Gender Differences in Participation and Achievement in Science: Implications and Intervention Strategies for Scientific and Technological Development in the Caribbean

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Abstract

Gender differences in science have received serious attention in science education research for the last two decades. Boys and girls have been compared on various variables such as achievement, attitude, motivation, interest, and performance behaviors. Moreover, the differences have been linked with unequal representation of men and women in science and technology – related careers indicating levels of contributions of men and women to national development. Therefore, this paper contends that it is difficult to address the issue of national development particularly in science and technology without recourse to the gender factor. Specifically, the 1995 Commonwealth Plan of Action on gender and development, indicates that "the Commonwealth shall work towards a world in which women and men have equal rights and opportunities in all stages of their lives to express their creativity in all fields of human endeavour and in which women are respected and valued as equal and able partners in establishing values of social justice". This paper poses and answers these questions: (a) What is the pattern of gender differences in science achievement internationally and in the Caribbean? (b) What are the possible explanations for gender differences in science achievement internationally and in the Caribbean? (c) What are the effects of gender differentials in science on national development? (d) What are the possible intervention strategies towards gender balance in science achievement? This paper presents answers to these questions using reports of meta-analysis of science education research and goes ahead to offer suggestions for action as to how gender gaps can be bridged in the Caribbean in order to ensure contributions of both men and women to regional scientific and technological development.

Key words: Gender, science achievement, science participation, scientific development, technological development

1. Introduction

As science and technology is becoming increasingly important in all nations of the world, so is participation and achievement in science and technology education. However, the role of gender in science and technology education has been and is being hotly contested. Some advocate single-sex schooling as a way to let girls' talents blossom, freed from boys' domination in the classroom and from sexual harassment by boys. Others emphasize gender differences in learning styles, citing evidence that girls perform best under cooperative learning conditions and boys perform best in competitive learning environments. According to Hyde and Linn (2006), these arguments rest on the assumption that psychological gender differences are large and exist in numerous domains. Also, boys and girls have been compared on various variables such as achievement, attitude, motivation, interest, and performance behaviors (Greenfield, 1997; Jovanovich & King, 1998) and the differences have been indicted to be responsible for unequal representation of men and women in science and technology – related careers and ultimately indicative of varying levels of contributions of men and women to national development. For instance, in a set of collected data in the United States of America in 2005, women earn 46% and men earn 54% of the PhDs in biology but women earn 25% and men earn 75% of the PhDs respectively in physical science. In engineering women earn 15% while men earn 85%. Also, 30% of the assistant professors in biology are women, 16% of the assistant professors in physical science are women and 17% of the assistant professors in engineering are women.

The Canadian Council on Learning (CCL) (2007) revealed that the dearth of women in scientific fields of study is reflected by a similar under-representation of women in science and engineering occupations. Over the past three decades, women in Canada have joined the labour force in ever-increasing numbers: as of 2006, women accounted for 47% of all workers in Canada. Over the same period, women have accounted for a steadily increasing proportion of workers in health care and social assistance and educational services, but the relative proportion of women in professional, scientific and technical services has declined compared to the overall proportion of women in the labour force. In the United States of America, the Committee on maximizing the potential of women in academic science and engineering, National Academy of Sciences, National Academy of Engineering, and Institute of Medicine reported that twenty-five years ago, Congress passed the Science and Engineering Equal Opportunity Act, which declares that "it is the policy of the United States that men and women have equal opportunity in education, training, and employment in scientific and technical fields. The committee reported further that major advances have occurred since then in the numbers of women enrolling in science and engineering classes in high school and college.

In Europe, the European Commission (2009) reported that the overall situation of women and men in the European Union. Described below is a summary of their findings:

- The employment rate of women increases but remains lower than men's, although women represent a majority of students and university graduates.
- Women continue to earn an average of 17.4% less than men for every hour worked and this figure remains stable.
- Women are still very under-represented in economic and political decision-making positions, although their share has increased over the last decade.
- The division of family responsibilities is still very unequal between women and men.
- The risk of poverty is higher for women than for men.
- Women are the main victims of gender-based violence and women and girls are more vulnerable to trafficking of human beings.

Generally, women remain sharply under-represented in some fields of study, particularly mathematics, physical sciences, engineering and applied sciences. CCL (2007) reported that this is true at all levels of post-secondary education, including college, undergraduate and graduate levels of study but in contrast, women are over-represented in other fields of study including education and health sciences. Needless to say then, that the dearth of women in scientific fields of study is reflected by a similar under-representation of women in science and engineering occupations. In Canada, CCL (2007) also reiterated that the under-representation of women in science and engineering contributes to a gender-based wage gap and that in recent years real wages have declined in female-dominated disciplines such as health and education while real wages have increased in male-dominated disciplines such as engineering, mathematics, computer science and physical sciences. Supporting this by an example, CCL reveals that the occupations commonly held by young women with university degrees are elementary and kindergarten teaching and that between 1995 and 2000, average earnings for women in these occupations increased by less than 1%. In contrast, earnings by young men in computer and information systems which are the most commonly held occupations among university-educated men increased by 15%. This wage gap is supported by Kimmel (2000) who recognized that once females entered a particular work force it is appears less demanding and requires a lower level of skills and hence the pay decreases.
In the Caribbean, Martin-DeLeon (2010) asserts that some conclusions can be gleaned from available data:

- Despite the preponderance of female students entering tertiary institutions, females have a disproportionately low representation in the pure and applied sciences and engineering, unlike the social sciences.
- Females who enter Pure and Applied Sciences and Engineering at the Bachelor's level compete favourably for postgraduate positions and graduates in proportions equal to, or higher than, those for males, This suggests that the females who enter these fields perform as well as or better than males.
  This is also supported by Kimmel (2000) who purports that only women or girls who are secure and most able undertake the task of courses such as physical sciences, therefore, those that do although they are few tend to achieve high grades.
- As academic professionals, females appear to be under-represented in the Pure and Applied Sciences, despite their success in completing postgraduate programs.
- Since male students enter the Caribbean institutions in lower proportions than females but females are under-represented in Pure and Applied Sciences and Engineering, both pursue scientific careers in lower proportions than they are represented in the population.

- It is noticeable that the Caribbean is not unique with respect to under-representation of females in Pure and Applied Sciences and in the preponderance of females in the Health or Medical Sciences as well as Healthcare providers in the workforce.

Globally, UNESCO (2010) revealed that:

- 29% of the world's researchers are women, but regional disparities occur, for example 46% in Latin America and the Caribbean, compared to 15% in Asia
- There is no gender parity in primary and secondary education in 60% of countries.
- Horizontal gender segregation occurs within sciences at PhD and research levels.
- In 91% of countries, men out-number women in science and engineering courses

These findings are most likely responsible for the clear statement in one of the UNESCO's global priorities called the UNESCO's Medium Term strategy for 2008 – 2013; 34 C/4 that priority will be given to the pursuit of gender equality through action in all of UNESCO's fields of competence.

The background provided so far brings to focus reasons for the recent rising global consciousness both at the grassroots and policy levels regarding the impact of gender issues in education and national development. According to Aguele and Agwagah (2007), there is also the growing consciousness that women constitute more than half of the world's population. Thus, this paper contends that it is difficult to discuss the issue of national development, particularly in science and technology without recourse to the gender factor. In other words, we cannot afford to ignore women in matters regarding national development and science and technology education which is a vital tool in the development of nations and regions of the world.

Moreover, on the Commonwealth front, there have been various moves and activities on gender equality and development. Specifically, the 1995 Commonwealth Plan of Action on gender and development indicated that "the Commonwealth shall work towards a world in which women and men have equal rights and opportunities in all stages of their lives to express their creativity in all fields of human endeavor and in which women are respected and valued as equal and able partners in establishing values of social justice". Within such a framework of values, men and women work in collaboration and partnership to ensure people-oriented development for all nations. The need to involve women equitably in national development needs no further emphasis. Hence, issues of governance and democracy, socio-economic development and peace can not be divorced from those of gender equality (King, 2000). In addition, it is becoming obvious that when women learn, a nation stands to benefit. Abbe and Momodu (1999) cited in Aguele and Agwagah (2007) states that women education positively correlates with several national and international goals and aspirations. The under-representation of women in science and technology careers is therefore a problem. Against this background, this paper poses and answers these questions:

- What is the pattern of gender differences in participation in science and technology internationally and in the Caribbean?
- What is the pattern of gender differences in achievement in science and technology internationally and in the Caribbean?
- What are the possible intervention strategies towards gender balance in science achievement and participation?

2. Pattern of Gender Differences in Participation in Science and Technology

The fact that female participation is low in Science, Technology, Engineering and Mathematics (STEM) subjects and careers appears to be a global issue. For instance, Croxford (2002) reported that in Scotland, females were less likely than males to study mathematics, informatics and engineering and that one quarter of students with two or more sciences at higher grade was studying medicine and dentistry, or subjects allied to medicine. The situation appears to be the same pattern in the United States of America where Billings (2000) reported that despite efforts over the last 20 years to redress female under-representation, the percentage of women studying computing and related subjects continue to fall. In the United Kingdom, the same trend was observed with females making up only 18% of those studying computer science and 11% of those studying software and engineering (Aguele and Agagah, 2007). They explained further that, not only are the enrolments low and declining, but proportionately more women than men drop out, fail courses or choose to major in another subject other than science. The deleterious trend is found in New Zealand also with women accounting for a mere 20% of undergraduates in information technology and the sciences (Brook et al, 2000).

Interestingly in the Caribbean, the tertiary educational institutions have gender distributions that are greatly skewed. Table 1 as given by Martin-DeLeon (2010) reveals a glaring and alarming paucity of males entering tertiary institutions.

Table 1: Caribbean Universities by Percentage Enrolments by Gender

Year	Institution	Male	Female	M:F
2009-2010	University of the West Indies, Mona campus, Jamaica	28%	72%	1:2.58
2004-2005	University of the West Indies, Cave Hill campus, Barbados	32%	68%	1:2.13
2005-2006	University of the West Indies, St Augustine, Trinidad & Tobago.	38%	62%	1:1.64
2008-2009	University of Guyana	36%	64%	1:1.78
2009-2010	St George's University, Grenada	48%	52%	1:1.09
2009-2010	Northern Caribbean University, Jamaica	29%	71%	1:2.45
2009-2010	University of Technology, Jamaica	43%	57%	1:1.33
2009-2010	University of Belize	34%	66%	1:1.95

Source: Martin-DeLeon (2010)

Obviously, the gap between male and female in terms of participation in higher education is high ranging from male to female ratio of between 1:1.09 to 1:2.58. For the campuses of the University of the West Indies this gap had not changed much over the past 10 years. According to Bailey (2003), in 1998-1999, the registrations of males to females at Mona was 29% / 71%; at Cave Hill it was 34% / 66% and at St. Augustine it was 42% / 57.4 %. However, when gender distribution based on science disciples is considered, a different picture emerges (Table 2) showing that females' participation in pure and applied sciences and also engineering is lower than male participation.

Table 2: Gender Distribution by Disciplines on Various Campuses

Year	Institution	Stage	Academic Discipline	Male	Female	Ratio M:F
2006/2007	Mona Campus	1st Degree	Engineering	73	27	2.74:1
			Med. Sciences	31	69	1:2.20
			Pure and Applied Sc.	47	53	1:1.16
		Postgraduate	Engineering	58	42	1.32:1
			Med. Sciences	42	58	1:1.14
			Pure and Applied Sc			
2004/2005	Cave Hill	1st Degree	Pure and Applied Sc	57	43	1:1.31
		Postgraduate	Pure and Applied Sc	38	62	1:1.62
2005/2006	St Augustine	1st Degree	Engineering	73	27	2.74:1
			Med. Sciences	39	61	1:1.6
			Pure and Applied Sc.	43	57	1:1.36
		Postgraduate	Engineering	60	40	1.53:1
			Med. Sciences	56	44	1.26:1
			Pure and Applied Sc.	49	51	1:1.03
2009/2010	U.Tech, Jamaica	1st Degree	Engineering/Comput.	79	21	3.8:1
2009/2010	University of Belize	1st Degree	Science & Technology	62	38	1.6:1
2009/2010	University of Guyana	1st Degree	Health Sciences	29	71	1:2.44
			Natural Sciences	47	53	1:1.13

Source: Adapted from Martin-DeLeon (2010)

Clearly, the pattern of participation of male and female students changed in almost all the science disciplines with the exception of medical sciences in favour of males, contrary to what is observed in participation in higher education. Moreover, at postgraduate level in the Universities under consideration, the pattern shows that more females than males participate in postgraduate studies in science disciplines. However, as academic professionals, unexpectedly, females

appear to be under-represented in the Pure and Applied Sciences, despite their success in completing postgraduate programs.

Researchers (Ferreira, 2003; Nelson and Rogers, 2003) offer several explanations for the low numbers of women at all stages of STEM careers:

- The classroom climate for girls in school classroom is not encouraging to them because ways of conducting discussions promote inequalities when boys are given more attention and praise than girls by the teacher.
- A dearth of role models.
- Poor preparation and lack of encouragement in STEM subjects.
- A lack of 'critical mass' of women. The theory of 'critical mass' asserts that as representation of women increases, so will their access to important resources and social network. 'Critical mass' is only meaningful if the organization is democratic and inclusive.
- Bias and discrimination in hiring and advancement of women leads to slower advancement of women in science, particularly in academic science.

3. Pattern of Gender Differences in Achievement in STEM

On the other hand, international student science assessment surveys report different gender patterns. According to Euridice Network (2010), Martin (2004 & 2008); OECD (2004) the Trends in International Mathematics and Science Study (TIMSS) often find gender gaps in favour of boys, whereas the Programme for International Student Assessment (PISA) reports generally show no significant gender differences and the analysis is thus:

- In 1995, TIMSS data showed that there were no significant gender differences in science achievement in the fourth year of school in seven participating European educational systems but in the eighth year, gender differences in science achievement in most participating countries started to emerge. Boys had higher achievement, particularly in physics, chemistry and earth sciences. By the final year of secondary school, males had significantly higher scientific literacy than females in all countries.

Similar findings were also reported in the TIMSS 2003 and 2007 reports.

- Contrary to TIMSS findings, the PISA 2000 assessment of 15-year olds' science achievements did not report significant gender differences.
- PISA 2003 reported male advantage only in few countries and no gender gap in the majority. Girls outperformed boys in Finland and Iceland. The differences in the results of TIMSS and PISA might be explained by the fact that the PISA assessment emphasizes life sciences more than TIMSS which is an area females perform better also in.

In the United States of America, among the fourth graders, trends reveal that the science achievement gap may be narrowing down between males and females. Amelink (2009) summarized the trend of science achievement in the USA as follows:

- In 2007, males and females showed no measurable difference in their average science performance. However, males outperformed females in earth science (536 v. 531) There was no measurable difference detected in the average scores by gender in either the life science or physical science domains.
- Males outperformed females overall in science in 2003, which was also the case in 1995.

Among U.S. eighth-graders, trends reveal continued higher performance in science by males in certain content areas:

- In 2007, males performed significantly higher than female classmates overall in science, scoring higher in three of the four content domains: biology (533 v. 527); physics (514 v. 491) and earth science (534 v. 516). There was no measurable difference detected in the average science scores of U.S. eighth-grade males and females in the chemistry domain.
- In 2003, males outperformed females in science, which was also the case in 1999 and 1995 (Gonzales et al.,2004).

In the Caribbean, many countries did not participate in both TIMSS and PISA therefore cannot be compared with other nations of the world based on those studies. However, the Caribbean Secondary Examination Certificate (CSEC) results and Caribbean Advanced Proficiency Examinations (CAPE) results organized by the Caribbean Examination Council (CXC) are reliable data for analyzing gender participation and achievement in the Caribbean region.

Table 3: CSEC January and May Entries by Gender for 2009

	CSEC JAN. ENTRY 2009		CSEC MAY ENTRY 2009	
Countries	Male (%)	Female (%)	Male (%)	Female (%)
Antigua & Bar	26.1	73.9	36.2	63.8
Anguilla	29.1	70.9	31.0	69.0
Barbados	33.1	66.9	37.7	62.3
Belize	-	100	35.1	64.9
BVI	40.0	60.0	-	-
Cayman	28.6	71.4	-	-
Dominica	36.7	63.3	32.0	68.0
Grenada	38.0	62.0	27.5	72.5
Guyana	31.4	68.6	40.1	59.9
Jamaica	30.8	69.2	37.8	62.2
Montserrat	33.3	66.7	35.8	66.7
St Kitts & N.	40.1	59.9	31.4	68.6
St Lucia	35.5	64.5	38.1	61.9
St Vincent	42.3	57.7	34.8	65.2
Trinidad & T	39.1	60.9	37.6	62.4
Turks & C.	44.1	55.9	50.0	50.0
St Maarten	44.1	55.9	-	-

Source: Caribbean Examination Council (2009)

Table 3 above indicates that in terms of the number of students passing out of secondary schools in the Caribbean, majority are females. In Belize, in January 2009, all of them were females. However, the number of students entering universities particularly to study science dropped significantly among both boys and girls. (See table 1)

When achievement patterns among males and females are analyzed, it is discovered that there are no marked differences between the achievement of males and females in physics, chemistry and biology.

Table 4: CSEC May/June 2008 Candidate Performance by Subject, by Gender and by Grades Awarded

Subject	Sex	Grades (% of candidates))					
		I	II	III	IV	V	VI
Chemistry	M	17.16	24.10	37.31	15.48	5.84	0.12
	F	16.93	25.29	35.95	16.51	5.28	0.05
Physics	M	15.0	25.99	33.14	19.50	6.47	0.31
	F	17.99	30.01	32.52	16.36	3.05	0.06
Biology	M	10.77	24.46	38.31	18.25	8.17	0.04
	F	12.46	26.16	36.82	16.79	7.74	0.02
Mathematics	M	0.15	0.43	0.71	0.70	1.32	0.06
	F	0.08	0.29	0.65	0.77	1.08	0.02
Integrated Sc	M	7.00	39.15	41.15	10.15	2.14	0.06
	F	6.20	38.67	44.96	9.20	0.96	0.0

Source: Caribbean Examination Council (2009)

For example, in Chemistry, 17.16 per cent of the males achieved grade 1 while 16.93 per cent of females achieved grade 1. This can be interpreted as no marked difference between the number males and females that made grade 1. Almost the same trend is observable in the other grades and subjects. Supporting this observation, Ogunkola and Fayombo (2009) reported that although there were significant differences in Barbados fourth form students' science achievement based on their school location, interest in science and study habits, there was no statistically difference in the students' science achievement based on gender. They also reported that both males and females did not perform satisfactorily in their science achievement. For instance Sweeny (2003:8) declared that 'of particular concern in the Caribbean is the relatively low extent of science education, as suggested by the number of students who successfully pass secondary level science examinations. He further stated that a cursory review of Caribbean Examination Council-CSEC results in biology, chemistry, physics and integrated science for the past ten years indicates that pass rates have, for the most part, fallen below 50% in these science subjects'. Also, CXC Statistical Bulletin (2008) revealed that in the CSEC May-June 2008, only 38.31%, 51.39%, 29.25% and 31.70% of the students that sat for the examinations in Barbados obtained Grades I and II in Chemistry, Physics, Biology and Integrated Science respectively. The underachievement

was even more pronounced in CSEC January 2008 with 15.38%, 25%, 0.00% of the students in Barbados obtaining Grades I and II in Biology, Chemistry and Physics respectively.

4. Implications and intervention strategies towards gender balance in participation and achievement in science for better contributions to scientific and technological development in the Caribbean

The implications of the findings enumerated in this paper on the issue of gender differences in participation and achievement in science and technology are:

i. The problem of participation and achievement in science is not restricted to the Caribbean. It is an issue of global concern.
ii. Participation of both males and females in science and technology in terms of studying science and technology disciplines and taking up careers in the area is still lower than expected.
iii. The participation of females in studying and taking up careers in pure and applied science disciplines, engineering, computer science, information and technology, etc with the exception of medicine is lower than that of males.
iv. The prevalent lower participation in science and technology careers by females is a reflection of some factors impacting negatively on female students learning. In other words, although, boys and girls have similar cognitive abilities and abilities in complex problem solving which is a skill considered to be highly relevant for science and engineering, as girls grow up, they tend to decrease in their interest for science. This explains why in both TIMSS and PISA, there were no significant gender differences in science achievement of fourth grade students but there were significant gender differences in science achievement among eighth grade students.

In order to have more females participate and excel in science and technology courses and careers, the following intervention strategies may be useful:

(a) Encourage girls' interests in science

It is well established in literature (e.g. Canadian Council on Learning, 2007) that parental encouragement is positively correlated to children's participation in science activities. Parents can encourage their children to participate in science by providing support for them – ask them what they did in science at school, source for whatever materials they need for science activities, facilitate opportunities for the children to meet successful women scientists, etc. The poorer mathematical reasoning ability exhibited by many female adolescents have several educational implications. Beginning at age 12, girls begin to like mathematics and science less and to like language arts and social studies more than boys. They also do not expect to do as well in these subjects and attribute their failures to lack of ability. So, by high school, girls self-select out of higher-level, academic-track mathematics and science courses such as calculus and surds. Early intervention in form of encouragement helps at the time.

(b) Science teachers should create more "girl-friendly" classroom environment

Teacher characteristics and the classroom environment are crucial in attracting or repelling students to or from science classrooms. Some young students have identified a science teacher as "a person who has made science, mathematics or engineering interesting" for them. (Gilbert, 1996). Many females have even complained of being passed over in classroom discussions, not encouraged by the teacher, and made to feel stupid. A girl-friendly classroom incorporates:

- Reduction of competition, public drill, and practice to very important ones
- Highly expressive teachers
- Hands-on activities
- Use of community resource-persons who are female role models
- Same-sex cooperative learning communities
- Avoidance of gender-biased books

(c) Use of variety of instructional strategies

Teachers' creation of instructional environments that make use of a variety of instructional strategies that address different learning styles have been shown to encourage female achievement in science classrooms (Amelink, 2009). It is

important then to expose teachers to professional development efforts that focus on gender equity in science classrooms.

(d) Mentoring

Along with an alteration in the method of instruction and curricular content, mentoring is required to reverse the current trend of low participation of females and to increase the number of students who choose careers in science and technology fields. Mentoring, according to Martin-DeLeone (2010) is not teaching but is often done by a teacher, it is devoting time to promote another person's career. It protects and nurtures and is a powerful natural human relationship with a lasting legacy.

5. Conclusion

Today, both knowledge-based society and economy of the 21st century are supported by vibrant scientific enterprise and are greatly dependent on innovations and technological advances. In order to enhance the international competitiveness of the Caribbean nations, it is important to promote science and technology. One way to do this is to ensure that more men and women are involved in science and technology either as students or as professionals.

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