of these countries, the important developmental path is to 'catch up' but, in that process, the errors and disadvantages introduced into the environment are being replicated. Scientists, in both the developed and the developing world, are beginning to raise queries about a headlong rush, for example, to adopt scientific processes which damage the environment and to abandon life-style principles which have been protective of societies in the past.

I would conjecture that rewriting the mathematics and science stories such that they are seen as being exactly that, stories, which different people create to match different circumstances, would radically change both those who engage with these subjects and, more importantly, the manner of that engagement. Such rewriting requires research which helps to generate a new consideration of the indigenous science and mathematics, which looks at similarities and differences between mathematical and scientific explanations and encourages learners to evaluate these.

Let us turn, then, to the pedagogy of mathematics and the sciences.

Pedagogically, are the disciplines similar?

The dominance of transmission teaching is shared between mathematics and the sciences which, given the shared epistemology, is not surprising. Equally unsurprising is the acceptance of testing as the most valued form of assessment since it fits comfortably with the idea of the 'delivery' of 'objective' knowledge.

> *'Students' performance on tests is not only dependent on the 'cognitive level' of the task, but also very much on the affective response to the content and context of the problem. This is something that we would expect to matter in the teaching and learning situation but typically assessors assume that content is irrelevant ... irrespective of what criterion was being assessed questions that involved such content as health, reproduction, nutrition, and domestic situations were generally answered by more girls than boys across the ages 11, 13, and 15. The girls also tended to achieve higher scores on these questions. In questions with a more overtly 'masculine' content, for example, building sites, racing tracks, or anything with an electrical content, the converse was true.'* (Beyer, 1995: 54/55)

However, as researchers such as Patricia Murphy (1993) and Joan Solomon (1987) have shown, context in the teaching of mathematics and science is by no means as unproblematic as is often suggested. Karin Beyer outlines some of the dilemmas:

> *'1. Presenting physics in an everyday context will often add to motivation, but students tend to give an everyday explanation in everyday language without the physical reasoning that is really required ... A pure physics problem disguised in an everyday context is more difficult than in the traditional version. It is especially difficult to change between the two different codes of scientific and everyday language.*
>
> *2 ...treating the interplay between science, technology, and society in a theoretical framework will make the subject very difficult ... adding STS as part of the curriculum ... does not in itself imply improvement in students' learning/understanding of the basic physical concepts and theories.'* (Beyer, 1995: 53/54).

My concern here is about the assumption lying behind these statements. Is it not possible for learners to express physical reasoning in language which is familiar and meaningful to them? Why, as teachers, are we driven to enculturate learners into science and mathematics, through a specialised and often meaning-obscured language before the need for such a means of communication has been appreciated and explored? And why do we not assume that to theorise is a necessary stage after establishing understanding. I believe that it is an urgent pedagogical necessity to find ways of challenging the technical hegemony which has dominated the sciences, and mathematics, for a very long time. This controlling hegemony, with its assumptions of universality over language, and particularly discourse, is exclusive. One of the pervading things that learners remember about science, for example, is the format through which experiments must be reported. Indeed, the structure of aims, methods, etc. is perceived by learners as being of far greater importance than the content of the experiment. Particularly is this so in those cases where experimental error leads to erroneous results and pupils are advised to copy from a more successful pupil or from the book. Discourse consequently also constrains the methods of learning the sciences which themselves have been shown to be exclusive. Alternatively, a discourse which grows out of the context of a shared problem which the learners need to unravel both in terms of solution but more importantly in terms of understanding what is happening and why, will inform and be informed by the process. This seems to me self-evident.

I am claiming, therefore, that both epistemologically and pedagogically, mathematics and the sciences share more than they differ. This shared epistemology of 'objective' knowledge with its shared pedagogy of control and transmission, constitute a major shared barrier to learning. That is not to deny the differences but to suggest that in the overall context of the learning environment, the power of what is shared is much more influential than the particularities of what is not. For example, the centrality of proof to the practise of mathematics and its cavalier dismissal, for example by the physicist quoted above, demonstrates a difference which is of great conceptual and methodological importance. None the less, I believe that such differences are neither made explicit to or by learners, nor proposed by them as reasons which substantiate why they do nor do not choose to study mathematics or science. Howev er, when questioned as to why they do not wish to pursue scientific studies, they are more likely to focus upon 'boredom', 'closure', 'lack of relevance', feelings of distance between their interests, questions, capacities and those of the discipline concerned. In this respect, I would suggest that the popularity of environmental science at a time of high environmental challenge should not be ignored. This bears out the pedagogical necessity of being involved in one's learning in order to want to continue engaging with it.

Much research remains to be done. For example, if mathematics and science are perceived by learners as sharing an epistemology and a pedagogy in the ways in which I have suggested, and if this perception is a disincentive to further learning, what effects does a shift in stance and style have, particularly on gender choices? How should such shifts be operationalised especially in a climate where reproducing content represents the main expectation? What social, as well as educational, strategies might be contributory to changing the views of politicians, scientists and the general public about the nature of science and its learning?

What do we need to know and how might we find out?

Is mathematics a barrier to the learning of science by females?

- Little substantiated evidence to support responses to this question.
- Growing recognition that the issues are embedded in a scenario of great complexity.
- Such research requires the use of methods which are sensitive to complexity.

Some researchable questions:

- What are the links between policy-making, context and evidence?
- What are the relationships between the social definition of roles and responsibilities and the educational and occupational opportunities available to girls and boys?
- What relationships do girls and boys perceive between schooling and expected life-style trajectories?

Should mathematics be perceived as a barrier to learning science?

- We cannot assume a simple relationship between the learning of mathematics and science, whether physics, chemistry or biology.
- Mathematics has not acted as a barrier to biology so much as it has appeared to block entry to physics and chemistry.
- Shifting patterns of power within the scientific disciplines provoke parallel shifting gendered patterns.
- Apparent relationship between mathematics and science is less influential than a more powerful socio-economic positioning which creates the pre-conditions for the genderisation of disciplines.

Some researchable questions:

- Can we cross-reference the shifting patterns of power within scientific disciplines to perceived gender dispositions?
- Does mathematics contribute to this scenario and, if so, in what ways?

Do mathematics and science differ as disciplines?

- Both are powerful and share an epistemology of 'objective' knowledge.
- This carries assumptions of homogeneity of knowledge and knowers which result in exclusivity.

- Researchers are beginning to clarify differences not only between mathematics and science but also to expose different mathematical and scientific cultures.
- Such re-conceptions are vital to the future of societies as well as to mathematics and science.

Some researchable questions:

- Are there similarities and differences between mathematical and scientific explanations in different cultural contexts, particularly those formerly unrecognised and under-valued?
- How can learners be encouraged to evaluate these?

Pedagogically, are the disciplines similar?

- Shared view of knowledge leads to shared pedagogy represented by transmission teaching, limited styles of learning and assessing. All have gender implications.
- The discourse within which science and mathematics are taught and learned imposes further limitations.
- Language and meaning, and consequently understanding and motivation to further learning, are interdependent.

Some researchable questions:

- What effects does pedagogical stance and style have, particularly on gender choices?
- How should shifts in pedagogical stance and style be put into operation, monitored and evaluated, especially in a climate where reproducing content represents the main expectation?
- What impact might there be on gender choices if mathematics and science were taught and learned in an environment in which meaning is explored and negotiated and 'stories' are told?
- What social, as well as educational, strategies might contribute to changing the views of politicians, scientists and the general public about the nature of science and its learning?

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Mathematics performance in Botswana public examinations: implications for girls' participation in science-oriented careers

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ABSTRACT

This paper looks at the possibility of having boys and girls participating competitively in the Botswana government's new scheme of scholarships for mathematics and science-related careers. It looks at the quality of girls' participation in mathematics through the analysis of Standard 7 and Junior Certificate examination results. These results suggest that girls perform poorly in secondary school mathematics and hence more boys than girls stand a chance of being sponsored for mathematics, science and science-related careers. Further analysis revealed that urban girls have an advantage over their rural counterparts in terms of access to grant schemes to pursue mathematics, science and technology education. The paper concludes by suggesting measures that could be taken to curb gender disparities in mathematics classrooms in Botswana.

Introduction

Concern about gender disparity in education is well documented the world-over (Mannathoko, 1995; Duncan, 1986; Taiwo and Molobe, 1994; Molobe, 1994; Marope, 1992; Costello, 1991: Fennema, 1981). Women's participation in tertiary education generally is gravely low (Duncan, 1989), let alone their participation in the scientific and mathematical fields (Marope, 1993; Taiwo and Molobe 1994; Taole, 1991). This trend is experienced not only in Botswana; it is world-wide. In African countries, this disparity could be attributed to the nature of both pre- and post-colonial education (Duncan 1989).

Traditionally, girls and boys were treated differently before and after the colonial era. For example, in Botswana before the advent of missionaries, girls of 13–16 years old were segregated from the rest of the family for about three months to be initiated into womanhood. Similarly boys of 16–19 years old were initiated into manhood. During these initiation ceremonies boys were taught that they were superior to girls and that they have the right to their fathers' wealth. On the other hand, girls were taught household chores and that they should be submissive to men. Both sexes knew the boundary lines and would not dare to step outside these gender roles (Duncan, 1986).

Unfortunately, these stereotyped roles were reinforced by the formal education introduced by the missionaries. This was evident in the allocation of practical subjects in the school curriculum. Girls were offered knitting, weaving, washing and ironing and were taught by volunteers. On the other hand, boys engaged in carpentry, building, etc. and were taught by qualified teachers. Girls' education was deemed unnecessary and unimportant by the missionaries (Duncan, 1989), while boys' education was seen as a priority and measures were taken to increase their participation, especially at secondary level. This trend existed even after independence, especially in the early years (1965–1980). Table 1 shows the participation of girls in primary schools for the period 1965–1995. During these years, girls were in the majority at this level.

Table 1
Girls' enrolment in primary school, 1965–1995

Year		Standard 1	Standard 2	Standard 3	Standard 4	Standard 5	Standard 6	Standard 7	Total
1965	N	17 449	13 579	11 341	8 620	5 952	4 746	4 364	66 061
	F	9 737	6 493	6 493	5 078	3 498	2 632	2 211	37 169
	%F	55.8	57.3	57.3	58.9	58.8	55.3	50.7	56.3
1970	N	12 721	14 160	15 816	13 569	11 377	8 790	6 913	83 346
	F	6 742	7 739	8 310	7 177	6 130	4 698	3 601	44 397
	%F	53.0	54.7	52.5	52.9	53.9	53.4	52.1	53.3
1975	N	25 414	20 511	20 309	13 877	10 893	10 840	14 449	116 293
	F	13 727	10 920	11 204	7 717	6 012	6 069	8 300	63 949
	%F	54.0	53.2	55.2	55.6	55.2	56.0	57.4	55.0
1980	N	32 065	27 071	23 823	24 172	22 135	21 316	21 332	171 914
	F	16 755	14 248	12 650	13 144	12 326	12 114	12 566	93 803
	%F	52.3	52.6	53.1	54.4	55.6	56.8	58.9	54.6
1985	N	38 224	34 641	30 877	32 867	29 294	27 251	30 454	223 608
	F	19 325	17 556	15 715	16 846	15 554	14 977	17 212	117 185
	%F	50.6	50.7	50.9	53.1	53.1	55.0	56.5	52.4
1990	N	46 795	43 484	42 041	42 640	35 384	38 156	35 096	283 516
	F	23 406	21 402	21 402	21 410	18 311	18 803	21 036	146 299
	%F	50.0	50.4	50.9	50.2	51.9	49.3	59.9	51.6
1995	N	49 941	48 491	47 921	46 153	45 261	47 973	41 565	327 305
	F	25 202	24 409	24 367	23 246	22 614	24 425	21 517	165 780
	%F	50.7	50.3	50.8	50.4	50.9	50.9	51.8	50.7

Source: Government Statistics (Republic of Botswana, 1995a)
N = total number of students; **F** = number of female students; **%F** = female students as a percentage of total enrolment.

In senior secondary school enrolment, the general trend is that there are more boys than girls (table 2). This low participation of girls in secondary schooling may reduce their chances of participation in higher education, particularly in mathematics and science-related subjects which may lead to high paying salary jobs.

Table 2
Enrolment of girls in secondary school, 1965–1995*

Year		Form 1	Form 2	Form 3	Form 4	Form 5	Total
1965	N	601	364	213	84	45	1 307
	F	292	155	78	28	14	567
	%F	48.6	42.6	36.6	33.3	31.1	43.4
1970	N	1 336	1 199	826	292	252	3 905
	F	644	588	386	116	97	1 831
	%F	48.2	49.0	46.7	39.7	38.5	46.9
1975	N	4 295	3 672	2 511	917	706	12 101
		2 411	2 085	1 270	348	278	6 392
	F %F	56.1	56.8	50.6	37.9	39.4	52.8
1980	N	6 081	5 160	4 194	1 602	1 288	18 325
	F	3 665	2 992	2 433	692	501	10 283
	%F	60.3	58.0	58.0	43.2	38.9	56.1
1985	N	10 577	10 455	6 772	2 277	2 091	32 172
	F	5 706	5 912	3 765	913	879	17 175
	%F	53.9	56.5	55.6	40.1	42.0	53.4
1990	N	22 198	17 023	6 839	6 286	4 546	56 892
	F	12 645	9 218	3 335	3 115	2 017	30 330
	%F	57.0	54.2	48.8	49.6	44.4	53.3
1995	N	35 987	53 426	9 517	9 330	8 179	116 439
	F	19 586	19 410	4 811	4 580	4 076	52 463
	%F	54.4	54.8	50.6	49.1	49.8	45.1

Source: Government Statistics Republic of Botswana, 1995a)
N = total number of students; F = number of female students; %F = female students as a percentage of total enrolment.
* NB: The entry for senior secondary level from 1988 to 1995 was Form 3.

Background to the problem

The study of gender disparities in mathematics has recently found popularity amongst researchers in education. This might be due to the fact that mathematics provides numerical computations for all school subjects (Taiwo and Molobe, 1994; Charakupa and Garegae-Garekwe, 1995) and is a prerequisite for admission for quite a number of post-secondary vocational courses (Malinga, 1993). In the Charakupa study, students were asked to say why they take mathematics at senior secondary schools. In their responses, they indicated that all school subjects, especially science, woodwork, design and technology, chemistry, physics and biology, require one to be conversant with computational skills. This is supported by Malinga (1993), who says that mathematics plays a significant role in the study of science and technology and is considered the basis for any science-oriented curriculum.

In the Taiwo and Molobe study, senior secondary students from pure science and combined science were asked to identify school subjects and careers they deem suitable for their own sex as well as for the other gender group. Most boys indicated that they liked mathematics because it is a requirement for science-related careers which they would like to pursue. Girls also indicated that mathematics is good for boys because boys are supposed to be both scientists and technologists. It is a general belief that scientific and technological careers are within male domains but arts subjects and home-based occupations fall within the female domain (Molobe, 1994). The results of this study are in agreement with studies conducted elsewhere in the world (Swafford, 1980; Perl, 1982).

The statement of the problem

After thirty years of independence, Botswana sees the importance of scientific and technological development as a critical indicator for boosting the country's economy. Thus one of the reasons why the second National Commission on Education (NCE, 1993) was set up was because of the poor performance in mathematics and science of school graduates. Because of this, a shortage of local manpower is reported in technical and vocational fields, including the mathematics and science teaching force. To curb this shortage the government has devised means of encouraging as well as attracting young Botswanans to participate in mathematics, science and technology through implementation of a new bursary system.

In the past, the government awarded scholarships to all students in the tertiary institutions regardless of the candidate's choice of career. The candidates contributed 5% of their starting salary to the ministry on the completion of the course. In 1995 the policy regarding scholarships changed (Republic of Botswana, 1995b). The new scholarship system is based on manpower needs of different sectors of the economy in the country. Students studying areas of critical manpower shortage such as the more technical and science-based professional studies or disciplines essential to the development of the economy receive more generous financial support from the government. Some examples of the fields given priority in the new bursary system include: architecture, technology, land surveying, agricultural engineering, medicine, radiography, ecology, dentistry, system analysis, mineralogy, zoology, actuarial studies, radiology, computer technical instruction, pharmacy, physiotherapy, aeronautical engineering, metallurgy, basic sciences, geology, mathematics, science, and setwana teaching. Students studying these fields will be given 100% grant on tuition and maintenance. Those students whose interests do not fall in the above list are expected to take out loans in order to pursue further education.

A good pass in mathematics is a prerequisite for almost all of the disciplines mentioned above (Republic of Botswana, 1992, 1995c,d; Malinga, 1993; Charakupa *et. al.*, 1995; Duncan, 1986, 1989). Therefore a good performance in mathematics gives one an opportunity to participate in the government scholarship scheme. This study, therefore, seeks to find out whether boys and girls have equal opportunities of participating in the scholarship system for areas of critical human resource shortage, especially science-related careers which lead to high-salary jobs. In particular, the study attempts to find out the state of affairs with regard to girls' achievement in mathematics in primary and secondary schools. The purpose of this study, therefore, is to answer the following questions:

1 Do girls and boys perform equally at Standard 7 (PSLE) and Form 2 public examination?
2 Does school location affect girls' mathematical achievement?
3 What possible classroom experiences affect girls' participation in mathematics?

Methodology

The data of this paper was collected through extended discussions and analysis of 1995 Standard 7 (PSLE) and 1994 Form 2 (JC) public examination results.

Extended discussions

These were carried out with 15 in-service student-teachers who had been in the field for at least two calendar years. The group was composed of 14 males and 1 female teacher.

Analysis of results

The Junior Certificate mathematics results of the public examination of 1994 and PLSE mathematics results of the 1995 public examinations were used in this study. The PSLE mathematics results of the seventh candidate in every centre were used. Six hundred and twenty-nine (629) schools participated in 1995 PSLE. In the case of JC level, the results of all junior community secondary schools which participated in 1994 JC examinations (from 167 centres) were used in this study. The symbols used in the examinations (A, B, C, D, E) were weighted to ease the statistical computations. That is, grade A was given five points, B four points, C three points, D two points and E one point. In PLSE the grades range from A to D only, and so grade A was awarded four points.

Results and discussion

Generally, more girls than boys enrol in primary and junior secondary schools in Botswana. But in senior secondary schools the reverse is true. This implies that boys perform better than girls in the public examinations which are used as a screening filter for further education. Further reports suggest that more girls than boys perform badly in mathematics (NCE, 1993; Taiwo and Molobe, 1994; Duncan 1989). As a result, few of them are enrolled in pure sciences at senior secondary level.

The 1994, Form 2 mathematics results showed the same trend. The *t*-test analysis showed a statistically significant difference in favour of boys as shown in table 3. A total of 30 265 students sat the examinations, about 54% of them girls. But the number of boys who obtained grades A, B and C exceeds that of girls: 4063 and 3673 respectively. These results are similar to those of 1990 JC analysed by Taole (1991). However, the 1995 Standard 7 public examination results do not reveal any statistical significant differences (at $p = 0.05$) between the performance of boys and girls (table 4). These results show that girls perform as well as boys at primary level. However, more boys than girls obtained grades A and B. It is worth mentioning that although there are differences, at least statistically, between the performance of girls and boys at this level, the possibility of having negative attitudes towards the subject which might influence the differences in performance at JC
at this stage cannot be ruled out (Shuard, 1986).

Table 3
Independent *t*-test on marks grouped by gender: 1994 Form 2 results

Group	Number	Mean	SD
Boys	167	2.205	3.340
Girls	167	2.060	2.278
	Difference	0.145	

$t = 4.250$ $p < 0.001$

Table 4
Independent t-test on marks grouped by gender: 1995 Standard 7 (PLSE) results

Group	Number	Mean	SD
Boys	334	2.060	1.247
Girls	295	1.959	1.10
	Difference	0.101	

$t = 1.115$ $p = 0.265$

In searching for explanations for the disparity at JC, the investigator conducted an extended interview with the in-service teachers. These are diploma holders who have been in the field for at least two calendar years and have come back to study for a BEd degree. They raised a lot of interesting issues pertaining to the classroom environment, such as teacher–student and student–student, student–subject interactions. Specifically, issues pertaining to attrition, teacher's attitude towards students, teaching styles, the attitudes of learners and the classroom atmosphere were mentioned.

Attrition

A number of factors were mentioned which contribute to low participation of girls in mathematics especially at higher levels. Poor performance as seen above was one of them. The drop-out rate due to teenage pregnancy was reported to be alarming as shown by table 5 below.

Table 5
Percentage of drop-outs at secondary school by form, sex and reason for the year 1992

	Male			Female		
Form	Pregnancy	Expelled	Other	Pregnancy	Expelled	Other
1	0.3	2.8	96.9	47.8	0.6	51.6
2	4.1	4.5	91.5	63.5	0.3	36.2
3	1.3	1.3	97.4	56.3	–	43.7
4	5.0	5.0	90.00	80.7	–	19.3
5	–	50.00	50.00	88.2	0.8	11.0
All	2.0	4.6	93.4	60.4	0.4	39.3

Source: Educational Statistics (Republic of Botswana, 1995a)

In 1992, 2091 girls dropped out of school, about 60% of them because of pregnancy. In contrast, about 2% of 647 boys who dropped out of school in 1992 did so because of impregnating school girls.

The irrelevancy of the subject/curriculum

Another reason for low participation and poor performance of girls in mathematics is that they think the subject is irrelevant to their future careers (Malinga, 1993). Most girls feel that the mathematics content taught in schools is not relevant to their future careers and thus they need not participate in it. Maybe it explains why girls are reported to be good at arithmetic but not geometry and spatial problems, because to them mathematics can help only in shopping, measuring and household chores (Charakupa and Garegae-Garekwe, 1995). However, this is not unique to Botswana. Stage *et. al.* (1985) report that girls have a perceived value of mathematics which differs from that of boys. Stage and his colleagues contend that it is the perceived utility value of mathematics and the interest in the subject that determines the sex-difference in mathematics involvement.

Nevertheless, in Botswana this disparity in perceived value of mathematics could be explained by the nature of mathematics teaching there. Prophet and Rowel (1990) report that the teaching in Botswana schools encourages procedural understanding as opposed to relational understanding. The teaching is characterised by chalk-and-talk where students are not given the opportunity to interact, either amongst themselves or with the subject through group discussions. But a study on women's ways of learning and knowing suggests that girls and women prefer learning through discourse that facilitates two-way communication (Belenky *et. al.* 1986).

Teacher variable

The interviewees confirmed that teachers treat girls differently from boys in classroom interaction. Most of the male teachers said when girls excel they are not happy for two reasons. First, they cannot freely interact with girls for fear of false implications being drawn either by the student community and/or the administration. There have been cases where some male teachers sexually abused female students and this situation has made things difficult for many male teachers. Sometimes female students are reported to have taken advantage of the situation and abused male teachers to the extent that they have left the profession. This is unfortunate because about 75% of mathematics teachers in Botswana are males.

The second reason why male teachers are not happy when their best student is a girl is that 'she will soon drop out' or that she will not pursue a scientific career. This corroborates well with Molope's study where teachers tallied scientific occupations with male students. The root of this gender-typing problem is the society and teachers are born, raised and educated in the society. The misconceptions in the society are their misconceptions too, although they are expected to enlighten the youth. Attitudes of teachers towards students influence their performance (Duncan 1989; Malinga 1993.) This observation is corroborated by the Stage *et al.* (1985) study in which the quality and type of teacher instruction was found to vary according to the sex of the student and the subject matter taught. It is reported that *'teachers interact with, provide more praise to, and provide more formal instruction to boys than girls especially in science and mathematics'* (1985: 242). Although Stage *et al.* and Fennema (1981) report similar findings to the present study, the reasons advanced in these studies for differential treatment of boys and girls differ from the ones reported here.

Teaching styles

Generally speaking mathematics learning encourages competition. The teachers have reported that girls do not want to compete. In fact, a female teacher indicated that whenever she outperformed her male counterparts when she was a student she did not want it made public. And if her teacher made an announcement to this effect she would feel discouraged and uncomfortable. Her male colleagues supported her and said such announcements undermine the intelligence of girls. It is like saying *'look the lesser sex has outperformed you [the superior sex]'*.

Five of these teachers also mentioned that girls want to be praised for the good work they have done. Usually, boys finish early and teachers praise them for the work well done. Later, when girls finish the work and it is correct, teachers do not usually praise them and thus they feel that their work is not respected. The teaching style is one area that needs to be explored in regard to gender bias in mathematics teaching in Botswana.

Peer pressure

Teenagers, especially girls, enjoy the company of their age mates. At present, good performance in mathematics may mean exhibiting masculine characteristics which may not be accepted in the group/company. Girls' competence in mathematics may be at the expense of femininity. The teachers mentioned that if a girl gets more educated or excels in science-oriented subjects, especially mathematics, the chances are that she will not be married because men do not want a non-submissive wife. Most of the girls fear to be single for their rest of the lives, so may choose to fail. Peer pressure is not unique to Botswana. Studies conducted in the United States show that peer pressure is one of the main influences in girls' attitudes towards mathematics (Leder, 1992).

The learners' attitudes

As mentioned in the studies by Taiwo and Malobe (1994) and Malinga (1993), attitudes on the part of the learner play a major role in the performance of the students. Both girls and boys indicated scientific careers and occupation as belonging to the male domain. Malinga's study further confirms that students' attitudes towards mathematics direct their career choices. This shows that for girls to participate in mathematics their attitudes towards the subject must be positive. Interviewees reported that students view mathematics as a masculine subject which is difficult, and as a result girls tend to shy away from the subject. These findings are similar to those found by Burton (1989) in her study of British junior secondary school children. Girls had a belief that boys become good in mathematics as they go into higher levels of education. On the contrary, girls expect mathematics to become more difficult as they move into secondary school level.

Performance of girls by school location

Further analysis on PLSE and JC results was undertaken to see if the school location has any influence on girls' mathematics performance. Both results (PLSE and JC) reveal statistically significant differences in favour of urban students. Girls in urban areas do better than their rural counterparts in mathematics as shown in tables 6 and 7.

Table 6
Independent *t*-test on marks grouped by setting: JC girls

Group	Number	Mean	SD
Urban schools	31	2.263	0.288
Rural schools	136	2.014	0.256
	Difference	0.249	

$t = 4.772$ $p < 0.001$

Table 7
Independent *t*-test on marks grouped by setting: Standard 7 girls

Group	Number	Mean	SD
Urban schools	34	2.676	1.224
Rural schools	261	1.866	1.064
	Difference	0.810	

$t = 4.104$ $p < 0.001$

Marope (1992), in her study on the determinants of academic achievement in Botswana junior secondary schools, found out that socio-economic background of students affects their performance at school. And in Botswana, most of the poverty-stricken families stay in villages (Duncan, 1989). This may explain why girls in the rural areas are not performing as well as their urban counterparts.

Summary and conclusions

This paper has touched upon how pre-colonial and post-colonial society in Botswana has segregated boys and girls in treatment and education and this has permeated formal education. Senior secondary schools are dominated by boys, giving them more chance to participate in mathematics, science and related subjects which prepare people for high-salaried jobs. Girls are deprived of participating in these subjects and consequently of the job opportunities they open up (Duncan, 1986)

As observed elsewhere in the world, teachers in Botswana expect boys to outperform girls in mathematics and related subjects. Unfortunately, even girls themselves believe that mathematics is a masculine subject and thus scoring low marks in the subject is a normal phenomenon for them. Girls in the urban areas do better than their rural counterparts, thus giving them more chances than rural girls to participate in senior secondary school mathematics, and ultimately better life chances. This reinforces existing disadvantages.

A high secondary school drop-out rate has been reported among girls, and a large proportion of this percentage is attributed to pregnancy (table 5). This wastage contributes to low participation of girls in tertiary institutions.

The aim of this study was to establish whether girls and boys in Botswana secondary schools have equal opportunities to participate in the new scholarship scheme now in place for the Cambridge Overseas School Certificate holders. The scheme gives priority to those whose interest is to pursue mathematics and science-related careers. In particular, the study sought answers to the questions of whether girls and boys perform equally at Standard 7 (PSLE) and Form 2 (JC) public examinations; whether girls in rural and urban areas perform equally in mathematics examinations; and, whether there are possible classroom experiences which affect girls' participation in mathematics.

The results indicate that at secondary school level, girls do not perform as well as their male counterparts. Girls in the urban areas perform better that those in rural areas. These results suggest that more boys than girls will be sponsored for science and science-related areas, and that those few girls who obtain these scholarship are likely to be from urban areas.

As in other parts of the world, classroom interaction has an impact on girls' participation. Boys and girls are expected to behave differently in mathematics classes. Both believe that science and mathematics are masculine subjects and hence scientific careers belong to the male domain. This ties up with the attitudes of both the teachers and learners towards the girl child. This situation needs addressing by teacher training institutions in teacher education activities.

Moreover, some action should be taken to combat girls' negative attitudes towards mathematics and related subjects, aimed at both learners and their socialisers, that is, parents, counsellors and teachers.

Recommendations

As a way forward, the government should embark on research which could help in closing the gender gap in secondary school mathematics. The recommendations below are split into research areas and suggested activities.

Research areas

1 A longitudinal audit of students' mathematics achievement (std 4, std 7, form 3 and form 5) recommends itself. School environment, teacher variables and learners' home background (ethnic, socio-economic) in regard to gender stereotypes should be included.

2 **Teaching styles.** This variable is reported to affect girls' participation in mathematics (Taole, 1995). The genesis of how this happens in Botswana should be investigated.

3 **Sex education.** Informal discussions with a science teacher indicated that 'reproduction', a topic in the Junior Certificate science syllabus, is either not treated adequately or left out completely because of the religious beliefs of some teachers. This must be studied to find out whether it is a general trend. Moreover, most parents are uncomfortable about teachers discussing sex issues with their children. Research in this area should be a priority to inform policy makers.

Sometimes there is a dearth of research information in Botswana concerning issues pertaining to mathematics, science and technology education, because people who have worked on these areas are either expatriates or mathematics/science educators. In this situation their work is not readily available and they may not be able to interact with either teachers or students. As a way of integrating theory into practice, it is suggested that the relevant people be involved in research of this nature. These should include the following sectors:

1 Mathematics/science educators.
2 Government in-service departments.
3 Teacher-training and development departments.
4 Secondary departments.
5 Vocational and technical instructors.
6 Teachers.

Suggested activities

1 **Undifferentiated treatment.** Most of the time, if not all the time, girls are charged with the responsibility of taking care of their siblings whenever parents are busy. Instead of reading, the girl will be collecting water and wood, and also cooking for the rest of the family. There is a need to sensitise parents to the fact that girls also need time to read and prepare for school activities. This sensitisation could be take place through:

(a) Kgotla (traditional meeting place for the ethnic groups) meetings.
(b) Parent Teacher Association (PTA) meetings.
(c) Church meetings.

Usually, the function of PTAs in Botswana is to raise funds for the construction of a shelter for cooking at primary schools or teachers' quarters at CJSS. If their function could be extended to include consideration of gender-typing and its effects on the economic development of the country, some change may be possible over time if not in the short term.

2 **Subject clubs: mathematics, science and technology.** The 'mathematics phobia' of some students is often attributed to the unconducive classroom atmosphere. Research on classroom interaction in Botswana (Prophet and Rowell, 1990), indicated that teachers keep on reminding students that they will fail their examinations and this fear of failure acts as a barrier to understanding mathematics concepts. However, if students are given an opportunity to explore new ideas outside the classroom, as in a subject club, they may find these enjoyable, and develop positive attitudes towards mathematics, science and technology. Low participation in these clubs may be a result of the extra-curricular activities which take place at the time scheduled for clubs. To improve the participation of students in these clubs they should not be scheduled parallel to other activities such as sports and general cleaning of the school. Moreover, activities such as competitions and fairs, formation of hobby groups, educational visits, and publication of magazines and newsletters could be incorporated in club activities to arouse more interest amongst girls.

3 **Role models.** Role models have been found to be an effective way of attracting women to engineering (Michel, 1988). The guidance and counselling unit of curriculum development through teacher counsellors should organise talks in schools where female scientists are invited to come and talk about their work.

4 **Mathematics teachers and the school community.** Teachers are the most important influence on students' learning of mathematics. They are in contact with students on a daily basis, and it is through this contact that teachers may communicate messages of undifferentiated performance for boys and girls through their treatment and expectations (Fennema, 1981). Therefore, discussions on sex-differentiated treatment in departmental and general staff meetings could sensitise teachers to gender stereotypes. Also seminars and in-service programmes should be in place for practising teachers. It is believed that some of the pre-service education courses include aspects of gender in mathematics teaching.

5 **Classroom libraries.** Poor performance in mathematics in the rural areas could be due to lack of facilities such as textbooks and/or resource materials. It could be helpful for the

Ministry of Education to put aside a classroom to store reference materials for both teachers and students in places where libraries are not available.

6 **Popularising mathematics in Women's Cultural Activities.** It has been suggested that girls perform badly in mathematics partly because their spatial abilities are not good (Orton 1992). One doubts if this could be true for Botswana women, who traditionally engage in many geometrical activities, such as wall and floor decorating, weaving and knitting activities and also decorating pottery. These skills are passed on from one generation to the next through observation and oral education. If women and girls could be made aware that these activities are mathematical, more girls would be interested in school mathematics, especially geometrical designs

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Mathematics as a barrier to learning science and technology among girls in Dominica (Eastern Caribbean)

Ezra Blondel

ABSTRACT

This paper reports on a pilot investigation of the hypothesis that mathematics is a barrier to girls considering jobs in science and technology in Dominica. The data suggested that at secondary school the majority of girls considering jobs in science and technology liked mathematics. The link between mathematics and science seemed tenuous however after secondary school, as very few women actually take up the science option (despite the high percentage who said they would and who liked mathematics).

The data raises questions of causality which this paper cannot address, not only because of the its limited nature, but because causality is multifaceted and cannot be narrowed down to the single factor of attitude towards mathematics or revealed through a questionnaire. The paper recommends that the influence of mathematics on science needs to be investigated in the wider context of the factors which influence career choices for boys and girls in Dominica.

Introduction

This report begins with a brief background to the location of the study – Dominica – followed by a short description of the data collection process. The main body of the report is taken up with analysis of the data. The data is discussed in the hope of establishing two links:

1 Between girls' choice of science and their mathematics.

2 Between girls' choice of science and their subject choices in the third year at secondary school.

A discussion of the shortcomings of this study precedes a presentation of an alternative hypothesis to the one suggested by the paper title. My hypothesis draws from the findings of this study and integrates questions raised by it but which, as yet, remain unanswered. The report ends with suggestions for future research.

Dominica – a brief background

Dominica is an island-state in the Eastern Caribbean situated between the two French dependencies of Martinique to the south and Guadeloupe to the north. The country is 305 square miles in area and has a population of approximately 72,000 people. The economy is mono-crop depending mainly on bananas shipped to Europe.

The indigenous Amerindian Caribs were almost wiped out and subsequently relegated to a reservation in the northern part of the island following the historic entry of Christopher Columbus into the Caribbean in the late 15th century. Dominica then shared with the rest of the

Caribbean a history of African slavery and colonisation well into the last half of this century: the island became politically independent from Britain in 1978. Our African origins are evident in almost every aspects of our evolving culture, but the experience of slavery and colonisation have made indelible imprints on our psyche and institutions, including the institution of education and more particularly in the area of gender relations.

Presently there are 65 primary and 14 secondary schools on the island. Every girl and boy from the ages of 5 to 16 has a place at primary school. Every child between the age of 10 and 13 is entered for the Common Entrance Examination which determines access to secondary school. If the child is unsuccessful in that examination she or he is offered a place at a junior secondary school (an extension of primary school) until the age of 16.

Four of the secondary schools, all situated in the capital, are single-sex. All four are administered by churches. Science and mathematics are compulsory subjects in all secondary schools up to 5th Form level and all schools offer a science set in the third year. Upon leaving school students can take up A-level courses or a technical option at the state-owned Clifton Dupigny Community College. Entry is selective and dependent on O-level Caribbean Examination Council (CXC) examination results.

The data from this study is drawn from the girls and their teachers from the technical wing of the Clifton Dupigny Community College, two all-girls' and one coeducational school, and three secondary school teachers. All the schools are located in the capital, Roseau.

Data collection

A total of 25 girls and five teachers gave written responses to the questions. Of the eight girls from Dominica Grammar School, four were in the science set and four not; of the ten pupils from St Martin's School who responded, half were in the science set. In Wesley High School seven girls responded, of whom four were in the science set and three not. This breakdown is summarised in the table 1 below.

Table 1
Responses by school and 'set'

School	Girls taking science option	Girls not taking science option	Totals
Dominica Grammar School	4	4	8
St Martin's School	5	5	10
Wesley High School	4	3	7
Totals	13	12	25

Of the teachers who responded, three were from the secondary schools and two from the Clifton Dupigny Community College.

The questions

The purpose of the data and the information required was explained on every question sheet. The questions addressed to the girls at secondary school focused on their career choices, their subject choices at third form, their consideration of a job in the field of science and technology and their attitude towards mathematics. For all the attitudinal questions the girls were asked to give reasons for their answers.

The focus of the questions for the girls at Clifton Dupigny Community College was on their feelings and successes in mathematics at primary and secondary school, the relevance of mathematics to their present course, the ratio of boys to girls on their course and their views about the topic of this paper.

In common with the Community College students, the teachers were asked about their views on the paper title. In addition they were asked for examples of critical incidents and memorable conversations with girls in the area of career choices, girls' perception of and 'ability' in mathematics and how that affected their desire to consider careers in science and technology.

Gender and science at secondary school

In this part of the paper I shall report on and discuss the responses school by school. For every school I am trying to establish a link between girls' attitudes towards mathematics and their consideration of a career in science and technology. I have distinguished between girls who are part of the 'science set' and those who are not as I believe that girls' consideration of careers in science and technology may he linked to their subject choices at third form level in secondary school.

The Dominica Grammar School

This is a state-owned school. It was single sex boys until 1973 when it became coeducational. Of the eight girls from the school who responded, four were in the science set and four in the arts set. Of the four girls taking the **science option** only two were considering careers in science and technology. One wanted to become a doctor and the other a marine biologist. Neither of the other two girls liked mathematics, one because she thought it was too demanding and the other because she thought it was too hard and complicated. Of the two not considering a science career, one wanted to be a fashion designer and the other an accountant. The prospective accountant was able to consider a career in science but chose accounting instead. There was no indication that her choice was related to mathematics, although she did not like mathematics. She wrote:

> *'maths demand a great lot and I can't really cope efficiently with the subject. Sometimes it can be enjoyable.'*

She wanted to be an accountant because:

> *'I like accounts and business-related subjects as well as numbers.'*

If mathematics was not a deterrent to taking up accounting why should it he a deterrent to science? It seemed here that her choice of accounting over science might have been related to her positive liking for the arts and not her negativity towards mathematics.

The would-be fashion designer was emphatic that she would not consider a career in science and did not like maths because she thought it was too hard and complicated. Were her dislike for mathematics and aversion to science related in this case? She gave no further explanation, neither did she explicitly relate mathematics and science. For both 'fashion designer' and 'accountant' their rejection of mathematics was based on their perception of the nature of school mathematics and not on how it related to science.

Of the four girls in the Grammar School science set, the two considering science careers liked mathematics and the two not considering science careers did not like mathematics. The coincidence cannot be denied but there is not enough evidence from their responses to conclude that their choices were dependent on their attitude to mathematics. They did not like mathematics because of their perception of the difficult nature of the subject and they did not want to pursue careers in science, not because of science or its relationship to mathematics but because they wanted to do something else.

Two of the four girls in the **non-science** set (a prospective French teacher and criminal lawyer) would have considered a career in science. One of the two liked mathematics. Not being in the science set was not a deterrent to either of them and not liking mathematics was not a double-deterrent for the would-be French teacher. She did not like mathematics, because, she wrote:

> *'... it is very challenging and tricky. I don't like such funny subjects.'*

Would she consider science 'funny' and was there an unwritten link in her mind between 'funny' subjects like mathematics and possibly science? If this was the case why then would she consider a career in a 'funny' subject?

Interestingly, although both girls (would-be French teacher and would-be criminal lawyer) would have considered careers in science, a career in science was not given as their first choice. One may speculate that not being in the science set is the underlying cause for them not pursuing their science dreams, but that is purely speculative as their responses did not indicate that.

The other two girls in the non-science set, a would-be journalist and a would-be economist, did not like mathematics and would not consider a career in science. The would-be journalist only studied science at school because she had to. She did not like mathematics because she could not do it. Her reasons related to her perception of her ability and not the nature of mathematics. The economist was not interested in science and did not like mathematics because she could not grasp the subject. Their attitudes towards mathematics and science seemed to be determined by a combination of their perception of the nature of science and their perceived abilities in mathematics. It is again coincidental that they both did not like mathematics and would not have considered entering science, even as a second option. Unless an empirical link can be established between perception of science and perceived ability in mathematics I am loathe to suggest, in these two cases, that attitude towards mathematics determined taking up careers in science.

Taken collectively, three of the girls did not like mathematics and would not have considered careers in science and technology. Conversely two of the girls who would have considered jobs in science did not like mathematics. Very coincidentally all the girls who liked mathematics would have considered jobs in science, but science was chosen by two of them, both in the science set, the other being in the art set. There were no girls from Grammar School who liked mathematics and would not have considered a career in science and technology.

St Martin's School

St Martin's School is an all girl's Catholic school. For many years it was a primary school but offered secretarial and home economics options to girls post-16. It became a secondary school in the mid 80s. Of the ten girls who responded half were in the science set.

Of the five girls responding in the **science set**, the only two girls wanting to pursue careers in science both liked mathematics. Would they have wanted to pursue a career in science if they did not like mathematics? (In the Grammar School sample there was one girl in the science set who would have pursued a career in science but did not like mathematics. However a career in science was not her first choice.) The one other girl who liked mathematics in that science set wanted to be a hairdresser because, she wrote:

> *'I always enjoy combing hair.'*

Her career choice seemed to be based on enjoyment of the field. It is not surprising that science was not her first or second choice as she wrote

> *'I never really enjoy doing science as a compulsory subject.'*

She offered no further explanation.

The two girls in this science set who did not like mathematics would not have considered a career in science. There does seem to be a link here between mathematics and science. But is this link causal? Let us look more closely at the reasons those who chose science gave for doing so:

> *'since I was small I have always dreamed of being a doctor to make a difference in my family because only teachers there are in my family.'* (Would-be gynaecologist)

Her choice had a long history and I would suggest mathematics or anything else would not be allowed to get in the way. In fact I would go further and speculate that if mathematics had been seen as a possible impediment, steps would have been taken at an early stage to overcome that. The other chose science because, she said,

> *'I love science and its challenges.'* (Would-be doctor)

Would that love of science have been in place if she did not like mathematics? It is impossible to tell from the data gathered.

Let us consider other reasons given for not considering a career in science. The would-be nurse gave this as her reason:

> *'I figure that there may be too many experiments, or duties to take care of, especially in the environment.'*

She did not like mathematics on account of its problem-solving nature. Can we infer a subtle link between the experimental nature of science and the problem-solving aspects of mathematics? Whatever the nature of the link the fact remains that she did not like mathematics and would not choose a career in science. (1 am puzzled about the fact that she did not see nursing as scientific.)

The one other girl at St Martin's School in the science set gave this as her reason for not considering a job in science:

> *'I am not cut out for that type of job.'* (Would-be lawyer/hotel manager).

She said of mathematics:

> *'I just cannot take it in.'*

The reasons given by these two girls seemed to be to do with the nature of the subject (mathematics) and their personal ability to cope with it.

Of that science set at St Martin's School the only two considering careers in science liked mathematics and indicated a science career as their first choice. And, the only two not liking mathematics would not have considered a career in science and technology. One of these two based her decision very strongly on the nature of science, and the other on her inability. It does seem more than coincidental that those who liked science liked maths and those who did not like mathematics did not consider science. Their choice of careers in science seemed directly related to their attitude to mathematics. Their reasons for not choosing science, coupled with the fact that the hairdresser's rejection of science was not linked to attitude towards mathematics however, make a causal link very dubious.

The five girls in the **non-science set** liked mathematics and would have chosen a career in science. Only one, however, actually chose science (would-be nurse) as her first choice. Another one had medicine as her second choice. Would the girls in this set have considered careers in science if they did not like mathematics? Would the girls in this group (bar the nurse) have chosen a career in science, as their first choice, if they were in the science set? A third question for the prospective teacher/doctor is: what were her reasons for placing 'teacher' as her first choice, before medicine? Did the would-be nurse consider that career to be science and or mathematics based? Because mathematics is not a problem for this group they must have other reasons for choosing careers outside of science.

Taken collectively, the data from St Martin's School does not show a direct link between girls, mathematics and their career choices. The data from the science set suggests a link which is called into question by the data from the girls in the non-science set.

Wesley High School

Wesley High School has been a Methodist school for girls from its inception. Seven girls responded to the questions. Four of the respondents were in the **science set**. Three girls among the four would have considered a career in science, but only two actually gave science as their first career choice. Of the two who gave science as their first career choice one liked mathematics and the other did not. For the one who did not like mathematics it was not allowed to be a deterrent.

Why would one girl in this science set, who liked mathematics, not consider a career in science (she wanted to be an accountant instead)? She was very clear about not wanting to pursue science but her explanation did not suggest that mathematics was the deterrent . She gave as her reason for not doing science:

> *'my heart is too soft for doctoring. I feel that the death of a person is all my fault.'*

For the would-be chemist/engineer, not liking mathematics was not a deterrent. The one possibility where mathematics may have been a deterrent was in the case of the would-be sociologist or psychologist. She did not like mathematics and although she stated she would choose a career in science and technology that was not reflected in her first or second career choices. Her reasons for her choices may be instructive. She wanted to be a sociologist or psychologist to:

> *'work with people to understand problems.'*

She did not like mathematics because

> *'it is a bit too difficult.'*

Presumably she did not see science as difficult and would have considered a career in science a means to an end in social science:

> *'...because if I can understand how people think and act and work physically, it could help me to understand how they work socially.'*

In this science set, in only one case is there a direct link between maths and a career in science. One person liked mathematics and would have considered a career in science, giving medicine as their first career choice. For the would-be chemist/engineer not liking mathematics seemed not to be a deterrent. There was no girl who disliked mathematics and stated a preference for a science career.

Three girls from the **non-science set** at Wesley High School responded to the questions. With this group there was a direct link between attitude towards maths and consideration of a career in science.

The one girl who liked mathematics would have considered a science career as her first choice. Would she have chosen a career in science if she did not like mathematics? The two who would not have chosen a career in science also disliked mathematics. Were their reasons located in their attitude towards mathematics? This was the reason given by one of them for not choosing a career in science:

> *'... I am not doing sciences including bio, chem, physics at present. I do not enjoy the field of medicine. I can't cope with mathematics much less for the awful and difficult subjects. I will get crazy.'*

This is the only one, of all 25 girls, who made an explicit link between the nature of mathematics and science. Her suggestion, I believe, was that mathematics was difficult and that science was considerably more difficult. It was not mathematics which was the deterrent, mathematics was only a gauge to measure the difficulty of science.

The other girl's stated reason for not choosing a career in science and technology was because she preferred business. She did not like mathematics because:

> *'it is too many different topics.'*

Taken collectively the data from Wesley High School makes verification of the hypotheses impossible. Although for the non-science set there seemed to be a direct link, this link was put into question by the inconclusive nature of the data from the girls in the science set. For the would-be chemist/engineer not liking mathematics was not a deterrent. Only possibly in the case of the would-be sociologist or psychologist was mathematics a deterrent because she did not like mathematics and, although she stated she would choose a career in science and technology, she did not give one as her first or second choice.

Is mathematics a barrier?

Having done a school by school analysis I shall now look at the schools collectively. There may be trends that are magnified (or challenged) with additional data, or some that are only apparent with a larger sample. For this discussion I shall incorporate data from the teachers' responses.

The data collected established that girls do consider careers in science and technology. Sixteen of the 25 girls responding did. If this small sample was representative of the female population, and those girls' wishes were realised, more than half of the female population (6490) would take up jobs in the fields of science and technology.

It seemed, that for particular schools and groups within these schools, there was a direct link between attitude towards mathematics and girls' choice of career in science and technology; in some cases this was an inverse link; in others cases there was no apparent link. Taken the data collectively, a slightly different statistical picture emerges, a picture that suggests a more direct link between mathematics and career in science, than the data for individual schools could show (table 2). Of the 16 girls who would have considered a career in science and technology, 12 liked mathematics. The remaining four, however, did not let their attitude towards the subject deter them.

Table 2
Consideration of career in science and technology and attitude towards mathematics

	I like mathematics	I do not like mathematics
I would consider a career in science and technology	12 girls	4 girls
I would not consider a career in science and technology	2 girls	7 girls

Only nine girls would not have chosen a career in science and technology. Of that small figure, a rather large proportion (seven out of nine) did not like mathematics. The five girls who did not like mathematics did not allow that to deter them from considering careers in science and technology. Only two girls (both in the science set, in different schools) were not considering a science career but liked mathematics. For these two girls and the five who did not like mathematics their reasons for choosing or not choosing science jobs seemed to be their mathematics. That left seven girls who did not like mathematics and were not choosing careers in science. What were their reasons? Could it be mathematics?

It would seem that, on the whole, those who did not like mathematics did not choose careers in science and technology. It cannot however be dismissed that many more girls considered a career in science than liked mathematics. These statistics, although taken from a small sample, and therefore tentative, are not insignificant. Significant though it is, the link between mathematics and girls' career choices in science and technology is a statistical, and not a causal one. Although I believe the existence of such a link to be more than coincidental this study does not explain it.

There was a perception among the teachers that girls who made it to technical college, unlike other girls, did not have difficulties with mathematics:

> *'The business students have more problems with mathematics than the science students.'*
>
> *'... The girls doing science subjects are good at maths.'*
>
> (Teacher 1 – Community College)

The above views were supported by a colleague who wrote:

> *'Science students are good maths students. It is usually those who opt for social science subjects who are weaker in maths. It may appear that they choose business because they are weak in maths but I don't think that is always the case.'*
>
> *'Generally students find A-level maths a challenge. However the female students who choose to pursue careers in science are usually those who have an appreciation of maths. In fact now female students are outdoing male students at maths. I don't see maths as a barrier for girls who are interested in science.'*
>
> (Teacher 2 – Community College)

The link with mathematics is questioned in the first part of the above quote but this is seen as independent of the point, made in the latter part of the quote, that on the whole those girls who chose science were able at mathematics.

Teacher 2 from the Community College, and the two secondary school teachers quoted below, were very clear that mathematics was not a barrier to girls considering careers in science:

> *'Not sure that maths is a barrier ... among girls in Dominica because of their choice of subjects at that particular school they are always choosing courses that have or require mathematics and are doing significantly well in CXC with them. However there is a problem in learning mathematics as a specific course, mainly because of the attitude towards the subject and the unwillingness to apply the knowledge of the concepts.'* (Secondary school teacher 1)
>
> *'I have noticed that most students who have a negative attitude towards maths fail the subject. Quite a number of students like science even if they are not performing well at mathematics.'* (Secondary school teacher 2)

The latter part of the quote was well borne-out by the data collected from the girls at school. However the difficulty with learning mathematics alluded to in the first of the two above quotes warrants further investigation.

There seems to be a group of girls who were hampered by the fact that mathematics was used as a prerequisite to entering certain fields:

> *'On many occasions students have indicated to me their interests in various fields where science is a prerequisite. They have also said to me that they do not like maths and so would prefer to choose careers where maths is not really a necessary prerequisite.' (Secondary Teacher 2)*

It cannot be denied that mathematics is a career sieve but that function did not always seem to deter. One important question is whether the choice of mathematics as a sieve is an arbitrary choice or whether attitude to mathematics, competence and ability to manipulate the subjects is necessary to be able to do science. The latter seemed to be the case, as all the girls at The Community College reported that mathematics was integral to all their courses.

What are the other factors within schooling which may be linked to girls' career choices in science and technology? One such factor may be subject options in the 3rd year. This is the focus of the next discussion.

Subject choices

One would expect a higher proportion of girls in the science set to opt for science-based careers in comparison to those taking the art option. This seems not to be strictly the case (table 3). Of the 13 girls in the science set only five would have considered a career in science and technology. Approximately half of the girls in the non-science set were considering careers in science and technology.

Table 3
Subject options at third form and consideration of career choice in science

	I would choose a career in science and technology	I would not choose a career in science and technology
I am in the science set	8	5
I am not in the science set	7	5

A significant part of the explanation may be related to the weighting of St Martin's School. There, all the girls in the non-science set considered careers in science and technology. They all liked mathematics. Three of the girls in the science set did not want to pursue careers in science and one of them did not like mathematics. Their reasons seemed to lie between a positive choice for another subject in the arts (literature, law, business) and a positive dislike for science, either because of the nature of the subject or their perceived inability to function successfully in relation to it. They did not indicate a relationship between mathematics and their choice bar one girl who saw the difficulty of mathematics magnified in science. It is significant, I believe that seven out of nine who would not choose science also did not choose mathematics. However, to deduce from this small investigation that one is the cause of the other would be misleading.

I believe it also to be significant that there were two girls who would not consider careers in science but liked mathematics. These were their reasons for not taking the science option:

> *'No. Because I never really enjoy doing science as a compulsory subject.'* (St Martin's science set)

> *'Never. Because my heart is too soft for doctoring. I feel that the death of a person is all my fault.'* (Wesley High School science set)

I believe the second girl was ill-informed about the possibilities in science other than medicine. Considering that these two girls were in the science set at their respective schools and that they liked mathematics, there must be other reasons outside of mathematics to explain why they were not considering careers in science. Further qualitative data is needed to explain such findings.

Taking St Martin's School out of the picture and looking at the Grammar School and Wesley High School collectively, the figures would be as in table 4.

Table 4
Setting and consideration of career in science and technology (bar St Martin's School)

	I would choose a career in science and technology	I would not choose a career in science and technology
I am in the science set	6 (8–2)	2 (5–3)
I am not in the science set	2 (7–5)	5 (5–0)

The majority of girls in this science set (6 out of 8) would have considered a career in science and technology and the majority of girls (5 out of 7) in the non-science set would not consider a career in science and technology. So it seemed that there was a statistical link between subject choice in the 3rd year and girls' choice of careers in science (taking St Martin's School out, where all the girls in the non-science set liked mathematics and would have considered careers in science and technology). Again, although a small trend seems to emerge from the two schools, a causal link cannot be established from such limited data.

Of the 13 girls in the science set, seven of them did not like mathematics. Of the 12 not in the science set, half liked mathematics. Of the 13 girls in the science, set eight of them would consider careers in science and technology. Of the 12 not taking, science, seven would consider entering the field of science and technology. What were the reasons for girls in the science set not considering a career in science and technology?

The question which underpins this whole discussion is: what determines girls' career choices in science? A look at the data from a sample of girls who have opted for careers in science and technology provides further indications which complicate our earlier findings and confirm that deterrents to women entering science and technology cannot be located entirely within mathematics.

Women in science and technology

Despite the earlier statistics that more than half of the girls would have considered a career in science and technology, this seems not to be reflected in their numbers in the technical wing of the Community College (table 5).

Table 5
Male/female ratio on courses (as reported by students at Clifton Dupigny Community College)

Course	Female	Male
Auto mechanics	1	14
Electrical installation theory	3	21
Building and civil engineering	3	16
Agriculture	8	24
Electronics	5	14
Electronics	5	12
Electrical servicing technology	5	12

Women make up more than half of the population yet the highest proportion of female students on any one course was 8 out of 32 (25%) – on the building and civil engineering course. The proportion of women went as low as one women out of a class of 15 (less than 10%).

Is there a link with their mathematics? A look at the evidence supplied by the female students themselves showed that of the 18 students who responded five rated their mathematics as 'not good at all', two as 'below average' and six as 'good'. None of them rated their mathematics as excellent even if that option was offered. Unless the girls underestimate their mathematics, mathematics for the 'below average' and 'not good at all' has not been a deterrent . Can it be a deterrent for some girls while at the same time not deter others? If the answer is 'yes' the explanation cannot be intrinsic to mathematics but coincidental with mathematics.

Of the 18 girls at college, only four disliked mathematics at primary school. All the others liked mathematics and some found it easy. Does this indicate that on the whole girls who take science like mathematics? This seemed to be the case. What is not the case is that all those who did not like mathematics let that deter them from doing science at college.

Some shortcomings of this paper

This paper has not investigated the proportion of the female (or male) population in science and technology jobs. It has not given a breakdown of the attainment in mathematics and science by gender at any level of schooling as that data was not available at the time of writing.

The population of girls at secondary school is much more than the randomly chosen 25 and so the results may be unrepresentative. Although data from the girls' self-reports could be checked against that of the teachers, the self-reports are not otherwise triangulated. There is an assumption that one girl's *'I like mathematics'* is qualitatively the same as other girls' within one school and across schools. This may not be the case.

Another major shortcoming is the unproblematic way in which mathematics and science have been presented in this paper and, also, that the nature of mathematics and science schooling has not been questioned. Failure to address these two issues ignores factors which greatly influence pupils' attitudes towards both subjects and subsequent career choices.

A notable absence, and one of significance to academics, is a review of literature in this area. There are many reasons for this. One is pressure of time and access. Pressure of time limited the access I could have to literature from the Caribbean. My efforts in that area drew many blanks, suggesting that if any material existed, it was not very accessible. There is an abundance of literature in the area of mathematics and science in Britain and America, but I am not convinced of its applicability to the Caribbean context. Although there are commonalties between the peoples of African descent in Dominica and the United States, there are significant differences which do not receive attention in the literature. It could be argued that Dominica has been so influenced by Britain, that the literature may be revealing in ways that I have ignored by not delving into it. My response to that assertion is that, although the histories of the Caribbean and Britain intersect, the peculiarity of our independent history makes gender relations in our part of the world specifically different.

It could be argued quite correctly that the theories implicit in my analysis can be traced to some of the theorising in British literature about gender and science. That however is only part of the story. One equally significant point is that existing literature does not link my theorising to the peculiarity of the Caribbean culture of which I am a product. I was not sufficiently convinced to the contrary to share the limited time I had available between data analysis and a literature review, when I believed the latter would only provide information which was tangentially illuminating.

Conclusion

Notwithstanding the above shortcomings, the messages from the data are not trivial. The girls could all have hated mathematics but that was not the case. They might all have wanted to shy away from science but that was not the case either. Those 'not good' at mathematics could have opted out of science options but that was not entirely the case. All those who liked mathematics could have considered a science career as an option yet only some did. The sample may be unrepresentative but the message is not meaningless.

All is not well with gender and science in Dominica. Women make up a little over half of the population but a higher percentage of men take up science places at the Community College. This cannot be explained by success in the school system as it is a common perception (grounded in evidence not provided in this paper) that girls 'outperform' boys at primary and secondary school and at sixth-form college.

This paper established a statistical link (in some cases a direct one and in a smaller number of cases an inverse one) between mathematics and girls' consideration of career in science and technology but not that one is the cause of the other. For the girls not in the science set and not liking mathematics one could speculate that mathematics was responsible. For those in the non-science set not choosing a career in science we may speculate that setting was responsible. For those in the science set, who liked mathematics but did not consider careers in science, what can we blame? The establishment of causality or the qualitative nature of the link requires a different type of investigation.

Recommendations

Except for the work carried out with women in agriculture, there is little research carried out in the Caribbean with regard to women in science and technology. The research carried out in agriculture suggests that, although women numerically dominate agriculture in the Caribbean, they have little access to technology within the field and they are not well represented in the agricultural hierarchies within their territories.

There is much need statistically to locate women in science and technology in Dominica and the Caribbean, and to monitor changes over time in this regard. More importantly though there is desperate need for research to uncover the factors which influence career choices for boys and girls and how these factors operate within the school system.

There is a perception among many men and women in the Caribbean that there are no institutional barriers for women in the areas of education and work. While many women and men in the Caribbean feel, know and have experienced, through our particular history as descendants of African slaves, that what men can do women can do, the evidence suggesting that all is well with regards to gender equality is very scarce. The follow-up to this pilot study could begin to address this.

All is not well with mathematics and schooling in Dominica either. Although there is insufficient evidence from this study, to identify mathematics as a deterrent for girls choosing science and technology options, the teaching of mathematics requires further investigation. There is some concern that the way mathematics is presented at school, as cold and impersonal and inapplicable, makes it somewhat off-putting, to girls. That is, there is concern about the nature of the subject and its teaching. Some girls perceived it to be hard and inaccessible; others saw the problem as their own inability and of these some transferred it to mathematics as they saw similarities between maths and science. It was interesting to me that only two girls saw mathematics as welcoming and challenging. Most saw it, quite legitimately, as a sieve and a means to an end and not valuable in itself.

So, parallel. to this investigation and independent of it must be an investigation into the nature of mathematics, the extent to which there is a differential in perception along gender lines, and how these influence schooling. An extension of such an investigation would be to consider how these perceptions are constructed and might be affected.

I would like to argue that mathematics and taking up science are not unrelated but the relationship is very indirect. Career choices are influenced by a multiplicity of factors, not least mathematics, but are more closely embedded in historical attitudes towards what girls should and should not do within schooling. Dominica has moved on from the days when there were two secondary boys school with labs and one secondary girls school with no lab and no science, through a stage when there were two secondary boys schools with labs and two secondary girls schools with no labs (and girls travelling to the boys' schools for science), to the present situation of all secondary schools having laboratories.

I postulate that it is our historic determination to survive and succeed that makes many of us overcome 'artificial' prerequisites like mathematics. What cannot be denied, along with this historic determination, is the influence of the church and of European notions of femininity which ascribed different status to what men and women do, suggesting first that women should stay at home and so required little formal schooling and then, when women were allowed schooling, that they should confine themselves to certain careers. Many Caribbean women have challenged those notions but the institutional factors have left their mark in our socialisation patterns.

I believe that the relationship between mathematics and science needs to be further investigated to dispel the myth of a causal link for women in Dominica. I would advise, however, that money would be better spent, within the constraints of the Dominican economy in particular (and the Caribbean generally), in seeking reasons in socialisation patterns: socialisation patterns in the home and wider community and as enacted in interpersonal relationships between pupils and pupils, and teachers and pupils in the classroom. For example, all the girls questioned had already made a career choice. At what age did they become conscious of becoming career people and what propelled that consciousness? What part did school play in informing that choice, both in terms of institutional organisation and interpersonal relationships in the classroom between pupils and between pupils and teacher? Particularly consideration must be given to the use of in-service training with teachers to make them aware of the many factors which influence gender relations in schools and sensitive them to their own role in the process. These are some of the places where I believe messages about career choices are constructed and communicated. It is in this context or overall framework that mathematics must be investigated.

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Participation of boys and girls in mathematics and science at secondary school level in India

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Introduction

The under-representation of women in science, technology and mathematics related occupations has been a matter of concern to educationists and policy makers for the last two decades. This under-representation, it is argued, prevents women achieving their full human potential, deprives them of the means to enter a wide range of occupations and confines them to ill-paid and the least secure jobs and sectors of the economy.

Earlier research studies on the subject from western countries often highlighted the socio-cultural and physiological factors responsible for this situation. Later studies from these countries attribute this under-representation to poor mathematics education of girls which keeps them out of programmes leading to vital scientific and professional careers. A warning bell is sounded that *'we are at the risk of becoming a divided nation in which knowledge of mathematics supports a productive technologically powerful elite while a dependent semi-literate or illiterate majority find economic and political power beyond reach'.*

Researchers into gender and mathematics have attempted to identify numerous cognitive, social, educational and cultural factors that may be affecting participation of women in mathematics (Fox, 1977; Fennema, 1977). These studies also point out that boys and girls do not appear to differ with respect to reported liking for mathematics as a school subject in the elementary school (Ernest, 1975). Yet very few girls opt for mathematics in high school when it becomes optional (Haven, 1970; Ernest, 1975) The inequities are attributed to gender socialisation. Researchers also suggest that a traditional view of mathematics as a male domain has contributed to the decline in performance, attitude and ultimate participation of females in high school mathematics classes. (Ernest, 1976; Fennema, 1981; Fennema, 1984; Sells, 1980).

Anxiety over mathematics has been cited as a deterrent to achievement in maths and to career options.(Tobias, 1978). It is also indicated in these studies that women experience mathematics anxiety more frequently than men. Consequently *'girls learn to approach mathematics and science with greater uncertainty and ambivalence than boys, with inadequate practice and unfamiliarity in practical skill areas (like spatial skills) and more generally with conflicts about competence and independence'* (Skolnick *et. al.*, 1932).

The present study and its objectives

Research studies on gender and mathematics in India are still at the infant stage and existing literature is fragmentary in character. In the Indian context the problems of under-development, coupled with a low literacy rate and certain other socio-cultural factors, are major barriers to the participation of women in science and technology. Yet to what extent mathematics contributes to this situation is not known. This research has been undertaken as an exploratory study to gain an insight into the problem of under-representation of girls in science and mathematics in the Indian context.

The major objectives of the study are to find answers to the following questions:

- What infrastructural facilities are available for girls to study science in schools?
- What is the participation rate of boys and girls in science?
- Do boys and girls differ markedly in their performance in mathematics as suggested by western researchers?
- Do girls perform better in single sex schools or co-educational schools?

Methodology

This study has been confined to Delhi and all secondary schools in Delhi have been included. Data for this research have been collected from the examination records of the Central Board of Secondary Education (CBSE). The background information regarding pattern of schooling, curricula etc., can be found in brief in Appendix 1.

Data were obtained for the classes X and XII in all 877 schools for the years 1993, 1994 and 1995. Being an exploratory study, no sophisticated statistical techniques were employed in the analysis of data.

Role of mathematics in the curriculum

The curriculum planners and educationists view mathematics as an indispensable tool and have made it a compulsory school subject up to class-X. Theoretically, mathematics can be chosen by any pupil from any stream after class X, but in practice it is chosen mainly by pupils in science streams. The demand for maths comes next from the commerce streams. Since many prestigious colleges prefer pupils with mathematical backgrounds for commerce/business studies at undergraduate level, pupils study it mostly because of compulsion by parents who want their children's career options to be broad-based. Very few students from humanities/vocational streams choose mathematics.

In 1995, the CBSE made maths compulsory for pupils in science streams, perpetuating the belief that it is needed only for (physical) scientists. It is interesting to note that the CBSE entrance examination for the MBBS (Medicine) Course does not include mathematics.

Analysis of data

Delhi has a total of 877 schools. The percentage of all-boys, all-girls and co-educational schools are more or less the same, with slightly more boys' schools (table 1). Thus facilities available in terms of number of schools compare well for boys and girls.

Table 1
Number and nature of secondary schools in Delhi (1993)

Total	Boys	Girls	Co-educational
877	312 (35.6%)	279 (31.8%)	286 (32.6%)

Schools in Delhi fall under four types of management. The Kendriya Vidyalayas or Central Schools are managed by Kendriya Vidyalaya Sangatan (KVS) or Central School Organisations; these schools are intended solely for children of Central Government employees and draw children from educated, salaried middle-class families.

The Delhi Government is responsible for the education of children in the national capital territory. Education in these schools is free or a nominal fee is charged for higher classes. These schools cater for the underprivileged section of the society. Children in these schools are either first-generation learners or from semi-literate families.

Government-Aided Schools are mostly run by linguistic minorities, various trusts etc. Pupils in these schools have a tradition of education, they are culturally homogeneous and their performance in public examinations is good.

Independent Schools are private schools where pupils pay for their education. Better physical facilities characterise these schools and pupils also supplement their school education with private tuition.

Table 2 shows the percentage of schools under the various types of management. It can be seen from the table that more than half of Delhi schools are State (Government) schools. Independent schools, which constitute 22 per cent of the total, are mainly co-educational schools, whereas state schools do not encourage coeducation.

Table 2
Percentage of schools under various types of management

	Total	Boys	Girls	Co-educational
Government	511 (58.3%)	251 (49.1%)	217 (42.5%	43 (8.4%)
Government-aided	147 (16.8%)	55 (37.4%)	51 (34.7%)	41 (27.9%)
Independent	194 (22.1%)	6 (3.1%)	11 (5.7%)	177 (91.2%)
KVS	25 (2.8%)			25 (100%)
TOTAL	877	312	279	286

The curriculum

A cursory analysis of the curriculum offered by boys' and girls' schools (table 3) show that only 79 girls' schools (out of 279) compared with 163 boys' schools (out of 312) offer science. While 70 per cent of boys' schools offer a choice of three streams, only 30 per cent of girls' schools provide this choice. Four-stream schools have less science sessions. Of the 79 girls' schools offering science, 46 are run by the Government, 22 are government-aided and the remaining 11 are under private management.

Table 3
Number of secondary schools offering science streams with other subject streams in Delhi

Type of school	Boys	Girls	Co-educational	Total
Subject streams				
Science only		1	11	12
Science/commerce	12	3	57 (24.1%)	72
Science/humanities	8	13	12	33
Science/vocational	–	–	–	–
Science/Commerce/ humanities	113 (69.3%)	24 (30.4%)	145 (61.2%)	282
Science/commerce/ vocational	2	–	2	4
Science/humanities/ vocational	2	6	3	11
Science/commerce/ humanities/vocational	26 (16.0%)	32 (40.5%)	7	65
TOTAL	163	79	237	479

The curriculum offerings of the remaining 200 girls' schools are presented in table 4. There are 63 (31.5%) schools which offer only humanities and 61 (30.5%) which offer commerce and humanities. Hence it may be said that facilities available for girls to study science are not very attractive.

Table 4
Girls' schools offering humanities. Commerce and vocational streams

Type of school	Government	Government-aided	Independent	Total
Subject streams				
Commerce	4	–	–	4
Humanities	59	4	–	63
Vocational	1	2	–	3
Commerce/humanities	43	18	–	61
Commerce/vocational	2	–	–	2
Humanities/vocational	19	2	–	21
Commerce/humanities/ vocational	43	3	–	46
TOTAL	171	29	–	200

Participation in science

Let us now have a look at the number of pupils who enter a science stream after class X (table 5).

Table 5
Participation in science

	A. Number of pupils who passed in class X in 1993					B. Number of pupils who opted for science in class XI in 1993–94				
Type of school	Number passed			Percentage		Number enrolled in science			Percentage	
	Total	Boys	Girls	Boys	Girls	Total	Boys	Girls	Boys	Girls
KVS	3837	2170	1667	56.6	43.4	1520 (39.61) *	925	595	42.6**	35.7
Government	55565	29264	26301	52.7	47.3	2361 (4.25)	1495	866	5.1	3.3
Government-aided	13145	7269	5876	55.3	44.7	1588 (12.08)	989	599	13.6	10.2
Independent	25601	14748	10853	57.6	42.2	3655 (14.28)	2359	1296	16.0	11.9
TOTAL	98148	53451	44697	54.5	45.5	9124 (9.3)	5768	3356	10.8	7.5

Figures in brackets indicate percentage.
* percentage of total pupils
** percentage with respect to total number of boys

While 40% of pupils (table 5) from KVS schools opt for science, only 4.2% pupils from Government schools do so. There is not much difference in the percentage of pupils who enter science in the Independent and Government-aided categories. Gender differences are seen in all categories but the differences are not very pronounced.

If the participation rate (of both sexes) in science is only 9.3%, is mathematics a deterring factor? Comparisons of failure rates in mathematics and science for boys and girls have been made in an attempt to answer this question (table 6).

The percentage failure in mathematics is more than in science and it is the same for all the three years. Girls mostly perform better than boys in mathematics as well as science. Slight variation is seen in 1994 in the KVS school category; the percentage of girls failing in maths is slightly higher than boys.

Once again, it is the Government schools that account for more failures in both subjects. In the case of mathematics slight improvement is seen in performance of boys over the three years.

Table 6
Failure rates in mathematics and science for class X in different types of schools (percentages)

Type of school	Year / Subject	1993 Maths	1993 Science	1994 Maths	1994 Science	1995 Maths	1995 Science
KVS	Total fail	14.3	2.8	22.6	3.1	4.9	4.2
	Boys	14.0	3.1	21.7	3.5	5.3	4.4
	Girls	14.8	2.4	23.8	2.7	4.5	3.9
Gov.	Total fail	54.5	32.5	53.2	26.5	39.4	33.1
	Boys	57.4	36.4	53.8	30.7	45.8	39.3
	Girls	51.0	27.7	52.4	21.6	32.1	26.1
Gov.-aided	Total fail	34.3	14.5	37.8	12.1	21.0	12.7
	Boys	38.1	17.8	40.4	15.8	27.2	14.1
	Girls	29.8	10.1	34.6	7.4	13.6	10.1
Indep.	Total fail	7.4	1.5	10.7	1.6	2.8	2.3
	Boys	8.6	2.0	11.8	2.3	3.7	2.9
	Girls	5.7	0.8	9.2	0.8	1.6	1.4
TOTAL	Total fail	41.4	24.2	39.9	17.9	26.9	22.0
	Boys	43.6	25.9	40.5	20.7	31.2	25.6
	Girls	38.6	19.6	39.3	14.4	21.9	17.8

Once the decision is taken to pursue science how do boys and girls perform in various subjects? Do they fail more in mathematics or in physics or chemistry (table 7)?

Table 7
Comparison of percentage failure rates in mathematics, physics and chemistry for class XII

	Mathematics			Physics			Chemistry		
Year	Total	Boys	Girls	Total	Boys	Girls	Total	Boys	Girls
1993	19.2	22.7	16.0	20.0	13.8	16.3	15.5	17.4	13.9
1994	13.8	17.6	10.0	17.7	20.8	16.0	16.5	18.3	14.4
1995	16.1	19.3	13.6	17.9	23.9	11.1	17.2	25.9	10.4

A comparison of failure rates in physics, chemistry and mathematics for a period of three years shows that more pupils fail in physics than mathematics; however the percentage difference is only marginal. Except in 1993, mathematics failures are less than in chemistry. Comparison of boys and girls shows that girls do better than boys except in 1993 in physics.

Co-education

To answer the question whether girls do better in maths in single-sex schools or in co-educational schools the failure rates of girls in single sex schools has been compared with the failure rates of girls in co-educational schools. Similarly the failure rates of boys in single-sex schools and co-educational schools has been compared. The findings are presented in table 8. (* As the data for mathematics were combined for all four streams some kind Of sampling became necessary. Data were collected from 56 schools offering science and humanities where pupils offering mathematics in humanities stream was negligible.)

Table 8
Comparison of percentage failure rates of boys and girls in mathematics in single-sex and co-educational schools (1993)

	Girls		Boys	
Type of school	**Co-educational**	**Single sex**	**Co-educational**	**Single sex**
Government	48.7	51.2	43.2	59.0
Government-aided	31.4	28.8	32.9	40.8
Independent	5.9	3.9	8.9	4.3
TOTAL	15.8	47.0	19.3	55.8

The total percentage failure rates are higher in single-sex schools than in co-educational schools. Again it is the government schools that show huge failure rates and, as shown earlier, most of the government schools are single-sex schools (table 2).

Co-educational schools are run mostly by private agencies or they are aided by the government. A comparison of the performance of girls in single-sex schools with their counterparts in private co-educational schools show that in single-sex schools the failure is less. It is the same for boys.

Both boys and girls seem to do better in single-sex government-aided schools. No clear picture emerges from the above data regarding the impact of co-education on the performance of girls.

Coming back to the question of whether mathematics is a barrier, the huge failure rates at class X level suggest this could be so. A poor teaching-learning process within the classroom is suspected to be a major reason for this. To verify this hunch the failure rates in mathematics at middle school level were analysed and a comparison made with failure rates in science and social studies.

Three co-educational aided schools were selected from central Delhi and data were obtained from school records for the years 1993, 1994 and 1995 (table 9).

Here again, we find that the maximum number of failures occur in mathematics. Science, compared with social studies, shows less failures for all the three years.

Table 9
Comparison of percentage failure rates in mathematics, science and social studies for class VIII

	Mathematics			Science			Social studies		
Year	Total	Boys	Girls	Total	Boys	Girls	Total	Boys	Girls
1993	40.3	40.6	40.1	26.3	25.0	27.9	30.8	30.8	30.9
1994	45.6	49.7	40.8	32.1	34.1	29.8	32.3	38.2	25.6
1995	29.1	43.1	35.8	23.3	26.7	19.3	28.6	31.2	25.6

Except in 1993, where the percentage of failures in science is higher for girls, they seem to do better than boys in all the three subjects and in all the three years.

Discussion of findings

This study, undertaken to address the question 'Is mathematics a barrier to learning science for girls' was mainly exploratory in character. Its aim was to generate some preliminary data so that hypotheses could be developed about gender and mathematics in the Indian context. The drawbacks of the study are freely admitted, but its findings are not without significance.

A major factor that is restricting the entry of girls into science is the lack of opportunities to study science in schools. Only 79 girls' schools out of a total of 279 offer science. Humanities without mathematics or commerce are the common streams found in these schools. Thus the initial barrier seems to be erected by the school system itself.

The restricted number of places available in science streams creates a competitive situation within the school system. Entry into science is difficult, even for above average girls who are willing to study science.

In their attempts to choose the best, school administrators lay down their own criteria for selection. Pupils are offered science on the basis of their performance in class X public (external) examinations. Aggregate marks of two or three subjects (science, mathematics and English) are used as criteria for selection purposes. This selection procedure, based on one-time performance, provides no scope for judging qualities so essential for doing science as intrinsic interest, perseverance, etc. Instead of pupils choosing the subject streams freely according to their interests and career aspirations, the school system which assigns them to various groups. For many, subject choice is only a theoretical concept. Pupils, especially girls, are driven automatically to study humanities and commerce which are less demanding and 'maths-free'.

The findings of this study show that, on the whole, only 9.3 per cent of pupils who pass class X, enter a science stream. While the KVS schools have the maximum number of girls (as well as boys) entering science, the figures for government schools are the lowest. Instead of widening the social base for recruitment of scientists, the educational system perpetuates its present hereditary character. The door to science is ruthlessly closed for the underprivileged right at the entry point. It is the children of educated middle-class parents who go into science streams. In this context, the question arises: how do we select those who will do well in science?

The performance of girls, as judged by failure rate, shows that girls do better than boys at every level, both in science and mathematics. Yet fewer girls enrol in science. More studies are needed focusing on the reasons why science is not appealing to girls. Many of the factors enunciated as responsible in the western context may not be applicable in the Indian context.

Findings regarding the impact of co-education on mathematics are conflicting, making it difficult to arrive at a conclusion.

Finally, mathematics does appear to be a barrier in this study if the huge failure rate and enrolment figures are taken as pointers. As mathematics is a sequential subject, any deficiency in the teaching–learning process at one stage is carried over to the next. This cumulative effect, it is argued here, is responsible for the huge failure rate at the first public examination. Early difficulties with mathematics may be a reason for a majority of girls (also boys) turning away from science and mathematics. Failures and poor performance often lead to negative attitudes and feelings towards mathematics. Research on attitudes of girls towards mathematics may throw more light on this.

Concluding remarks

If mathematics and science are to be tools of empowerment special attention should be paid to them in the education of girls. Tokenism will not cause women to surge forth to fill the rank of scientists. Concerted efforts by teachers, counsellors and parents are essential. Girls need to be encouraged right from the middle school stage to think seriously about careers in science, maths and engineering so that they do not opt out of mathematics in secondary school. More girls' schools should offer science and science and maths curricula need to be revamped, taking into consideration the interest of girls so as to make science more meaningful to them. Teaching girls about the ways in which mathematics and science can be used in applied science and mathematics (e.g. environmental problems, oceanography, health, statistics) could stimulate interest in the application of mathematics and science to real-life problems. The relevance of mathematics for the study of biology, social science and management studies needs to be stressed and different courses in maths devised for different streams. It is heartening to learn that the CBSE is also realising the imperative need to formulate a more 'functional syllabus' in maths for students of different streams.

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Enhancing women's participation in mathematics education

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ABSTRACT

Barriers to studying mathematics faced by students and in particular female students have been studied. The study was carried out through questionnaire from three cities of different categories in the state of Gujarat. The psychological approach was taken. Five mental faculties related to mental processes and mental capacities have been considered. Accordingly five different teaching methods were devised, including one method of folk drama. Preliminary data have been collected to study the effect of these five methods on male and female students. The results show that statistically the difference in the responses is not significant.

Introduction

Since the creation of the entire Universe, it has been pronounced in Vedas that Aditi is the supreme power and the first form of Brahma. She is termed Kali, Durga, and sarvadevarupini in our ancient literature of different ages, from Mahabharat (5000 BC) to Devibhagvat (900 AD). The teaching of Shri RamKrishna paramhans (the Guru of Swami Vivekanand) of our age is similar. He says Brahma and Sakti are not separate. When Brahma is in the state of inactivity, he is called Pure Brahma. When he causes creation, contains existence and makes destruction, he is called Sakti.

Napoleon Bonaparte also attached importance to female education for the prosperity of a nation in these words: *'The hand that rocks the cradle, rules the world'*. All the foregoing prove the importance of women's literacy for the uplift of society all over the world. Recently Dr (Mrs) Kiran Prabha of Kanpur University also tried to prove the same thing in her article 'Women's education – a retrospective' with logical reasons especially for India.

By the end of the 20th century independent and democratic countries like India will have to think of the percentage of women's participation in science and technology to achieve real prosperity. Today India is poor, not because of its economic condition alone, but also because of its neglect of women's literacy in modern science.

In the state of Gujarat only one-fourth of the academics, at any level from secondary to university, are females. The percentage of females in science faculties would be still less (table 1).

Table 1
Females participating in education in the state of Gujarat in September 1993

Level	Total no. of teachers	Female teachers
School (6th to 12th standard)	63,872	14,687 (23%)
College (arts, science and commerce)	8393	2145 (25.55%)
University	351	142 (22%)

These data invite investigation of the reasons why women are discouraged from studying maths, as it is the basic requirement for the study of science and technology. For the purpose a questionnaire was prepared, considering different barriers such as social, educational, economic and professional. The main findings are given in table 2.

Table 2
Barriers to learning maths for females

Barriers	Question	Percentage of 11th standard students (without maths)	Percentage of graduates and higher courses (with maths)
Social or family	Lack of parental support	18%	0.07%
Educational	Methods of teaching are dry and uninteresting	38%	64.00%
Professional	Limited opportunities/gender bias	58%	80.00%
	In private jobs	71%	84.00%
	In government jobs	70%	78.00%
Economic	no significant problem in the urban area of the state of Gujarat		

The statement describing an educational barrier in the following words drew special attention. 'The methods of teaching are dry and uninteresting.' In order to solve this problem the author thought of trying a psychological approach.

Psychological analysis has proved the fact that a person is interested in the activity, which appeals to his prominent mental faculty. On the basis of psychological analysis the author developed different methods of teaching theorems in geometry, including the method of folk

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drama. The following project to teach theorems on parallelograms by different methods was planned and implemented for the students of std. IX.

Objectives

1 To develop different methods of teaching geometry for secondary school students.
2 To find out the effect of the teaching methods on the understanding of the students, with special emphasis on the gender difference.
3 To find out the difference in learning capacity of students according to mental faculties.
4 To observe the effect of the school environment on the understanding of female students.

Hypotheses

1 Different methods of teaching geometry can be developed.
2 Students can learn geometry with greater interest, if different methods of teaching are used.
3 There is no gender difference in the understanding of geometric concepts by different methods.

Tools

1 Psychological model

A leading Indian psychiatrist, Dr M. D. Parikh has developed a model explaining different mental abilities of human beings. It is based on psychological analysis. The main idea of this project was taken from that model. Some oral discussions also took place. The model explains that when a person is given a stimulus, we get a variety of responses. This is due to the mental processes working in the mind of a human being. These responses are divided into five groups or 'mental faculties'. Their strengths vary from person to person, which accounts for different interests or mental abilities. The tool is outlined in table 3.

Table 3

Mental faculty	Mental process	Capacity depending on the predominant faculty
1 Retentive	memory	academic orientation
2 Conative	action	athletic feats
3 Rational	intellaction	scientific pursuits
4 Communicative	perception	Communication
5 Sentient	affective change .	Artistic taste

2 The script of a folk drama

In order to teach the students having predominant sentient faculties, it was essential to prepare a drama script to prove the theorem. It was, however, uncommon and a little difficult, because the basic concepts of geometry were to be combined with elements of drama and literature. Just to serve the purpose the author discussed this idea with other teachers from time to time. Teachers teaching languages, mathematics and music were selected from different schools, who helped materialise the idea by giving useful suggestions and guidance. By the end of a week's discussions the script was made ready in the form of a folk drama known as 'BHAVAI' in Gujarati – the local language of Gujarat. Copies of the script can be had from the author. An explanation of terms in the script is given in Appendix 1. All the elements of Bhavai are not taken into consideration:

1 No Naman and Ganesh prayer is taken.
2 No music is given as street drama.
3 Central characters of both sexes have not been selected, i.e. Rangali is not taken as a character.

The reasons for dropping these elements were:

1 As the script was to be used for the classroom teaching of one period only, the prayer would consume some time.
2 Music was not used only to avoid the external help of musicians.
3 Rangali was not taken along with Rangala because the students of Standard IX. are teenagers. Their attention might be diverted from learning geometry. Hence there may be some educational loss instead of gain.

The script was then discussed with the students, who were going to play the folk drama. They suggested adding a dialogue of two quarrelling factions to make the drama lively, realistic and interesting. Accordingly two pairs of students were fixed in such a way that no one would try to move from his place. So the equal distance between two pairs of opposite lines would be maintained. Ultimately the parallelogram would not be disturbed and converted into a common quadrilateral. Thus the drama was divided into two parts:

A The first part includes basic concepts of parallel lines and angles and also gives types of quadrilaterals and properties of a parallelogram.
B The second part gives the proof starting form the statement of the theorem.

Explanation of the folk drama

The drama begins with the advent of two female students of standard IX discussing how boring their subject, geometry, is. At the same time, the central character, a male student known as 'Rangalo', enters and gives correlation of the subject with live demonstrations by singing. The central character – a male student – was selected to encourage no gender bias. The folk drama is divided into two parts.

The first part gives conceptual clarifications of geometry found to be confusing for the students of standard IX. By the end of the first part students are clear about the properties of a parallelogram.

In the second part social problems of life are woven into the drama. Two pairs of quarrelling boys rush in and lodge complaints against each other before Rangalo and request him to settle their disputes. The central character, Rangalo, is very wise and witty. He listens to them patiently and asks them to stand in such positions that each one makes the vertex of a parallelogram. Then he himself takes up a position where two diagonals intersect and starts giving the proof of the theorem in his unique method of conversation. But since the boys had come quarrelling, they did not follow the given data on the theorem and what was to be proved. It was, however, clarified by means of dialogues. On queries by girl students, Rangalo starts the proof by taking two corresponding triangles formed by threads of different colours. In order to make the triangles congruent he makes use of the SAS (side, angle, side) condition of congruency. He is standing in the position of a mid-point of two diagonals, hence the two sides of the triangles are congruent. The interior angles of the two congruent sides were required to be proved congruent to fulfil the condition of SAS. They, being vertically opposite angles, are always congruent according to the previous theorem. As the triangles were proved congruent, the remaining parts of the triangles were automatically proved congruent. The remaining congruent angles were alternate angles, formed by a transversal intersecting two lines. Thus the opposite sides of the quadrilateral were proved parallel. This showed the girl students how to prove the other pair of corresponding triangles congruent. Then the students themselves discussed and proved the other pair of opposite lines parallel. As both the pairs of opposite sides were parallel, the quadrilateral was proved to be a parallelogram according to the definition of a parallelogram.

3 Test paper

This was a teacher-made test. Questions were based on the basic concepts of theorems, which were learnt during the project. Two questions per faculty were constructed for all five faculties. All the questions carried equal marks. Thus there were a total of 10 questions in the paper carrying 50 marks. (see Appendix 2)

Sample

Students of standard IX have to study theorems on parallelograms. So one class from each of three secondary schools from the city of Ahmedabad was selected. Of the three schools, one was exclusively a girls' school, while the other two were co-educational (table 4).

Table 4

				Total no. of students
Name of the school	DBMS	RMW	MKV	
Girls	29	11	25	65
Boys	34	17		51
TOTALS	63	28	25	116

Implementation

The project of teaching theorems on parallelograms by different methods was planned only for five theorems out of 12. The first five
theorems were selected, because:

- The psychological model consists of only five mental faculties.
- Only one method per faculty was to be prepared.

- The selected theorems were giving the properties of parallelograms and their converse only.
- In the case of all the selected theorems except the first one the statements are given without logical proof or discussion in the textbook.
- It can be inferred that these four theorems have equal difficulty value.

The statements of theorems are reproduced here with justification of the method adopted for the same.

Theorem 1
A parallelogram has both pairs of opposite sides and opposite angles congruent.

This theorem was selected for the lecture method, because:
- It is a base for all the theorems on parallelograms.
- The theorem is given in the textbook with logical proof.
- The students are used to learning geometry by the lecture method, so they would not find it strange.
- The lecture method is the best one for the students with predominant retentive faculty.

Theorem 2
The diagonals of a parallelogram bisect each other.

This theorem was selected for the experimental method, because:
- The students with predominant conative faculty can learn better by doing the experiments themselves.
- Only the statement of the theorem is written in the textbook i.e. no proof or logical discussion is available in the textbook.
- Confused concepts held by the students about quadrilaterals could be revealed and corrected by the teacher.

Theorem 3
If the two pairs of opposite sides are congruent then the quadrilateral is a parallelogram.

This theorem was proved by the analysis synthesis method, because:
- There is no logical proof or any discussion available in the textbook.
- This method makes use of the mental process of intellaction. So a person having a strong rational faculty would benefit.
- The process of teaching can be a two-way method, with the students solving their difficulties by asking the teacher questions.

Theorem 4
If two pairs of opposite angles are congruent, the quadrilateral is a parallelogram.

This theorem was selected for the project method, because:
- No logical proof or discussion of this theorem is given in the textbook.

- The students with predominant communicative faculty would be encouraged to learn geometry.
- Some of the students would get training in the presentation of data as leaders.
- Students will get experience of group discussion in mathematics.

Theorem 5
If two diagonals bisect each other, the quadrilateral is a parallelogram.

This theorem was to be proved by a drama method, because:
- No logical proof is given in the textbook.
- The teenagers are very sensitive. Such a socio-cultural approach would make geometry live and interesting for them.
- The students, who are weak in geometry, can grasp the concepts easily and without any burden.

The project of teaching theorems was given to the selected sample schools as preliminary work. It was conducted with the help of teacher trainees. The teaching lasted one week, with one theorem being taught each day. The following week the students were given a questionnaire correlated to the method of teaching or the mental faculty (table 5).

Table 5
Patterns of analysis

	Theorem	Suitable method of teaching	Predominant mental faculty	Question number
1	Parallelogram has 2 pairs of opposite sides and angle congruent	lecture	retentive	4,10
2	Diagonals of a parallelogram bisect each other	Experimental	conative	3,8
3	If 2 pairs of opposite, sides are congruent, a quadrilateral is a parallelogram	Analysis Synthesis	rational	6,9
4	If 2 pairs of opposite angles are congruent, a quadrilateral is a parallelogram	Project	communicative	1,7
5	If diagonals bisect each other, the quadrilateral is a parallelogram	Folk drama	sentient	2,5

Analysis and interpretation

The data obtained from the sample students is shown in table 6 below.

Table 6

Faculty 1

	Score 0	1–5	6–10	Total no.
Girls	11	49	5	65
Boys	24	19	8	51
TOTAL	35	68	13	116

Faculty 2

	Score 0	1–5	6–10	Total no.
Girls	33	28	4	65
Boys	27	22	2	51
TOTAL	60	50	6	116

Faculty 3

	Score 0	1–5	6–10	Total no.
Girls	17	42	6	65
Boys	23	25	3	51
TOTAL	40	67	9	116

Faculty 4

	Score 0	1–5	6–10	Total no.
Girls	51	14	00	65
Boys	44	7	00	51
TOTAL	95	21	00	116

Faculty 5

	Score 0	1–5	6–10	Total no.
Girls	7	20	38	65
Boys	19	9	23	51
TOTAL	26	29	61	116

Every student possesses all the five mental faculties with more or less strength. Keeping this in mind, theorems were taught by different methods. Nothing is given in the textbook except the statements of the four selected theorems. Students therefore had to answer the questions according to their grasping capacities, which would, in turn, be determined by their strongest mental faculties. For example, students with a powerful sentient faculty would grasp most easily the theorem learnt through the drama and therefore answer questions 2 and 5 in a better way. On the other hand, no student would be able to answer all the questions perfectly, because he could not have all the faculties equally strongly. So ultimately no student would have full marks nor nil marks in the test paper. It thus proves the first and second hypotheses.

The project was done on a preliminary base. No statistical calculations were found necessary. From the analysis table it is clear that students of the secondary school level have no gender bias in learning the theorems. Thus the third hypothesis is accepted.

Over and above the hypotheses, results prove that scores of faculties 1, 3 and 5 are somewhat encouraging, that is, students can learn and grasp better by the lecture method, analysis method and drama method respectively. The communicative faculty, however, shows a very poor score. It is a matter for serious concern that teenagers have little liking for self-learning.

Appendix 1

Explanation of terminology used in the script

Gujarati	English
Samantar Rekha Parellel lines	
Bhumiti ma	In Geometry
Saman Antare	At equal distance
Salia	Rods
Patiya	Board (Black board)
Chheda samantar	Parallel edges
Chhedika	Transversal
Swatantra	Independent
Yugmakone	Alternate angles
Anukone	Corresponding angles
Antahkone	Interior angles
Chhedika karane	Due to transversal
Samatality rekha	Coplannerline
Ekarup	Congruent
Purak	Supplementary angles
Triji rekha	Third line
Pramey	Theorem
Be chhedika	Two transaversals
Samantar baju chatushkone	Parallelogram
Samalamb chatushkone	Trapezium
Bicharo	Poor
Sama baju chatushkone	Rhombus
Choras	Square
Lamb choras	Rectangle
Gundharmo	Properties
Samsameni bajuo	Opposite sides
Sabachakono	Of parallelogram
Vikarno	Diagonals
Chhed bindu	Intersecting point
Dubhag bindu	Bisecting point
Rachana chaturmukhi	Figure of quadrilateral
Fariyad	Complain
Aropi	Guilty
Karamat	Trick
Bhadi	Suspense
Path bhumiti no	Lesson of geometry
Prashno hal kare	Solve the problems
Samajyo	Understand
Ramat	Game (play)
Anokhi	Unique

Na khasta	Don't move
Jagya perthi	From the place
Tran bindu samrekha	Three linear points
Ek	One
Pagla saman	Equal steps
Anya	Another
Shikhavadashe	Will teach
Sabit shu karvanu chhe?	What to prove?
Sharati	Conditional
Paksha	Given (data)
Sadhya	To prove
Vidhan	Statement
Anurup trikon	Corresponding triangle
Rekhakhand	Line segment
Madhya bindu	Mid point
Bakhuba Purvdharna	SAS Postulate
Abhikone	Vertically opposite angles

Appendix 2

Test Paper

1 If 2 pairs of opposite angles are congruent, the quadrilateral is a parallelogram. To prove this theorem which type of pair of angles is utilised?

2 If diagonals bisect each other, the quadrilateral is a parallelogram. To prove the statement, which condition of congruency would be applied?

3 Draw a parallelogram PQRS and measure PR and QS.

4 Give the statement in which 2 properties of a parallelogram are present.

5 What given data of the theorem 'DHAVAL' said in the folk drama?

6 If 2 pairs of opposite sides are congruent, the quadrilateral is a parallelogram. To prove this statement SAS condition is used. Correct the statement.

7 In correspondence ABC<->PQR A = P and C = R.
Which 2 sides should be congruent to fulfil ASA condition?

8 Draw a square ABCD and measure the diagonals AC and BD.

9 In a quadrilateral KLMN, KL = MN and KN = LM. Which condition of congruency should be applied to prove it a parallelogram?

10 Which two triangles should be made congruent to prove AB = CD and AD = BC in a parallelogram ABCD?

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Girls, mathematics, science and technology education in Kenya

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ABSTRACT

The participation of girls in mathematics, science and technology education is of paramount importance in the developing countries. Females constitute more than half of the population of these countries and contribute enormously to their socio-economic development. In this paper, participation of girls in mathematics, science and technology education is discussed, giving a few examples from the Kenyan situation. Some of the drawbacks that girls face are highlighted and some recommendations are given that can enhance the achievement of girls in mathematics, science and technology.

Introduction

In Kenya, a study carried out in 1985 (Eshiwani, 1985) to analyse the participation and achievement of girls in science and technology education revealed that generally girls are under-represented in these fields. This study, and that of Kagia (1983), showed that girls' achievement in mathematics and science subjects was relatively inferior to that of boys. This led to fewer girls being selected for science and science-related subjects in the universities. This situation has not changed much; for example in the 1993 Kenya Certificate of Education examination, fewer girls than boys performed well in mathematics. While 65,256 males scored B and above, only 33,277 girls had similar scores.

The number of girls pursuing science and other professional courses has remained relatively low in Kenya. For example, in the 1991/92 academic year, only two out of 27 students admitted for the pharmacy course at the University of Nairobi were females, while out of the 145 admitted for medicine, only 45 were females. In 1992/93 there were four female students out of the 33 admitted for pharmacy while 19 females were admitted for medicine as against 127 males (Aduda, 1995). Girls' underachievement in mathematics at secondary school level affects the number who are selected for mathematics, science and technology studies both at the universities and in tertiary institutes. In Kenya, most of the science and technology courses require a pass in mathematics (see table 1). As seen in this table, the Kenya Polytechnic emphasises the importance of mathematics as a selection criteria for most of the courses. This just shows the role of mathematics as a 'critical filter' to science and technology studies and careers.

Table 1
Advertisement for the Kenya Polytechnic courses commencing in January 1996 (Source: Kenya Times, Thursday 19 October 1995).

Course title	Minimum requirements: KCSE or equity
Diploma in Applied Biology Diploma in Applied Chemistry Diploma in Medical Lab. Science Diploma in Earth Sciences Diploma in Food Technology	Average Grade C–, including C– in Maths, Chemistry, Biology or Biological Science, Physics or Physical Science. (Note: As303 includes mandatory 1 year attachment.)
Higher Diploma in Applied Biology – Animal Physiology/ Pharmacology/ Microbiology	Ordinary Diploma in Applied Biology
Higher Diploma in Applied Biology – Entomology/ Plant Pathology/ Soil Study	Ordinary Diploma in Applied Biology
Higher Diploma in Applied Chemistry – Analytical	Ordinary Diploma in Applied Chemistry
Higher Diploma in Medical Laboratory Technology – Microbiology/ Immunology	Ordinary Diploma in Medical Laboratory Sciences
Higher Diploma in Medical Laboratory Technology – Physiology/ Histopathology/ Parasitology	Ordinary Diploma in Medical Laboratory Sciences
Higher Diploma in Medical Laboratory Technology – Chemical Pathology/ Haematology/ Immunology	Ordinary Diploma in Medical Laboratory Sciences
Higher Diploma in Food Technology	Ordinary Diploma in Food Technology
Higher Diploma in Earth Sciences	Ordinary Diploma in Earth Sciences
Certified Public Accountants Pt 1 Certified Public Secretaries Pt 1	Average Grade C+, including C+ in Maths and English, or ACNC I or II, or KATC or KACE with 2 principals credit passes in Maths and English at KCE level
Diploma in Business Administration	Average C–, including C– in English, Maths, Accounting, Economics or Commerce

Diploma in Accountancy Diploma in Marketing	Average C, including C– in Maths, English and C– in any one of the following: Accounting, Economics or Commerce
Diploma in Building Diploma in Civil Engineering Diploma in Water Technology	Average C–, including C- in Maths, English, Physics and Chemistry or Physical Science or a 2nd division at O-level with credit passes in the mentioned subjects.
Diploma in Electrical and Electronic Engineering (Electronics Option)	Average C–, including C– in Maths, English, Physics, Chemistry or Physical Science.
Diploma in Electrical and Electronic Engineering (Telecommunications Option) Diploma in Electrical and Electronic Engineering (Power Option)	Electricity or Drawing an advantage
Diploma in Labour Studies in Management	Average C–, including C– in Maths, English, History and Government and Economics or Commerce.
Diploma in Environmental Studies	Average C–, including C in Maths, English, History and Government or Kenya Polytechnic Library Assistant Certificate
Diploma in Mechanical Engineering (Production Option) Diploma in Mechanical Engineering (Plant Option) Diploma in Mechanical Engineering (Automotive Option) Diploma in Mechanics (Welding/Fabrication) Diploma in Mechanical Engineering (Aeronautical Option) Diploma in Mechanics (.Refrigeration/Air Option)	Average C–, including C– in Maths, English, Physics and Chemistry or Physical Science, or credit pass at O-level in the above subjects.
Diploma in Land Surveying Diploma in Cartography	Average C–, including C– in Maths, English, Geography and Physics or Physical Science
Diploma in Applied Statistics	Average C–, including C– in Maths, English and two other subjects

Some drawbacks girls face in mathematics, science and technology education

Social-cultural attitudes

Girls do not achieve very well in mathematics, science and technology because of society's stereotyped view that these subjects are a male domain. Added to this, the few females who have entered these non-traditional fields have encountered numerous problems to the extent of giving up their careers.

Lack of facilities

The facilities required for proper science and technology are not available in many girls' schools in Kenya. Recently, Prof. Florida Karani, a deputy Vice-Chancellor at the University of Nairobi and also in charge of academic affairs said most girls' schools lacked laboratories, workshops and home science rooms (Aduda, 1995). In such schools, the girls who opt for science subjects are not properly taught as they end up memorising notes from their teachers or the textbooks. Even in some schools where facilities are available, there is a lot of gender bias in the teaching methods and materials.

Financial constraints and other poverty-related problems

Financial constraints tinged with cultural prejudices ensure that many parents send their sons for higher education at the expense of girls. Also, numerous household chores deny many girls the chance of private study, yet our system of education requires that students work extra hard to succeed.

Another factor here is the low female literacy in most developing countries and the large number of homes headed by women. These homes are more vulnerable to poverty and girls in such families are more likely to drop out of school due to many factors, including early pregnancies.

Conclusion and recommendations

It is evident that girls have been underachieving in mathematics, science and technology and there is an urgent need to address this problem. Kenya, like many other developing countries, needs scientists and technologists and girls should not be left behind in these subjects, or in education in general. The following recommendations are suggested to enhance the participation of girls in mathematics, science and technology education.

Constant guidance and counselling

Our girls should be freed from the fear of mathematics and science that the society instils in them. They should be guided and counselled at all stages and encouraged to learn and understand mathematics and to enrol in science and technology courses.

Role models

Provide opportunity for girls to meet with female role models in science, technology and mathematics-related careers. In Kenya, the Kenya Women Association of Scientists and Engineers (KWASE) should be vigorous in this endeavour. KWASE should also pressurise the media to give greater emphasis to gender issues and to raise awareness of the problems females may encounter on entering non-traditional fields and to enlighten them on possible coping strategies for these problems.

Cultural resources

Local institutions like the National Museums should utilise available cultural resources to enhance/demystify mathematics, science and technology. These resources should link the experiences of the girls to problem-solving in a fun-like manner. This calls for greater collaboration between the museum education officers and the teachers.

Classroom teaching methods

Classroom teaching methods and teaching materials need some examination to ensure that they enhance the participation of girls. This calls for joint efforts from the policy makers and the classroom teachers. During training, teachers should be gender-sensitised. Teachers already in the field should be given some in-service training to raise their awareness of the needs of girls.

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Mathematics and the learning of science and technology amongst girls in Malawi

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ABSTRACT

This paper gives a brief historical outline of the education system introduced in Malawi by early educators in relation to girls' attitudes towards learning. Some socio-cultural, educational and personal attitudes which might be deterring girls from serious study of science, mathematics and technology are highlighted. The author has tried to unveil some of the obstacles by carrying out interviews in villages with old men and women who either attended basic primary education up to standard 4 or did not, and young men who are engaged in carving and handcraft business. Among other things the author discussed with girls the problems and constraints faced in pursuing their education in co-educational and in single-sex girls' secondary schools. Apart from socio-cultural problems, research was extended to schools, to look into girls' participation and performance in science and maths. Five schools were selected for the study: two single-sex girls' schools, two single-sex boys' and one co-educational school. The study analysed the teacher's role and attitude towards girls' education in co-educational schools, subject combinations and girls' attitudes towards mathematics. Questions such as 'What is a curriculum?' are looked at from the context of the paper. Definitions of the term 'curriculum' vary with views about the function of schooling (Skilbek, 1984). In this paper schooling is taken to be the process of acquiring knowledge and skills necessary for survival in a society. The curriculum, therefore, is a selection of knowledge and experience or activities, organised in some way, to be passed on to the pupil (Gunsaru, 1990). The Physical Science Curriculum discussed in this paper then refers to the content and organisation of such documents.

Introduction

The mid-1990s will go down in history as years of great change in the world's social order. In sub-Saharan Africa, a wind of change has ushered in new democratically elected governments which have opened certain areas for more participation by women, although this had been going on in our country, Malawi, for some time. There was a lot to be done because of the imbalance between males and females in the field of education in science, mathematics and technology. This prompted many studies aimed at finding out what exactly was stopping these girls and young women rising to the same level as their male counterparts. Policies have been put in place to promote education and revision of the curriculum is needed as a matter of urgency.

Many problems have hindered girls from going to school, prolonging their education or progressing in mathematics and science. They can be categorised as cultural, social, economic and educational.

Some interviews have been carried out to find out whether mathematics is a barrier to learning science and technology for girls as is alleged by many people in the education field.

Socio-cultural attitudes

Handwork

For many years Malawian girls have been considered to be the housekeepers. Their sole job was to fetch fuelwood, water, cook and look after the children. Girls have been kept away from boys as much as possible. For many countries all hand and difficult work had to be carried out by males, for instance construction of houses, granaries, fences and graalls. Both males and females could weave mats and baskets, do pottery work and carving. All this required the use of indigenous knowledge of mathematics. As time went on there was a great demand for the said items by tourists and other customers. Males found themselves doing a lot of carving and selling these curios while females withdrew. This trend of withdrawal from handwork by females applied in all fields. Males have sharpened their way of doing things with precision. Males have become more creative and imaginative and consider themselves more intelligent than girls. Boys have been more courageous and adventurous in confronting new challenges.

During construction work, boys have used a lot of mathematics in measuring angles, distances and heights, counting and estimation of materials to be used. A lot of scientific thinking is involved in the weaving of baskets and mats, for instance in the design, size, angles and even mixing of different special plants to make dyes of different colours for decoration. All these factors have led to a belief that boys are more intelligent than girls, and to girls considering themselves inferior to boys. There are many games played by both boys and girls or by a single sex. A survey carried out revealed that many games played by boys today were at one time in the past played by both boys and girls. Most of these games involve a lot of thinking, addition and subtraction, which helps to sharpen these skills. Girls, discouraged by their elders from mingling with boys, are thereby denied the opportunity of learning and sharing ideas with boys. In schools most of the games such as chess and drafts are played by boys. Boys dominate the games. They say the games are fit for boys and not girls because they require a lot of thinking and solving. This has led to girls having an inferiority complex and to boys taking advantage in decision-making in crucial matters everywhere.

No incentive for girls education

Parents have for many years considered girls to be a mother's right-hand in carrying out household chores. Parents felt obliged to send a boy to school rather than a girl, even if the girl was older than the boy. At times a girl would be sent to school to learn how to write her name and read the Holy Bible. They saw no employment benefit of giving girls years of schooling. Girls were not allowed to take risks looking further afield for employment.

Missionary and co-educational schools

The early missionaries did not accept co-education; instead, they established separate-sex boarding schools with strict sex segregation rules. Girls were allowed no male visitors except genuine parents. There was no interaction between boys' and girls' schools. Girls were taught to regard all boys as hungry 'wolves', which literally meant that if girls were to mix with boys then pregnancy cases would rise. So girls were confined within their premises. This shut them off from the new knowledge people were gaining from the outside world.

The last decade has seen many co-educational schools spring up, as well as Malawi College of Distant Education Centres. A lot of girls are enrolling in these schools, and this has helped to dispel the misconception that all boys are 'wolves'.

Girls entry into primary school

A study was carried out to find out the age group that enrol in standard 1 in primary schools. It was discovered that many over-aged girls from economically poor families enrol. Most of these girls do not persist. They drop out of school at early stages of their primary education. In secondary schools girls from high socio-economic backgrounds persist and continue with their education because most of these girls live in towns where interaction with their male peer group is possible.

School and teaching scenario

Some studies conducted have revealed the information outlined below. Five secondary school were chosen for study: two single-sex girls schools, two single-sex boys schools and a co-educational secondary school. The study was carried out for the years 1993, 1994 and 1995. These schools were Likuni Girls, Nkhamenya Girls, St Patrick's Boys, Likuni Boys and Namitete co-education secondary.

Subject choice

A study was carried to see in what science subjects pupils do well in their final-year examination (table 1). Three key subjects were chosen: physical science, which includes physics and chemistry and is an optional subject, and biology and agriculture, which are compulsory. The table also shows some pupils who had an interest in the subject but failed it.

Table 1
Preferences in science subjects

School	Year	Final year pupils	Agric.	Biology	Physical science	Passes in agric.	Passed biology	Passed physical science
Likuni Girls	1993	124	124	124	59	98%	80%	66%
	1994	133	133	133	62	97%	49%	94%
	1995	134	133	134	93	99%	30%	48%
Nkhamenya Girls	1993	89	88	89	81	76%	31%	52%
	1994	80	90	102	77	96%	97%	63%
	1995	102	98	102	102	98%	86%	39%
St Patrick's Boys	1993	75	60	74	56	100%	92%	75%
	1994	85	77	85	62	100%	88%	96%
	1995	80	73	80	64	97%	90%	75%
Likuni Boys	1993	67	44	63	67	100%	94%	91%
	1994	72	50	71	72	94%	92%	76%
	1995	87	62	63	86	100%	76%	81%
Namitete	1993	121	26	121	92	97%	28%	46%
Co-ed.	1994	126	105	125	120	88%	69%	68%
	1995	143	103	143	139	89%	27%	54%

The table reveals the following:

- That not many candidates in the final year in any schools dropped physical science except Likuni Girls Secondary.
- A follow-up interview revealed that pupils from other schools join the school in form 3 to replace those who failed. These girls come from schools where physical science is not taught.
- The pass mark for girls' schools is equal although it is below that of the boys' schools.
- There are variations in the passing percentages for biology.
- There is consistency in the results for all subjects in both boys schools.
- The co-educational school shows very poor results.
- The subjects which demands a lot of application (thinking), namely biology and physical science, are poorly performed by girls.

Deficiency in the table
Table 1 does not show the degree of passing each subject. A mere pass would not warrant a University Selection and entry.

Table 2
Mathematics performance

School	Year	Total candidates		No. passed		No. failed		% Pass
Likuni Girls	1993	124		24		100		19
	1994	133		28		105		21
	1995	134		50		84		37
Nkhamenya Girls	1993	89		47		42		52
	1994	80		21		55		26
	1995	102		54		48		52
St Patrick's Boys	1993	70		47		23		67
	1994	81		75		6		92
	1995	75		69		6		92
Likuni Boys	1993	67		58		9		86
	1994	72		54		18		75
	1995	87		77		10		88
Namitete Co-ed.		**Boys**	**Girls**	**Boys**	**Girls**	**Boys**	**Girls**	
	1993	87	39	41	4	42	35	31
	1994	90	36	52	12	38	25	52
	1995	108	35	18	26	82	17	36

Table 2 reveals that:

- Boys do well in mathematics.
- Girls perform poorly in mathematics.
- The co-educational school results are not very encouraging.
- One girls' school has been doing very badly in mathematics.

This shows two things:

- either the teacher is weak or
- the girls do not take mathematics seriously.

Girls lack skills such as numerical skills and communication skills that may be used for calculation and problem-solving. As mathematics has a language of its own, many Malawian students, especially girls, fail to grasp the subtle ideas within the questions during the examination.

Numerical skills

It was discovered that girls lack the necessary skills to analyse data, the use of calculators and the presentation of results graphically. This lack of skills in the more mathematical aspects of science presents a barrier to progress and reduces motivation to study sciences. For all science subjects – biology, chemistry, physics and agriculture – mathematics is a prerequisite because of the need to calculate weights, volume, distances, forces, energy, etc. In biology a lot of mathematics is involved both in the laboratory and outside – for instance in genetics, population, probabilities, and so on. It has been revealed that girls mix up units and that they do not want to work with long figures. These difficulties discourage girls from taking up science because of the mathematical aspects of them.

Table 3 shows clearly that girls' performance in science subjects is lower than that of boys. Boys work harder than girls in science subjects and as a result a good percentage obtain good grades. Boys face stiff competition amongst themselves for university selection. Girls at a co-education school fare worse than those at a female single-sex school.

Table 3
Grades obtained in 1994 Malawi School Certificate examination

Grades	1	2	3	4	5	6	7	8	9
Likuni Girls									
Agriculture	–	2	4	9	22	41	33	14	2
Biology	–	–	2	1	7	11	29	37	45
Maths	–	1	1	2	3	2	5	14	105
P/science	1	6	4	8	4	12	15	8	4
Nkhamenya Girls									
Agriculture	–	2	4	8	16	20	12	3	2
Biology	–	–	–	1	4	13	22	26	12
Maths	–	–	1	2	3	3	6	6	55
P/science	–	2	4	6	6	13	16	14	28
St Patrick's Boys									
Agriculture	2	10	10	10	8	12	8	2	–
Biology	–	–	2	9	12	15	21	16	10
Maths	–	7	11	9	11	11	16	10	6
P/science	1	10	9	5	12	13	17	7	3
Likuni Boys									
Agriculture	–	1	2	18	10	11	5	–	2
Biology	–	1	2	5	9	14	23	12	5
Maths	3	5	5	5	10	6	11	9	17
P/science	5	7	1	5	9	8	8	12	16
Namitete									
Agriculture	–	1	6	11	19	22	30	14	3
Biology	–	–	2	4	5	211	24	29	38
Maths	2	4	3	3	1	6	10	19	69
P/science	3	3	4	2	6	10	20	20	29

Note: Grading system is as follows: 1 and 2 are distinctions; 3 and 4 are strong credits; 5 a good credit; 6 a fair credit; 7 a pass; 8 a marginal pass; 9 a failure.

The mathematics and physical science curriculum

The mathematics and physical science curriculum is outdated because there has not been a mechanism of adapting it. In Form 4 only 424 were selected for science-related courses in university colleges in the year 1989/90 academic year. This is only 6% of the 7000 pupils. Out of this 6% about 1% were girls. The curriculum is very much tuned towards the needs of the minority that go into higher education. It is overloaded with content which is basically aimed at preparing boys for study of the subject in higher education. This is why many girls have a negative attitude towards mathematics and physical science.

MSCE examination and university selection

An examination for selection has a 'gate-keeper' role by which it can open and close doors for individuals to future life chances (Broadfoot, 1979). In a situation where opportunities are very few while those who aspire to them are many, the combined effect of concerns for accountability and importance of certification for selection create immense pressure on teachers and pupils alike. This, combined with lack of equipment, has resulted in teaching methods that have not kept pace with the changes that have taken place in the field of psychology of education, the pupils and attitudes towards science (Dzama, 1992). The curriculum has become irrelevant to present-day concerns. A relevant curriculum taking into account girls full participation in mathematics and science should be developed. The existing curricula were developed about 23 years ago by white expatriates who could not understand fully the needs, attitudes, beliefs, culture and social status of Malawian pupils, particularly girls.

Two other factors that have conspired to make the curriculum irrelevant are its origin and the failure of the developers to recognise the different categories of students in the Malawi Secondary Schools. Fabiano (1980) identifies three categories of students studying science in Malawi:

- Those who will go on to study science and science-related courses in higher education institutions.
- Those who will not go into higher education but will find jobs in science-related areas in industry.
- Those who will neither go into higher education nor engage in science-related employment.

The first category is always a minority; for example, in the 1988/89 school year, out of 7000 pupils only 424 were selected for science-related courses in university colleges.

There is an emphasis on rote learning. This may explain why Dzama (1992) found that many pupils prefer being given notes. The author has studied this and has found out that girls are not interested in understanding the different concepts and principles but in memorising them for examination. This does not help the pupils to understand the concepts. A survey conducted by Fall among African teachers points out that pupils' problems in assimilating certain science concepts come from the teaching methods which often *'lead pupils to recite set formula and even to describe experiments without having really understood the physical reality to which they refer'*. (UNESCO, 1984: 29).

Table 4
Girls' and boys' attitudes towards learning mathematics

		Positive response		Negative response	
		Girls	Boys	Girls	Boys
1	Maths is one of the top three subjects I enjoy	22	81	78	19
2	I have always scored more than 50% in each maths test	19	98	81	2
3	Maths is very difficult	66	15	34	85
4	I do well in maths in all my homework	40	70	60	30
5	I always fail maths tests	90	0	10	100
6	I will not apply maths in my job	83	6	17	94
7	It is very difficult to work maths problems alone	75	4	25	96
8	Gifted and brainy students pass maths	79	40	21	60
9	Maths is taught very fast at our school	51	20	49	80
10	I like maths very much although I do not obtain high grades	60	77	40	23
11	I have enough time after classes to study and practice maths				
12	At times when I excel in maths my friends ridicule and mock me	70	5	30	95
13	Maths is for boys	90	5	10	95
14	I understand maths when the teacher is working some problems in class only	82	31	18	69

Table 4 reveals some girls' and boys' ideas about mathematics. It reveals that:

- Girls like maths but have not enough time to practise and very few pass their homework (4, 7, 10, 11).
- Girls are not encouraged by their friends once they do well but are mocked called names (12).
- Because of this girls regard maths as for boys (8 and 13).
- Girls can only do well after several group work practices and not in class. The time spent by a teacher in class is not enough (14, 7).
- Because of lack of support in girls' education in mathematics girls become frustrated and cannot rate maths as one of their top best subjects, consequently failing to do well (1, 2).
- Girls conclude by saying that they will not use maths in their everyday life (6).

Girls have fixed in their minds the idea that mathematics is very difficult. Some social factors prevent girls from performing well in mathematics.

Teachers' role in class in co-education schools

Some studies have shown that girls at a co-educational school do badly in most subjects, except Chichewa which is a vernacular language. The cause is not girls being weak, but teachers play a role in their failure. Each time girls do better than boys, the teachers go and warn boys with words such as:

> *'Boys are being beaten by girls in class. Watch out. I want to see you beating those girls. What type of boys are you that you get beaten by females?'*

Such remarks are demoralising for girls. Teachers consider girls to be second-class people. Most of the time teachers ignore the girls whom they consider to be laggards, and pay more attention to boys. In many schools the teaching attitude is authoritarian or repressive, in total contrast to the socio-affective approach. The development of the latter could deeply affect the pedagogical practice of teachers and change the whole classroom atmosphere.

Two studies were conducted, one at each of two selected co-educational schools. Girls were put in a separate class from boys. They were taught the same subjects as the boys. The studies, carried out at Namitete Co-education school and Malosa Co-education school, revealed a marked improvement in the performance of the girls in all subjects (Chancellor College Research Centre on Gender Education).

Suggested solutions

The socio-affective approach and daily classroom life

Many teachers are surprised at the difficulties experienced by certain of their girls in mastering various concepts, whether in mathematics or science. Some girls show little interest in their studies and appear to have very little aptitude for listening or paying attention. These girls are considered as 'bad pupils', but repression or reprobation on the part of their teachers can no more help them out of their difficulties than can 'bad marks' or punishments. The problem is solved more effectively by inviting the pupils themselves to work on problems and discuss them in groups in the presence of their teacher rather than for homework. This will lead to an awareness and a thoughtfulness and to an enhanced appreciation of the validity and effectiveness of the rules of mathematics. Thus in the intellectual and affective approach, the pupil fully comprehends what she has experienced in action.

School visits

Mathematics and science quizzes between girls' and boys' schools with problems in mathematics being discussed fully in groups will be valuable. Teachers must emphasise the importance of mathematics as a backbone to science and technology. This intervention will eventually assist girls in appreciating mathematics. This can be done on a reciprocal basis.

National mathematics competition

OLYMPIAD sponsors a mathematics competition annually for form 3 students throughout the country. In 1993/94 academic year a girl from my school won the national top prize. This invigorated some girls and more entries were submitted in the following year.

Science newsletters

The Mathematics Association in Malawi (MAM) and Science Teachers Association in Malawi (STAM) have encouraged the learning of maths and science by publishing newsletters and booklets in which certain points in mathematics and science are tackled. There is a need to produce such booklets oriented to girls' education in science. The Malawi government has introduced basic science and technology in the primary schools for an early age group and at the lowest class. Both girls and boys should progress with science knowledge and technology as they reach higher classes. This will enable each girl to acquire or choose her career and devote her whole life in studying it. Teachers should be trained to be able to sensitise girls to various technical careers. The effectiveness of educational management should be enhanced, especially in the formulation of a curriculum focused on finding new ways of changing girls' attitudes towards boys and mathematics. The media too should take a major role in influencing the socialisation of girls.

Finally, let me close this paper by saying that the curriculum developers and policy makers should redesign the syllabus to include a lot of mathematics at a simple low level, and science and technology which is suitable for both boys and girls. A lot of emphasis must be put on girls' science so that they are able to participate in science and technology activities.

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Mathematics as a barrier to learning science and technology among girls in Papua New Guinea

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ABSTRACT

In a world which is realising that development cannot and must not be blind to gender, Papua New Guinea as a developing nation has the opportunity to avoid the mistakes of history. The country's unique resources demand research and technological development in the fields of agriculture, mining, fisheries, architecture and forestry – fields in which women traditionally have been active at the grass-roots level. Women's participation in the country's scientific and technological advancement is important, not only in itself, but as a way of ensuring that such development maintains a relevance to all levels of society.

Unfortunately mathematics, which plays an integral role in these fields, can act as a barrier to women's advancement, since it is often presented in schools as abstract and without practical application. Girls, often lacking the encouragement and reinforcement received by their brothers, realise only too late that mathematical knowledge is essential for a career in science. The solution seems to lie in using rather than abusing the cultural reality and teaching mathematics creatively at every level of the education system as a part of the Papua New Guinean woman's heritage.

Introduction

The South Pacific island nation of Papua New Guinea attained independence from Australia on the 16 September 1975. In this year of Papua New Guinea's twentieth anniversary, many of those involved in charting the course of the country's future, including educators like myself, have chosen to pause in the headlong rush towards modernisation and prosperity, to take stock. As a 'developing country' – I use the term cautiously – we have the chance to do this, to stop and reflect on our past, and try to learn from the mistakes and successes of our older neighbours. For Papua New Guinea as a developing country, it is fortunately not too late to take this realisation into account when we make our plans for future development. In the words of the first prime minister, Michael Somare, one of the advantages of being a developing country is the lack of pressure to 'set the pace, to take the lead'. In the early years of colonialism, Papua New Guinea was forced into the world of technology. Now is the time for the country to grow into this dubious inheritance.

Papua New Guinea must not make the mistake of believing that the course of its development can be gender-blind. Furthermore, the very notion of development is a colonial one in its very nature, with connotations of a country 'progressing' from its 'primitive' state. So how can

Papua New Guinea determine its future without being misled by the imperialist and sexist mindsets that accompany the idea of development? The question is specially important for my topic, that of Papua New Guinean girls, since they are doubly imperilled when gender and race intersect.

It is a universal phenomenon that girls and women do not experience equality in science and technology. They are poorly represented in science and technology education and training. This limits both their employment opportunities and access to positions of influence in science and technology where decisions about their uses are made. This further limits their participation in and ability to shape science and technology. It is true that careers in mathematics and sciences are not so well paid compared to the high-powered jobs in government, commerce, industries and management. Most of these jobs have an added bonus of perquisites which are not available to scientists or mathematicians. In Papua New Guinea only a small percentage of men and hardly any women have chosen academic careers in the two universities. As a consequence there are not many female role models; most of the staff at the universities and teachers' colleges are male expatriates. It is therefore quite evident that women's education in science and technology should be given high priority so that they can participate in the decision-making process in these fields. The contributions of women to science and technology should be recognised, their benefits should be shared and should be used as a common heritage for all.

Mathematics and Higher Education

Mathematics plays an important role in the degree courses offered in the two universities in Papua New Guinea. It is still considered a difficult subject. In the PNG education system, mathematics is a compulsory subject up to grade 12, although there is an option of choosing a course either in major or minor mathematics. The Papua New Guinea University of Technology caters for degree courses in engineering, architecture, business studies, agriculture and forestry, etc. To obtain admission to any of these degree courses, students need to achieve good grades in mathematics in their grade 12 examinations. Mathematics and sciences are still considered as male-oriented subjects and unless girls show a special interest or are encouraged to take mathematics and obtain good grades, they miss out on admission to these courses in the universities and consequently cannot choose a career in these fields. There is a clear under-representation of Papua New Guinea women in jobs commanding high positions in fields related to science and technology. The education system, the social and cultural factors, all play an important role in this situation.

The Papua New Guinea education system has three main divisions. The community schools teach children from grades 1 to 6, the provincial high schools from grades 7 to 10 and the national high schools grades 11 and 12. Due to the non-availability of seats in these institutions at various stages, we find that there are drop-outs at grades 6, 8 and 10. According to the statistics provided by the department of education, only about 33% of grade 6 students are selected for grade 7 in the provincial high schools and of these about 30% are females. A high percentage of girls also drop out from schools between grades 1 and 6 for various reasons and also at various other stages in the provincial high schools.

Attrition rate of girls from grade 1 to grade 6

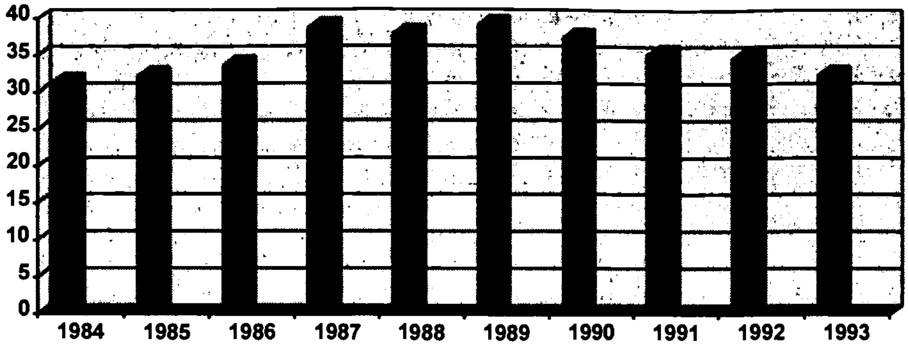

Figure 1
Attrition rate for girls from grades 1 to 6, 1984–1993 (%).
(Courtsey: Department of Education, PNG)

The graph indicates that there is a high attrition rate, at least 30%, of girls in the past few years. The statistics from the Department of Education reveal that only 66% of the girls enrolled in grade 7 go on to complete grade 10. One of the factors here is that there are grade 8 drop outs because only a limited number of seats are available for grades 9 and 10. Only the top 10% of the grade 10 students are able to go on to grades 11 and 12. Out of these, only a third are females. At the national high schools, the completion rate of female students is very good – 95% compared to the low percentage in the lower secondary school. By this time the girls are already aware that this is their only chance to complete and go on to higher education. As we can see, only the privileged ones go to the national high schools and to the universities thereafter. It is a further problem that only a fraction of the students who would like a tertiary education actually receive it, since places are very limited at Papua New Guinea's institutions. The options for those who must drop out are minimal. There are free parochial programs run by various missionary organisations, which offer boys a technical education and girls a domestic one. Hence if we are to increase the number of girls receiving education in the universities, we have to start increasing the numbers from the very bottom, in the community schools, and to make sure that there are enough seats at each stage of the ladder for all those who are capable of going on to higher education rather than them being denied a chance due to lack of seats available in the universities. National Education Strategy (Conroy, 1980) stated:

> *'Clearly in Papua New Guinea, one's chances of getting to school, one's chances of progressing in school and one's chances of occupational mobility are affected by one's sex. The chances of a girl succeeding in these areas are much less than of a boy. Specifically, the chances of advancing higher up the educational ladder are so much less if one is a female.'*

Women's participation in Papua New Guinea's economy

Papua New Guinea's economy is heavily dependent on its natural resources: agriculture, mining, fisheries, forestry, etc. Therefore further research into the technologies relevant to these natural resources is advisable. It is worthy of note that Papua New Guinean women, in general, have traditionally played very central roles in each of these industries at the grass-roots level, to the extent that, to take one example, women's co-operatives revolving around cultivating, harvesting, processing and trading various fruit and vegetable products, have been in place for many generations. And yet, if we look at the relative percentages of men and women undertaking the formal study of these industries in institutions such as the University of Technology, the Forestry Institute or the National College of Fisheries, we are led to believe that women's involvement is reduced, rather than reinforced, by education. Therefore, the full participation of girls in the study of science and technology in Papua New Guinea is essential, not only in their interests, but in the interests of the nation as a whole. Given the important roles that women play in the exploitation of natural resources at the grass-roots level, by facilitating their presence in these industries at the technological level, we will ensure that the development remains relevant to all strata of society in Papua New Guinea, and becomes neither elitist nor gender-biased.

According to the agriculturist Mr Steve Woodhouse (Woodhouse, 1995):

> *'Papua New Guinea can no longer afford to be complacent. PNG agriculture must be aggressive and technically competent as the world markets for primary produce get more competitive. If one includes forestry and fishing as rurally based, then the primary sector contributes one-third of the entire gross domestic product, in excess of K330 million. The sector employs more than 80% of the labour force and provides for the daily needs of more than 80% of its rurally based population'.*

He noted, however, that agriculture had always been a low priority sector, in 1994–95 receiving less than 5% of the national budget:

> *'Many Papua New Guineans see agriculture as an employment for the uneducated and this mentality needs to be challenged. One has to look north to see what can result from an efficient agricultural economy. The economies of Malaysia and Thailand for example are both becoming industrialised at a rate that outperforms any western economy. The basis of this has been downstream processing of agricultural products and rural farmers are now benefiting from these developments. The basis of a sound economy and a socially stable nation lies solely in agriculture. To achieve similar rate of growth, the country needs increasing numbers of highly skilled agriculturists, research personnel and marketing experts.'*

He also added:

> *'Papua New Guinea being tropical has a wealth of genetic material which is both underexploited and in a large number of cases unused; we need to develop these latent resources, not allow others to gain advantage by exportation and exploitation of the nation's genetic resources.'*

Also, to quote Sir Alkan Tololo, Chancellor of both the universities in PNG:

> *'PNG's future lies with agriculture; there is mining, there is oil but those resources will be exhausted and at the end we will fall back on agriculture.'*

In spite of agriculture and mining being so important in PNG's economy, not many women have opted for these careers.

In 1995, in Vudal Agricultural University College, there were 116 male and 21 female students registered and at the end of the year, 111 male and 19 female students completed their course. In the Bulolo Forestry College 33 students graduated, of which 6 were females. In the University of Technology, 29 graduated, out of which 4 were females. These figures show that females are very poorly represented in these fields which are so important to PNG's economy. If we look at the enrolment of girls taking various courses at the University of Technology in 1995 (table 1), we see that the largest number of entrants opt for business studies, the second choice being applied sciences (food technology and chemistry).

Table 1
Percentage of female students enrolled in various departments at the University of Technology, 1993–1995

	Agric.	Arch.	Applied sciences	Business studies	Forestry	Computing	FYEng.	Surveying
1993	10	15	27	34	20	6	11	5
1994	14	10	34	34	21	15	10	10
1995	19	10	33	34	20	25	8	11

With the growing importance of agricultural research and related job opportunities, more and more females are choosing this field. With the introduction of the computer science programme in 1993 at Unitech, more girls are attracted to this discipline. There is a steady decline in the percentage of girls opting for engineering subjects in favour of computer science; business studies and applied sciences still seem to be popular choices compared to the others. It is very important that more girls should opt for agriculture and mining so that they can choose a career and be a part of the decision-making bodies.

The overall percentage of girls studying at the Unitech has not increased much. In fact, if we consider the enrolments of female students studying in the PNG University of Technology in the past 8 years (figure 2), we see that the percentage of female students is very low compared to the male students, although the number is slowly but steadily increasing. Due to these small numbers, they are also under-represented in careers involving these fields.

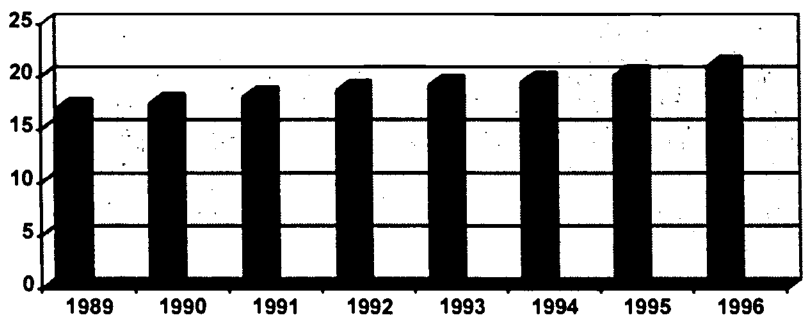

Figure 2
Female enrolments at the University of Technology, 1989–1996 (%).

In spite of such a low rate of enrolment and a privileged situation where only a top few can go into higher education, there is still a high drop-out rate among female students at both the universities in PNG. There have been several barriers for girls in Papua New Guinea pursuing higher education, in a predominantly male-oriented society. In the villages, the girls are not encouraged to go to schools but are expected to help with household chores and looking after the younger siblings. However, changes are taking place due to the introduction of free primary education and encouragement by the government. Normally girls have been perceived as home-makers and child-minders. Even in educated families sometimes we find that the boy is sent to an expensive international school, with the most modern facilities for schooling, whereas the girl is sent to a community school that has hardly comparable schooling facilities.

The problem also resides largely in the fact that Papua New Guinea's provincial school system is an antiquated inheritance from the colonial era, both in its curriculum and its overall design. Structured loosely on a base of old missionary schools, the system is heavily marked by its history: after all, it was created initially in an effort to develop a virtuous and docile population of labourers, rather than dynamic leaders. In this country, where, since colonial times, the economy has been based on cash crops such as copra, coffee, tea, rubber and palm oil and minerals such as copper and gold, the Papua New Guineans were trained to be skilled manual workers or low-level administrators. Furthermore, the persistence of sex-segregated classes, where girls are taught domestic sciences while boys receive training in woodwork and basic mechanics, creates an inhibiting mindset that only perpetuates racist gender stereotypes about the career fields appropriate to Papua New Guinean men and women. There is no reason to hold on to this residue of a system that wanted to cultivate polite female servants and obedient male workers. As Papua New Guinea progresses beyond the plantation-owner norm, the education system seems more and more incongruous, and nowhere is the anomalous nature of the curriculum more apparent than in the manner in which mathematics is taught.

The main flaw in the teaching method itself is the presentation of mathematical concepts, from the derivation of square roots to the idea of fractions, without the aid of possible practical applications. Students are inevitably alienated by the fact that, in this context, mathematics seems irrelevant to their lives and the realisation of its importance in their future career goals can come too late. In the University of Technology, taking mathematics as a major subject is a prerequisite for admission to most courses. Many applicants, especially women, are not specially advised or encouraged to take this option at secondary school level. We also find that the attitudes of teachers towards girls are not the same as towards boys. Mathematics is normally considered as a male subject and often girls do not have the self-confidence to take higher mathematics courses in a class dominated by boys.

The transition from national high school to the universities, which came into their own after independence, and therefore carried less colonial baggage, can be very jarring for successful applicants. In the University of Technology, for example, where mathematics obviously plays a pivotal role in all of the courses, we see entering students, especially female students, experience a drop in performance levels in mathematics classes compared to boys, although their results in grade 12 at the national high school level were not significantly different (Sukthankar, 1995). Robertson (1993) found that the failures in the first year of business studies at Unitech were directly related to the grade 12 mathematics results of these students. He had recommended therefore that the Business Studies Department should only accept students with A grades in minor maths and should not accept at all students with major maths less than grade C and minor maths less than A. To investigate this issue further, we studied the progressive mathematical performance of students in the Business Studies Department from grade 12 in the national high schools to the second year of their education in the University of Technology. We were interested in investigating how the grade 12 results had a recurring influence on the progress of these students and also in the relative mathematical performance of female students compared to their male counterparts (table 2). For the sake of completeness, we give here some of the results of Sukthankar (1995).

Table 2
Students' performance in the years 1989, 1990, 1992 in the Department of Business Studies

	Males	Females	All
	50	33	83
1989	54.24	55.97	54.928
	9.709	8.053	9.075
1990	63.220	59.121	61.590
	14.437	11.973	13.583
1992	63.18	64.424	63.675
	9.009	8.474	8.77

Note that, in 1991, there were students strikes and therefore they boycotted the exams. The same students rejoined in 1992.

Two tests were performed to determine whether there is any significant difference between the relative performance of the male and female students in the first and second years of their university examinations (table 3).

Table 3
Significant difference tests

	N	Mean	Std dev.	SE mean
Results of the first test for 1989/90				
Males	50	9.0	12.3	1.7
Females	33	3.2	11.1	1.9
$p = 0.028$				
Results of the second test for 1990/92				
Males	50	0.0	11.4	1.6
Females	33	5.3	11.8	2.1
$p = 0.045$				

Both the tests show that the results are not significant at 0.05 level.

There is no increase in the mean of male students from first year to second year. However, the female students have a 5.3% increase in their mean over the first year. There were several reasons why females did so badly in the first year. They were faced with lots of problems while settling down in the first year which affected their performance, but they appear to have made up for the loss in the second year.

It seems more than probable that having to adapt from very abstract mathematics to a kind of mathematics which is far more integrated into their career path, proves somewhat disturbing for all students. At least for boys, the exposure to applied mathematics through technical courses in high school permits an easier transition. It is noteworthy that performance in mathematics has improved by the second year. This is largely attributable to the foundation mathematics classes implemented by the university in order to prepare students for the specific skills demanded by the particular field of study that they have chosen, whether that is mining, mechanical engineering or business studies.

The teaching of mathematics is also complicated by the fact that, for the majority of the students in Papua New Guinea, English is a second, if not third, language. This is especially problematic for girls since, in many of the ethnic groups in the country, they are not permitted access to popular culture in English, though their brothers are, making the double translation from their mother tongue into English and into mathematical thinking more laborious for them. The popular conception of mathematics as a universal language does not give us permission to consider it as an entity which can somehow be isolated from the cultural contexts in which it is taught. And yet, in a country of 700 different languages, there is really no option but to use English, which is rendered generally familiar by virtue of the history of its use in the country.

What is being done to counter these problems?

What are the remedies?

- The University of Technology has started a 'Popularising Mathematics Programme' over the past five years. We have been publishing a regular feature called 'Fun with Mathematics' which is informative and interesting for the students. We give a couple of mathematical problems to be solved and the students are requested to send in their solutions which are published the following week. Often photographs of all those sending correct entries are also published and some prizes are given. This has encouraged many PNG girls and boys to take part and it has become a very popular feature of the *Unitech Weekly* with a PNG-wide circulation. This is also enjoyed by the PNG national academic staff who missed out on such fun in their student days.
- Since 1992, the University of Technology has also started an annual mathematics competition for all the tertiary educational institutions in the country. It is encouraging that girls are participating with enthusiasm in the competition and have been regular top prize-winners.
- A computer-aided teaching programme has been introduced in the university to teach mathematics and other subjects. We find that, especially for mathematics, the students enjoy learning in this new environment. The visualisation technique of certain abstract mathematical topics is appreciated, rather than the standard learning process of theory and problem-solving. We have also found that assignments and projects have made learning mathematics faster, easier and more interesting. It is worth noting that girls participate comfortably in small-group discussions and often take leading roles in this atmosphere, compared to their normal shy and quiet presence in the large classrooms.

There is a lot that needs to be done at the school level.

- The school curriculum should be developed so that it is need-specific. It should focus on an education which offers the maximum number of possibilities and opportunities, retaining the national identity. The material should be tailored to cater for student interests.
- Parent sensitisation is essential.
- Teacher training is important. Teachers should not be gender-biased and should be able to teach mathematics by applying it to day-to-day problems. Gender equity in the classroom is essential and peer pressures and expectations should be closely monitored. Full participation in the classroom should be encouraged.
- Making mathematics more concrete, demonstrating throughout its relevance to all aspects of life.
- Non-elitist emphasis through less use of text books, assuring more direct teacher contact.
- Teachers should ensure positive classroom dynamics with more student involvement.
- Secondary schools should emphasise the choice of career-related courses to reduce abstractness.
- In any development project, it is important to identify needs and solutions to problems of men and women separately, since their needs are different. It has often been recommended that one way to promote science among girls is to have exhibitions with the objective of popularising mathematics and science.
- Women should be exposed to new technology to assist them in making appropriate choices directly affecting them and also enabling them to identify solutions to these problems. They should be using their traditional knowledge, which is often suppressed as inferior and inappropriate by so called agricultural scientists.

Conclusion

Central to the teaching and learning of mathematics and science are perceptions, aspirations, beliefs and motives the teacher brings to the classroom. These effective elements are influenced by social interactions and expectations as well as previous classroom experiences. In turn they influence the learner's relationship with the teacher, their peers and their science and mathematics experiences. Change in teaching practice in the classroom is an important key factor in promoting long-term change in the field of science and technology. The teachers should be encouraged to change their practices in such a way that the girls are empowered to learn science and technology in a manner which meets their needs, interests and culture. The teachers should be motivated to change their teaching practices. Mathematics and science are not parts of Papua New Guinea culture. There is an inherent fear of mathematics. It is not just mathematics but science in general are still considered as difficult subjects.

It is impossible to undo the cultural reality of colonialism in Papua New Guinea. Desiring both the integrity of the country's identity and the advantages of technology professed by the old rulers, we must, as Homi Bhabha (1994) says, want to join the two, while never forgetting to look for the join between them.

Acknowledgement

I wish to thank my daughter Ashwini for her valuable help.

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Mathematics as barrier to learning science and technology amongst girls

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In Tanzania mathematics is given a lot of emphasis in terms of time allocation and contribution to further education. At primary level, time allocation as compared to other subjects is as follows:

	Mathematics	Kiswahili	English	Science	Total no. of subjects
Standard 1–2	33.3%	33.3%	0%	0%	7
Standard 3–4	14.3%	14.3%	17.1%	6%	11
Standard 5–7	15%	12.5%	15%	6%	13

All children at pre- and primary school level must do mathematics. The primary school leaving examination is comprised of three papers as follows:

		Subjects	Marks	Total
P1	Mathematics	Mathematics	50	50
P2	Language	Kiswahili	25	50
		English	25	
P3	General knowledge	history	10	50
		geography	10	
		science	10	
		domestic science	10	
		civics	10	
			10	

Selection to government secondary schools is based on results from these examinations. Selection to all good private secondary schools is based on entrance examination by the schools. Most schools examine mathematics and English with more weight placed on good performance in mathematics. It is obvious that poor performance in mathematics at primary level results in a child not securing a place at a reasonably good and well equipped secondary school.

At secondary ordinary level basic mathematics is compulsory for all students. Since 1976 the secondary education system has four biases, namely agriculture, home economics, commerce and technical subjects. Students take compulsory and optional subjects as per bias. Time allocation is 20% for the bias subjects, 15% for mathematics while other subjects are allocated 5–10% of the time. Mathematics is a prerequisite for 26 out of the 1992 proposed 30-subject combinations at Advanced level (some of the 30 combinations are yet to be taught). Mathematics is a prerequisite for all combinations leading to science and technology studies.

As such, failure in mathematics limits to a great extent the chances for advanced secondary level education and hence tertiary level education in general. In particular, one has absolutely no chance of studying for science and technology professions without passing mathematics.

At Advanced level, all science and technology, commerce, economics, computer science, and geography combinations include the study of mathematics at a principal or subsidiary level.

A student with the combination of mathematics, physics and chemistry at Advanced level can be admitted to 9 out of 11 degree programmes at the University of Dar es Salaam and in 2 out of 3 of all the Advanced Diploma programmes in the tertiary-level institutions in Tanzania.

The performance in mathematics by girls starts to drop when they are in standard 4 and by the time they reach standard 7 the difference in gender becomes apparent, particularly for girls in rural areas. This has led to most girls joining the poor quality private secondary schools. Girls enrolment in science and technology studies is greatly restricted by their poor background and poor performance in mathematics.

Mathematics as a barrier to learning science and technology amongst girls in Uganda

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ABSTRACT

It is difficult to establish facts concerning mathematics as being or not being a barrier to learning science and technology amongst girls in Uganda without conducting a proper research project. Nevertheless, through the limited pilot qualitative research, I carried out using interviews on a small number of 35 (11 male and 24 female) interviewees and document analysis, supplemented by scanty literature review, the following arguments are put forward.

Mathematics is a science. Its symbolic nature makes it a means of communication that is precise and concise. Most sciences use it in expression of their principles and theories. Mathematics is used so much as a tool in science and technology that some, like physical sciences, become very mathematical. To people that fear and dislike mathematics, science and technology is likely to be seen as a threat. This appears to be the case with girls in Uganda.

Introduction

In this paper, science, technology and mathematics are defined and the relationship between them briefly pointed out. Science learning and the role of mathematics in it is outlined, leading on to discussion of the connection between mathematics and the learning of science and technology by girls in Uganda. Appendixed is a brief report on the findings of a mini qualitative research project carried out by the writer, and some statistics of girls in mathematics, science and technological careers at Makerere University.

What are science, technology and mathematics?

Science is the study of matter, its forms and interactions. It is a search for systematised knowledge derived from observations, study and experimentation, so as to establish, understand and explain facts and principles and to establish methods.

Technology is the practical application of scientific knowledge and understanding to satisfy human needs. It consists of the practical knowledge of what can be done and how. It is characterised by techniques, devices, procedures and materials. It seeks to translate scientific ideas into practical workable realities.

Mathematics may be defined in various ways (Kattsoff, 1949). They are of two main types: they may be mathematical (if they result from consideration of the critical philosophy of mathematics) and they may be epistemological (if they result from considerations of the speculative philosophy of mathematics). According to Mutunga and Breakell (1987) they vary depending on the view of the definer. In this paper mathematics is defined, as in Mutunga and Breakell (1987), as:

> '– *A way of thinking in which one determines and interprets the truth of an idea or information. A language, which like other languages, uses carefully defined terms, symbols, to express ideas and communicate thought.*
>
> – *An organised and well structured body of knowledge, where ideas, concepts, principles, and theorems are built logically from previously built ideas, thoughts etc.*
>
> – *An abstract system of ideas.*
>
> *And as Bell points out, mathematics is:*
>
> – *The study of numbers, operations on numbers, shapes and measurements, patterns, shapes and relationships that one studies in school mathematics.*
>
> – *A collection of interesting and useful discoveries that have been made throughout the centuries.*
>
> – *An interesting hobby, pastime and diversion. A fascinating mental activity that permits us to test and extend our intellect.*
>
> – *A very useful tool for exploring and describing many aspects of our environment as well as the functions of our minds and bodies.*
>
> – *An indispensable tool for trade, commerce, and other types of human interaction and communication.*' (1987: 4–5).

Mutunga and Breakell summarise mathematics as 'a creation of the human mind: concerned with ideas, processes and reasoning..:' (1987: 57)

The relationship between mathematics, science and technology

It is important to understand the relationship between science and mathematics if one is to understand how mathematics can be a barrier (or not) to learning science and technology.

Mathematics, a science

Mathematics has been categorised as a science by philosophers such as Kattsoff, (1949) and Hull (1965). According to Kattsoff, mathematics is a science of numbers and magnitudes which has for its object the indirect measurement of magnitudes and deals with the universal laws (forms) according to which all extant things must behave. Mathematics deals with the investigation of concepts which express the relationships of objects to each other and draws necessary conclusions.

Paul Ernest (1991) discusses the philosophy of mathematics developed by Imre Lakatos (1976, 1978) as accounting *'for the nature of mathematical knowledge as hypothetico-deductive and* *quasi-empirical, building a striking analogy with Popper's 1979 philosophy of science.'* (1991: 38) He goes on to say that Lakatos *'accounts for errors in mathematical knowledge and provides an elaborate theory of the genesis of mathematical knowledge.'* This he says *'potentially accounts for much of mathematical practice and for its history.'* (1991: 38).

Ernest, however evaluates quasi-empiricism as offering *'a partial account of the nature of mathematical knowledge and its genesis and justification.'* (1991:40). Nevertheless, he says 'quasi-empiricism has the potential to offer solutions to many of the new problems Lakatos posed for the philosophy of mathematics.' (1991: 40).

Ernest's arguments also point to mathematics being a science in some ways. If, as according to Kattsoff (1949), Hull (1965) and Ernest (1991) mathematics is categorised as a science, it follows that its study is capable of helping the learner gain something of what is gained from the study of science. According to White (1993) the learner gains ability to apply the scientific method from the study of science; part of which is *'reflection on observations: framing questions to oneself about why something happened.'* (1993: 163). Another part being *'the varying of one factor to study its effect while holding other factors constant.'* 1993: 163). Both of these parts of scientific method do manifest themselves in the study of mathematics. However, this depends heavily on the teacher's presentation of the mathematics to the learner.

Mathematics, a tool in science

Secondly, mathematics is a tool in science and technology. There is historical evidence that mathematics and science developed side by side. For example, Hull (1965) recorded that the rise of Greek geometry was an essential preliminary to serious scientific advance. He also acknowledged mathematical methods to be valuable in predicting the consequences of what is already known empirically to be the case. Bell's statement in 1937 that *'the great mathematicians have played a part in the evolution of scientific and philosophic thought comparable to that of the philosophers and scientists themselves'* (p.4), also in a way implies the usefulness of mathematics in the development of science.

Ernest (1991) agrees with Cockcroft (1982) who summarised the usefulness of mathematics as arising from its provision of a powerful concise and unambiguous means of communication. Cockcroft went on to say that some people see it as a basis of scientific development and modern technology. In this, he was right. An example is Mustaq, a professor of mathematics in Quaid-i-Azau University, Islamabad, who in 1990 called it a foundation of science and technology.

Ernest summed up the usefulness of mathematics in the following statement:

> *'Overall, the applicability of mathematical knowledge is sustained by the close relationships between mathematics and science both as bodies of knowledge and as fields of inquiry, sharing methods and problems. Mathematics and science are both social constructs and like all human knowledge they are connected by a shared function, the explanation of human experience in the context of a physical (and a social) world'* (1991: 59-60).

Intrinsic uses of mathematics in learning science

Besides being a tool in science and technology, mathematics has some intrinsic uses. These are, however, appreciated by few people. For example in the interviews at Makerere University only 25% of those interviewed appreciated and mentioned them. But the study of science inculcates in the learner, skills and abilities, sharpening them (if already existent) for use in science learning and for other activities in life. Problem-solving, logical thought, neatness, accuracy, honesty and patience are some of them.

Of course, some people may argue that some of these skills and abilities are not especially noticeable amongst mathematicians. To them I would say, like Mutunga and Breakell (1987), that the extent to which these skills and abilities are achieved will depend mainly on the way mathematics is taught. Besides, as Bell expresses so well:

> *'it must not be imagined that the sole function of mathematics, "the handmaiden of the sciences", is to serve science. Mathematics has also been called the "Queen of Sciences"...; mathematics has a light and wisdom of its own, above any possible application to science, and it will richly reward any intelligent human being to catch a glimpse of what mathematics means to itself.'* (1937: 4).

Before we go on to see the connection between mathematics and the learning of science, let us look at factors that affect the learning of science.

Factors that affect learning of science

White (1988) presented descriptions and predictions about the acquisition of knowledge of science and its application in understanding natural phenomena. He put forward a model depicting learning as a performance determined by teaching, the learner's knowledge, ability, attitudes, needs and perception of the context in which he or she is placed; that it is an outcome of these various influences (figure 1).

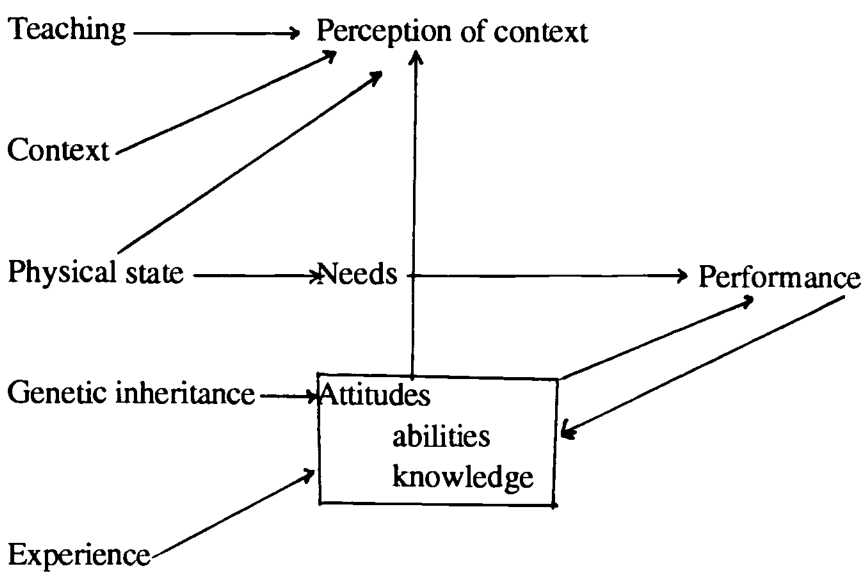

Figure 1
Model showing influences on performance (Source: White, 1993, p.15)

The connection between mathematics and the learning of science and technology of girls in Uganda

Now we come to the connection between mathematics and the learning of science which should lead us on to see how mathematics can be said to be a barrier to learning science amongst girls in Uganda. From White's model, it might be argued that mathematics is connected to learning science in as much as it forms part of the learner's experience, and therefore influences attitude formation, facilitates knowledge acquisition and contributes towards inculcation and sharpening of skills and abilities. It may therefore be argued that it influences perception of context and ultimately performance.

Does this make sense in the Uganda context? An answer would be: mathematics may be a hindrance to the learning of science by those girls already on the course; but it may also bar entry into scientific courses of those girls who may wish to study science. Let us see how it does this.

Mathematics, part of learners' prior knowledge

Because science is hierarchical, knowledge acquired from earlier lessons and experiences contributes to future learning of science. Since mathematics is the language of communication in sciences (Ernest, 1991; Cockcroft, 1982) it forms part of the learner's earlier experiences which contribute towards acquisition of prior knowledge necessary for acquisition of new concepts. Cockcroft rightly pointed out that:

> *'Mathematics is not only learned in mathematics lessons, a great deal of it is used and learned in science especially in the physical sciences and technical drawing'* (1982:.281).

Besides, in Uganda, mathematics is compulsorily studied from kindergarten (3–6 years of age) to Ordinary level of secondary school (16 years of age).

Now if learning mathematics is part and parcel of most of learning science, it can be argued that mathematics is likely to affect learning of science in various ways.

Effect through attitudes

One of these effects would be through attitudes, as seen also from White's model. Most girls in Uganda have a negative attitude towards mathematics (Lobund 1991), that of fear (Ssajjabbi, 1992). Many say it is hard and have little confidence in their ability to do it; as a result they accumulate anxiety (Ssajjabbi, 1992) and also lose interest in it.

It is very likely that this negative attitude towards mathematics spreads to science learning, causing many to shy away because they see lots of mathematics in science, and are constantly told so by teachers and others.

Effect through insufficient knowledge of mathematics

Another way in which mathematics is likely to affect girls' learning of science lies in the fact that the majority of girls (and boys) in Uganda perform poorly in mathematics. Kagawa (1993), in searching for reasons for the high failure rate in mathematics at Ordinary level, found that there was a general feeling by students that mathematics *'is wide and difficult to understand'*.

The poor performance arising from lack of understanding influences the prior knowledge of mathematics needed for science learning. The girls are therefore likely to find science difficult to understand.

Also lack of understanding of earlier taught mathematics concepts is likely to affect the understanding of later taught concepts. This may lead to lack of interest in the lessons that follow, resulting in little or no participation on the part of the learner. The end result is that the girls may not acquire the skills, abilities and knowledge that the study of mathematics avails to the learner.

These skills and abilities (for lack of a better word), although White (1988) calls them minutiae, and the majority of people tend not to see them as important acquisitions from the study of mathematics, *are* important and contribute greatly to learning science.

Quick, sharp-thinking and logical reasoning among others are vital in learning science and doing scientific and technological work. Skills like accuracy and neatness are vital to any successful scientist, for they are needed in measurements during experimentation. Virtues such as honesty and patience, acquired through solving the long, 'hard' problems of mathematics, are needed in scientific work.

Some of the school girls interviewed pointed out that mathematics instils into a learner an alert, active and hardworking nature. They also pointed out that there are girls who are lazy and do not like to bother themselves and therefore they cannot do mathematics. The above-mentioned qualities are important to learning science because of the observations, measurements and calculations that have to be carried out in scientific experiments.

One mathematics educator interviewed mentioned that problem-solving skills learnt in mathematics enable him to come to solutions to problems at his place of work much faster than his colleagues who are not mathematically minded. These problem-solving skills are also needed in learning science.

Once the girls fail to acquire these skills and abilities though their lack of interest in mathematics, they are likely to fail to learn science.

Mathematics, a requirement for most science and technological courses at university and college levels

Another way in which mathematics is likely to be a hindrance to girls' learning of science, especially at high school, college and university levels, is the fact that most of the science subject combinations at high school, which are a prerequisite for entry into courses at higher levels, require one to study mathematics either at principal or subsidiary level.

In any case, most science and technological courses at university require some knowledge of mathematics, which makes mathematics 'a critical filter' (Ernest, 1991). To emphasise this point, one experienced female mathematics educator, who taught mathematics in one of the best performing girls' secondary schools in Uganda, explained that in the past (1970s and early 1980s) when the high school mathematics had mechanics as an option (Alternative S(P440)), the faculty of Technology at Makerere University (then the only University in Uganda) would hardly admit male students who did Alternative S(P440). This was because they expected most of the girls who did this alternative not to have done mechanics which was a necessity for the engineering courses. And indeed many girls used to opt out of mechanics at school level.

Mathematics in the science syllabuses and the way science is taught

One other way that mathematics is likely to affect girls' learning of science may be traced to the science syllabuses and the way it is taught. It cannot be stated with certainty about Uganda, but White (1988) suggested that some teachers, when teaching science, end up teaching mathematics. He illustrated this by an example in physics of Faraday's Law of Induction quantified as the Faraday Neumann Law ($E = d\phi/dt$). He said that teaching often concentrates on training students to apply that formula to exercises, resulting in students being practised in algebra.

Two secondary school science teachers completing a masters degree in education pointed out that there is a lot of mathematics in school chemistry. They talked of physical chemistry being the basis of other branches of chemistry, that it is taught for the first time in schools and the 'mole concept' which involves mathematics runs through the course.

Although nothing convincing can be argued from this until further research is done, when one observes the way sciences are taught in Ugandan schools, one may be tempted to believe White's suggestion.

There are many newly established schools and in these there are no laboratory facilities; science is taught theoretically. In such schools, measurement, observation and scientific method are lacking while emphasis is placed on intellectual skills of identifying values of quantities and substituting them in formulae. This *'should not dominate school science'* (White, 1988: 163)

Evidence from university enrolment statistics

Another source, from where it may be argued that mathematics is likely to be a hindrance to girls' learning of science and technology in Uganda, are the statistics of enrolment into undergraduate science and technological courses at Makerere University (see Appendix C). It may be observed for example, that more girls (135/461) enrol in medicine (not considered to be mathematical) than in engineering (41/249) (considered to be too mathematical).

Conclusion

In conclusion, from the above arguments, it is possible that mathematics hinders Ugandan girls from learning science and technology. The negative attitude of girls towards mathematics is a major cause because it directly affects learning of not only mathematics but also of science and technology.

Girls find mathematics hard to understand and so give it up at an early stage, hence undermining their understanding of it and that of science and technology. Their lack of understanding affects their interest in learning mathematics, leading to their failure to acquire the skills, abilities and knowledge which the study of mathematics inculcates into a learner and which are vital in learning science and performing all scientific and technological work.

The views of the majority of people interviewed in the mini research project (70%) suggest that mathematics can hinder girls' learning of science and technology. Whether the views of these people are their own or originate from elsewhere, their views represent those of the majority in society.

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Appendix A

Report of the mini research project carried out in Kampala concerning mathematics as a hindrance to girls' learning of science and technology

Interviewees

The interviewees comprised of 24 females and 11 males with a minimum education of Ordinary level of secondary schooling. There were 6 university lecturers, 4 postgraduate students doing masters (MSC/MA/MEd) degrees, 5 secondary school teachers, 15 secondary school students, 3 working people and 2 school leavers. Some were arts-oriented while others were science-oriented.

Interviews

The interviews were short informal and conversational. Questions in the interviews included:

1 Would you say that mathematics can be a hindrance to girls learning science?
2 What is it in mathematics that hinders girls learning of science and technology?
3 Do you think that there is a lot of mathematics in sciences so that it scares girls away?

These questions and others arising from them were asked. The other questions, asked in a conversational way, probed further into the meanings of the interviewees' views, seeking explanations and elaborations.

Methodology

All the interviews were impromptu, conducted informally, and without prior arrangement/appointment. The researcher interviewed anyone whom she happened to meet and who was in a position to talk. She also visited a girls' secondary school where she interviewed nine girls, also without prior notice. The school students and some others were mainly interviewed in groups. Many were interviewed as individuals. Their responses were recorded in a notebook from where they were analysed and organised into the report below.

Responses of the interviewees

When asked whether mathematics can be a hindrance to girls learning science and technology, the majority (70%) of the interviewees agreed that it can be. The majority could not explain why and how mathematics can be a hindrance to girls' learning of science and technology but a few scientists and mathematics educators (25% of the interviewees) gave some insights about the issue. These pointed out that mathematics develops quick, sharp thinking and logical reasoning, makes the learner more alert, active and hardworking. It inculcates in the learner skills of problem solving and helps in the interpretation of scientific calculations. Some mentioned that the feeling that people have that mathematics is hard, causes mathematics to be a barrier to girls in their study of science. They suggested that if this attitude of girls and the public at large could be changed, it would help girls to do mathematics and hence participate in science and technology. This mental attitude is reflected in the responses to question 2.

When asked what it is in mathematics that hinders girls' learning of science and technology, the main response was that girls are scared of mathematics because it is hard. Some female secondary school students :said that the mathematics is not taught well and needs hard work and interest, if one is to do it well. One school girl and two school boys observed that many girls are lazy and mathematics needs continuous practice.

When asked whether there is a lot of mathematics in science so that it scares the girls away, many agreed that in physical sciences, there is a lot of mathematics and that in order to cope one needs to be able to do mathematics. However, interviewees that are specialising in biological and environmental sciences, did not think that there is enough mathematics in these sciences to scare away anybody; the mathematics that there is, is manageable.

In summary

The majority of the interviewees (70%) agreed that mathematics can be a hindrance to girls' learning of science and technology. However, only a few (25%) could attempt to explain how this comes about.

Appendix B1

Enrolment of female students in undergraduate mathematics and pure science courses

Figures from Makerere University Academic Registrar's department, Undergraduate Students Nominal Roll 1994–95

Course/ subject	Math	Chem	Bot	Zool	Geog	Geol	Biochem
No. of girls	46	64	99	103	33	12	26

Appendix B2

Enrolment of students in undergraduate mathematics courses

Figures from the Department of Mathematics at Makerere University Nominal Roll 1995–96.

Year	1B	1B	1B	1E	1E	1X	1X	1X	2S	2X	2X	2Y	2Y	2Z	3X	3X
Course	SC	BLIS	SS	SC	STAT	BLIS	ED	SC	STAT	ED	SC	ED	SC	SC	ED	SC
No. of students	60	2	1	33	78	1	56	218	63	51	80	5	4	8	16	70

KEY

B A remedial mathematics course that terminates after one year, taken by those students intending to be teachers or mathematicians.

E Mathematics course that terminates after one year and taken by students doing Bachelor of Statistics degrees.

X Mathematics course pursued by students intending to be teachers.

Y Mathematics course pursued by physics students.

Z Mathematics course pursued by those students who intend to specialise in mathematics.

SC Science

SS Social Studies

BLIS Librarianship

ED Education.

Appendix C

Registration statistics

Ugandan students registration statistics for 1994/95 as at June 1995 (Makerere University) for undergraduate science and technological courses.

Course	MB, CHB	BDS.	BSc Nurs	BPharm	BSc Ag	BSc For	BFST
No. of students:							
male	326	30	0	31	258	107	51
female	135	20	17	7	77	17	29
TOTAL	461	50	17	38	335	124	80

Course/ subject	BSc Ag/Eng	BSc Eng	BSC Surv	B. Arch	B Stat	BSc	BSc Ed	BVM
No. of students:								
male	62	208	42	36	145	590	117	182
female	2	41	2	12	34	208	50	16
TOTAL	64	249	44	48	179	796	167	198

KEY

MB,CHB	Bachelor of Medicine and Bachelor of Surgery
BDS	Bachelor of Dental Surgery
BPharm	Bachelor of Pharmacy
BSc	Bachelor of Science
BSc Ag	Bachelor of Science in Agriculture
BSc For	Bachelor of Science in Forestry
BFST	Bachelor of Food Science and Technology
BSc Ag/Eng	Bachelor of Agricultural Engineering
B.VM	Bachelor of Veterinary Medicine
BSc Eng	Bachelor of Science in Engineering
BSc Surv	Bachelor of Science in Surveying
B Arch	Bachelor of Architecture
BStat	Bachelor of Statistics
BSc Ed	Bachelor of Science with Education
BSc Nurs	Bachelor of Science in Nursing.

The relationship between the learning of mathematics and the learning of science and technology amongst girls in Zambia

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ABSTRACT

The paper looks at the mathematics needs of school science and technology and notes that there is a reasonable basis for relating the performance of pupils in these subjects to their competence (or lack of it) in mathematics. It draws on the work of the 'Girls Into Mathematics and Science Study Group (GIMSSG)' in Lusaka, Zambia, on a study done at one of the secondary schools in Lusaka and on related literature and concludes that much as mathematics might be a barrier to girls learning science and technology, other factors might be exerting even more influence and that the case for the relationship between the learning of mathematics and science needs more rigorous study.

Introduction

In addressing the question of whether or not mathematics is a barrier to the learning of science and technology amongst girls, some preliminary questions call for answers. First, is there a problem of learning science and technology amongst girls, that is, are girls performing less well than boys in science and technology and/or are girls opting out of these subjects? Second, how much mathematics do school children need for their learning of science and technology, that is, is the amount of mathematics in school science and technology high enough for weaknesses in mathematics to have any serious bearing on the learning of science and technology?

The Open University/Inner London Education Authority (1986) has summarised the work of John Ling (1977) on the amount of mathematics in school subjects. It says:

> 'Physics *is by far the most extensive user of mathematics, drawing on all aspects of mathematical enquiry.*
>
> Chemistry *places relatively low demands on mathematical skills up to O-level; nevertheless it requires use of symbols, decimals, ratio, proportion, algebra, geometry, logarithms and so on.*
>
> Biology *involves a fairly small range of mathematical topics: graphical representation, percentages, proportion, scale factors, volume and statistics.*
>
> *Technical subjects are practical rather than theoretical but nevertheless involve arithmetic, mensuration, geometric construction and orthographic projection.'*
> (OU/ILEA, 1986, pp 19)

From Ling's analysis of the mathematical content of other school subjects, we would expect that should mathematics be a barrier to the learning of science and technical subjects, the degree to which this would be the case would be (in increasing order of the extent of the effect) technical subjects, biology, chemistry and physics.

The discussion that follows will explore the relationship between the learning of mathematics and the learning of science and technology amongst girls in Zambia.

Performance of boys and girls at O-level in Zambia

Table 1 shows School Certificate results for selected subjects in Zambia for 1994. School Certificate examinations in Zambia are combined with General Certificate of Education (GCE) examinations and are graded on a 9-point scale. Under School Certificate, grades 1 to 8 are passing grades while under GCE, only grades 1 to 6 constitute (O-level) passing grades.

The subjects in the table can be divided into three categories:

- Low Mathematical Content (LMC) subjects – English, literature in English, CLT and history.
- High Mathematical Content (HMC) subjects – the technical subjects (woodwork, metalwork, geometric and mechanical drawing and computer studies), geography, biology, chemistry, (physical) science and physics.
- Mathematics.

The criterion for the classification is based on the writer's perception of the extent to which the subjects use mathematics rather than on any detailed analysis of the syllabuses. But while a systematic analysis of the possible mathematical content of the various syllabuses would be useful, some of the use of mathematics in other subjects is likely to depend to a large extent on teacher activity and attitude.

Table 1
School Certificate results for Zambia for 1994 (Source: Examinations Council of Zambia)

Subject	No. of candidates	% Pass	% Fail
English			
Boys	15 473	85.6	14.4
Girls	7 543	85.1	14.9
Literature in English			
Boys	3 033	74.2	25.8
Girls	2 499	75.2	24.8
Christian living today (CLT)			
Boys	1 047	81.2	18.8
Girls	1 090	91.8	8.2

History			
Boys	5 163	69.5	30.5
Girls	2 695	58.6	41.4
Geography			
Boys	12 897	79.6	20.4
Girls	5 995	60.9	39.1
Woodwork			
Boys	653	80.6	19.4
Girls	7	71.4	28.6
Metalwork			
Boys	540	81.7	18.3
Girls	2	50.0	50.0
Geometric and mechanical drawing			
Boys	1 313	87.7	22.3
Girls	27	63.0	37.0
Computer studies			
Boys	21	90.5	9.5
Girls	5	100	0
Biology			
Boys	13 349	79.5	20.5
Girls	6 570	70.0	30.0
Chemistry			
Boys	3 870	80.0	20.0
Girls	605	87.9	22.1
***(Physical) science**			
Boys	9 842	82.9	17.1
Girls	5 626	65.6	34.4
Physics			
Boys	4 071	81.9	18.1
Girls	617	68.7	31.3
Mathematics			
Boys	15 222	61.7	38.3
Girls	7 475	37.7	62.3

* In Zambia the subject 'chemistry and physics', was previously called physical science but is now simply called science.

In interpreting the results in table 1, it is worth noting that the Ministry of Education in Zambia requires that every pupil takes English, mathematics and at least one science subject. The number of candidates in English and mathematics indicates the total enrolment for the year. The two numbers differ due to incidences of re-sitting for some papers and some schools not being under strict government control. The Ministry's requirements on subject uptake have implications for judging the level of difficulty as well as determining the popularity of the subjects.

In **LMC subjects**, with the exception of history, there is

- a low failure rate by both boys and girls;
- generally similar performance of boys and girls, though in CLT the performance of girls is clearly better than that of boys. However, this fact should be understood in the context that most of the schools offering CLT are grant-aided schools (mission schools) and 15 of the 27 such schools are for girls only. These schools usually have better qualified teachers, are better resourced and generally have a tradition of good examination results.

In **HMC subjects**, with due regard for the exceptions:

- the performance of boys is not very different from their performance in LMC subjects;
- the performance of girls is poorer than their performance in LMC subjects;
- the performance of girls is a lot poorer than that of boys;
- the subject uptake in pure physical sciences, i.e. chemistry and physics, and in technical subjects is generally very low and for girls it is much lower than for boys. For example, while 25% and 26.3% of boys sat for chemistry and physics respectively (number of candidates compared to that in English), only 8% and 8.2% of the girls sat for the two subjects respectively.

In **mathematics**, the performance of boys is very poor. For girls, a failure rate of more than 60% cannot even be called very poor. It is 'scandalous'!

Conclusions

From the above analysis it can be concluded, taking due note of exceptions, that:

- the performance of girls gets poorer the higher the mathematical content of the subject, with the poorest performance being in mathematics itself where there is a 'scandalously' high failure rate;
- the difference in performance between girls and boys in low mathematical content subjects is minimal but the difference gets wider with higher mathematical content of subjects, the biggest difference, of 24%, being in mathematics.
- fewer girls relative to boys take physical sciences and technical subjects.

Opting out of science and technical subjects

Table 1 shows a high uptake of biology by both boys and girls. As indicated earlier, the Ministry of Education requires that every pupil takes at least one science subject. It seems that where a pupil takes one science subject, that subject will be biology. The fact that biology uses much less mathematics than physical sciences seems to suggest to both pupils and teachers that it is an easier science. Many schools encourage their pupils to take two science subjects. Where there is need for two science subjects, the preference seems to be for biology and science. In practice, the decision on whether to take one or two science subjects is taken by school authorities. The real choice pupils have, if any, could be in taking either science or chemistry and/or physics. In this respect, many fewer girls than boys take chemistry and/or physics.

In general, school authorities have more say on what subjects pupils can take. This position arises from requirements on subject combinations as recommended by the Ministry of Education and factors such as availability of teachers. Therefore, it is the case in Zambia that it is more accurate to say that **girls are grossly under-represented in science and technology subjects than to say that girls opt out of these subjects.**

The work of the 'Girls Into Mathematics and Science Study Group (GIMSSG)' in Lusaka (Nkhata and Kalumba, 1995) also indicates that girls are more left out of science than opt out. A study of the subject uptake in two GIMSSG participating schools, Libala and Munali, provides evidence to support this (tables 2 and 3).

Libala Secondary School

Two factors are important in understanding the statistics for Libala Secondary School (table 2). The first is that subject uptake was not by free choice of the pupils. Secondly, the girls were a pioneer group to be enrolled and this was long after the regular selection of pupils for grade 10, that is the girls would not have proceeded to grade 10 had it not been decided that the school turn co-educational immediately. On this basis, the school might have thought of the girls as academically weak and hence offered them 'soft' subjects.

Table 2
Subject uptake in Libala Secondary School

	*Grade 10, 1994 (enrolment)	
Subject	**Boys (166)**	**Girls (54)**
Religious education	13	26
Chemistry	99	0
Physics	99	0

*Grades 1 to 4 are lower primary, 5 to 7 upper primary, 8 and 9 junior secondary and 10 to 12 senior secondary school.

Munali Secondary School

The unequal representation of girls and boys in the arts and in science and technical subjects is evident (table 3). For example, there are no girls taking science. However, the circumstances of enrolment of girls in this school are similar to those at Libala.

Table 3
Subject uptake in Munali Secondary School

	Grade 8, 1994 (enrolment)	
Subject	**Boys (450)**	**Girls (161)**
French	69	25
Industrial arts	142	48
Art	69	25

Subject	Grade 10, 1994 (enrolment) Boys (324)	Girls (69)
(Physical) science	96	0
Biology	189	31
History	324	69
Commerce	94	56
Agricultural science	90	56
Religious education	94	18

The study at Lake Road School

A study was conducted at one of the GIMSSG participating schools, Lake Road, in November 1995 to investigate the relationship between the learning of mathematics and the learning of science. A questionnaire was administered to 23 boys and 27 girls chosen from grades 10 to 12 on the basis of being readily available to the teacher who administered the questionnaires. Lake Road is not a typical Zambian school in the sense that the fees at the school are very high and it is mostly children from affluent homes who attend the school. Another characteristic of the school is that the difference in performance between boys and girls in all subjects is minimal (Nkhata and Kalumba, 1995).

Findings

(a) Boys had proceeded to senior secondary school with a stronger mathematical background than girls. For example, 52.2% of the boys obtained distinctions at junior secondary school leaving examinations, while only 22.2% of the girls obtained the same grade.

(b) Girls liked mathematics less than boys did. While 78.3% of boys were positive about liking mathematics, only 40.7% of the girls were positive. This finding is consistent with others in Zambia (Sayers, 1994; Nkhata and Kalumba, 1995).

(c) In spite of Lake Road being a school for predominantly well-to-do families where both parents and pupils would be expected to be more conscious about the right of choice, nearly all pupils said the school had not given them any choice in the science subjects. Nearly all of them took biology, chemistry and physics. This finding contradicts earlier information from the same school based on what teachers had said that pupils not only had almost limitless choice of subjects, but had informed choice through the process of counselling of both pupils and parents (Nkhata and Kalumba, 1995).

The lack of choice does not mean the pupils did not like the subjects. Some statements made by the pupils were *'It was compulsory that I take them (science subjects) but I like them all the same'*; *'Sciences were compulsory though I feel that I would have taken them if they were optional'* and *'The science subjects are compulsory at my school and I like them all'*.

(d) There was little difference in the degree of enjoyment of the learning of science between boys and girls. 73.9% of boys and 70.4% of girls said they enjoyed learning science very much.

(e) Boys and girls had different reasons for *not* enjoying learning science. 18.5% of the girls (compared to the total sample rather than to those who had said they did not enjoy learning science) attributed their lack of enjoyment to poor teaching. No boy gave this reason, even though in the free comments, some boys also expressed displeasure with some of their teachers. One girl said *'my maths teacher is very good, but I don't like the way the chemistry teacher's approach in his subject, this also goes for physics. Because of this I find my sciences boring'*. One boy said *'I'm not as excellent in mathematics as I'm in my science subjects because I find the teacher unhelpful also discouraging and lazy'*.

Established difficulties in the learning of mathematics

The work of the 'Girls Into Mathematics and Science Study Group (GIMSSG)' in Lusaka was based on the Open University/Inner London Education Authority (1986) pack *Girls into mathematics*. The group interpreted the pack to be saying that research evidence had established the following as barriers to the learning of mathematics by girls:

Mathematics and the curriculum

The image of the subject: *Both boys and girls consider mathematics to be a male-subject.*

The relationship of mathematics with other subjects: ... *girls are less likely than boys to choose to study maths-related subjects.*

Feelings, attitudes and expectations

Feelings and attitudes of girls: *Girls tend to feel they are outsiders to mathematical subjects and tend to have more negative attitudes to the subjects than boys.*

Expectations: *Teachers, parents and employers tend to have lower expectations of girls' mathematical performance.*

In the classroom

Classroom interaction: *Boys tend to dominate the girls in classroom activities. For example, when conducting experiments, boys are more likely to be handling the equipment while girls just take the readings; Teachers tend to interact more with boys than they do with girls.*

Learning environment: *Competitive learning environments are more conducive to anxiety and therefore unlikely to suit girls as well as they suit boys; girls seem to prefer more collaborative learning environments.*

Bias in teaching materials

Classroom roles: *Teaching materials may reinforce the stereotyped view of boys taking the lead in activities while girls take a background position.*

Context of the materials: *The setting of the learning contexts tends to be more in the male realm of experience than female and applications also tend to be those that boys are more likely to identify with than girls.*

Assessment

Types of assessment: *In general, traditional style examinations are conducive to pressure and tension and girls tend to be more susceptible to this. Specific modes of assessment, such as multiple-choice questions may suit boys more than girls. Girls seem to have better ability and preference for self-expression and yet many examinations do not provide for this opportunity.*

Bias in questions: *Just as teaching materials may have a male bias, so can examinations. This tends to be by way of contexts in which the questions are set.*

Strategies in tackling tests: *Girls tend to have poorer examination strategies than boys. For example, Muriel Eddows* et al. *(1980), quoted in OU (1986), says* 'girls tend to try to recognise the situation and then and then "apply the rules to recognised situations" whereas boys tend to answer questions "using more independent processes – often successfully – in the more difficult questions".'

(Nkhata and Kalumba, 1995)

It is possible, as GIMSSG members decided to assume, that science subjects face the same difficulties as mathematics does.

Is mathematics a barrier to the learning of science and technology amongst girls?

OU/ILEA (1986) says

'... boys tend to receive considerably more reinforcement of formal *school mathematics in their other subjects than girls. There is some evidence that this additional mathematics practice contributes to boys' higher attainment in maths examinations at 16+. For example, a study by Shiam Sharma and Roland Meighan (1980) suggests that it is maths experience in other subjects, rather than the gender of the pupil, which most influences pupil performance. In their investigation of mathematics performance at O-level, they found that though, overall, girls did less well than boys, girls with a science background performed as well as boys with similar background. Conversely, no pupils in the sample without a science or technical background (whether boys or girls) obtained the two highest O -level mathematics grades. ...*

'There is some evidence therefore that the relationship between mathematics and other parts of the curriculum is of importance.'

The study conducted at two secondary schools in Lusaka on the relationship between the learning of mathematics and the learning of science provided some evidence of mathematics being a barrier to the learning of science. For example, 20.3% of girls as opposed to 14.3% of boys said they did not enjoy learning sciences because the subjects need a lot of mathematics. However, the small size of the sample (49 boys and 48 girls) makes it necessary for a more comprehensive study to come up with more reliable findings. But what came out more strongly was the teacher factor in pupils' enjoyment of learning science. Some pupils found their teachers boring, some found them uncaring and so forth. Perhaps arising from the 'over' success of the work of GIMSSG among teachers in the school, some boys felt that teachers were paying more attention to girls than them. One boy said *'maths teachers and chemistry teachers don't give much attention to male students around here. Mr ... is a good example.'* It is unlikely that pupils will pay adequate attention in class and work hard on a subject they do not enjoy.

Morse and Handley (1985) had useful results in their study on differences in science classroom interaction. First, they say that in a traditional, large-group science class, that is taught with a lecture method, learning is guided by questioning and by feedback and both these ways of guiding learning represent structure. They went on to say that questioning provides opportunities and variations for thinking about new concepts while feedback fine-tunes ideas. In both questioning and feedback, Morse and Handley found that:

> *'... boys received more attention and were also allowed to control other instructional and non-instructional interactions. This opportunity for becoming involved with science even in a very limited extent gave boys the immediate advantage over girls. Couple this idea to the stereotype of science as a male domain and other external pressures that limit participation in science by girls, and it is easy to see why girls do not later pursue science and engineering careers.'*

Ward (1986) says on girls and technology,

> *'Aspects of girl/boy differences in learning style, such as the dominance of aggressive boys in class, which are apparent in other areas of the curriculum, have shown themselves also in computing. Many girls do not demand the time and attention they need; fearing ridicule, girls do not volunteer responses in class. And when things go wrong, girls often blame themselves while boys blame the teacher or equipment.'*

The above quotations go to show some of the factors other than mathematics that might have serious implications for the learning of science and technology amongst girls.

Conclusion

It is evident that science and technology use a lot of mathematics. Most of the mathematics needed for school science and technology, with the exception of physics which needs 'all aspects of mathematical enquiry' (Ling, 1977 quoted in OU/ILEA, 1986), is at the level of basic skills such as use of logarithms, decimals, ratio and proportion, statistics and arithmetical processes. It follows therefore that a lack of fluency in basic mathematical processes will be an obstacle not only to the learning of science and technology, but to the learning of mathematics itself.

In many parts of the world, girls have been underachieving in mathematics relative to boys. The case for Zambia is such that to say girls are underachieving would be understating the magnitude of the problem, considering a failure rate of more than 60%. Given that there are clear needs for the use of mathematics in science and technology it is reasonable to expect a corresponding under-achievement by girls in the latter. As seen in table 1 of this paper, this is indeed the case in Zambia. However, it has not been possible in this paper to find substantial evidence to make a meaningful connection between the girls 'poor' performance in mathematics and their poor performance in science and technical subjects.

What this paper has been able to show is that there are circumstances within the teaching/learning process of science and technology which might be causing more serious obstacles to the learning of these subjects amongst girls. These factors include teacher performance, classroom and school practices, deprived learning environments and attitudes of pupils, teachers, parents and society.

Finally, **there is reasonable ground to suspect that mathematics is a barrier to the learning of science and technology amongst girls in Zambia**. Proof of the possible culpability of mathematics has to await more rigorous literature search and research. Considering that most of school science only needs basic mathematical skills, a particularly useful area of research will be how the current shift of emphasis in the teaching of mathematics from fluency in basic skills to investigations and problem-solving will affect the learning of science. For the learning of mathematics itself, the 'harm' is already showing. A report of the London Mathematics Society, quoted by Judd (1995) in the UK *Independent* newspaper, says that many university mathematics students cannot carry out basic arithmetical and algebraic calculations and that their ability to solve problems is getting worse. Judd goes on to quote the report as saying:

> *'teachers are not to blame but school inspectors have encouraged the decline in standards by suggesting that teachers should put less emphasis on basic skills and more on investigation and problem-solving.'*

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