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Improving Science, Technology and Mathematics Students' Achievement: Imperatives for Teacher Preparation in the Caribbean Colleges and Universities

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The concerns of this article are the unacceptable status of Science, Technology and Mathematics (STM) Education in the Caribbean and how to improve the students' achievement in the subjects involved through the instrumentality of better preparation of teachers by the Colleges and University faculties training teachers in the region. The index for measuring development among nations of the world is the level of scientific and technological advancement because the factors that influence development are based on human ability to explore, invest and utilize the natural endowments available in the nation. In other words, no nation can attain any reasonable level of development without meeting the vital demands of development particularly in the areas of science, technology and mathematics. Therefore, the article begins with the presentation of the importance and the status of STM education using the mirror of science students' achievement at global level. Moreover, it is established that the Caribbean education also has some challenges to deal with in the areas of science, technology and mathematics education. The tertiary institutions, particularly the colleges training teachers and the universities are then challenged with suggestions of what they can or should do in teacher preparation that may have direct impact on improving the science students' achievement in the Caribbean

Keywords: Achievement; Caribbean; Education; Science, Environment

Introduction

One of the most important goals of education is for it to be functional and utilitarian preparing the individual for life in the community and reforming the society for relevance, adequacy and competitiveness in the world. Education is known to hold the key to the economic, political, sociological and human resources development and well-being of any society. Obviously, Science and Technology are an integral part of a modern society whether or not all groups of the society perceive or understand it as that. It is not surprising, therefore that under the United Nations Human Rights Charter, access to basic education continues to be a well argued and well deserved human right and increasingly Science, Technology and Mathematics (STM) have become an essential part of this basic education. This is against the background that STM education can enable people provide those essential requirements that make life comfortable and worth living. According to Oriafo (2002), the bottom line of STM education is to put man on the highways towards accomplishing some of these basic tasks that keep the society healthy, productive and progressive.

Moreover, in the development of nations, STM education plays a vital role. Ukeje (1997) observed that without STM education, there is no modern technology and without modern technology, there is no modern society. Therefore, if any nation must develop, the study of science, technology and mathematics should be given adequate attention at the various levels of her education. Today, factors that influence development are based on human ability to explore, invest and utilize the natural endowments available in the nation. In other words, no nation can attain any reasonable level of deve-

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lopment without the vital demands of development particularly in the areas of science, technology and mathematics. Presently, in the developed world, according to Godek (2004), science and technology are growing very quickly because they know that scientific and technological development requires the development of science education. While industrialized countries are giving emphasis to science education, some non-industrialized countries are not able to succeed because of their deficiencies in many aspects of science education.

Table 1: Differences in Average Science Scale Scores of Eight-Grade Students, by country: 1995, 1999 and 2003

				Difference[1]	
Country	1995	1999	2003	(2003–1995)	(2003-1999)
Singapore	580	568	578	-3	10
Chinese Taipei	-	569	571	†	2
Korea, Republic of	546	549	558	13▲	10▲
Hong Kong SAR[2,3]	510	530	556	46▲	27▲
Japan	554	550	552	-2	3
Hungary	537	552	543	6	-10▼
(Netherlands)[2]	541	545	536	-6	-9
(United States)	513	515	527	15▲	12▲
(Australia)[4]	514	-	527	13▲	†
Sweden	553	-	524	-28▼	†
(Slovenia)[4]	514	-	520	7	†
New Zealand	511	510	520	9	10
(Lithuania)[5]	464	488	519	56▲	31▲
Slovak Republic	532	535	517	-15▼	-18▼
Belgium – Flemish	533	535	516	-17▼	-19▼
Russian Federation	523	529	514	-9	-16▼
(Latvia-LSS)[6]	476	503	513	37▲	11
(Scotland)[2]	501	-	512	10	†
Malaysia	-	492	510	†	18▲
Norway	514	-	494	-21▼	†
Italy[7]	-	493	491	†	-2
(Israel)[7]	-	468	488	†	20▲
(Bulgaria)	545	518	479	-66▼	-39▼
Jordan	-	450	475	†	25▲
Moldova, Republic of	-	459	472	†	13▲
(Romania)	471	472	470	-1	-2
Iran, Islamic Republic of	463	448	453	-9▼	5
(Macedonia, Republic of)	-	458	449	†	-9
Cyprus	452	460	441	-11▼	-19▼
Indonesia[5]	-	435	420	†	-15▼
Chile	-	420	413	†	-8
Tunisia	-	430	404	†	-26▼
Philippines	-	345	377	†	32▲
South Africa[8]	-	243	244	†	1

-Not available
†Not applicable
▲P < .05, denotes a significant increase
▼P < .05, denotes a significant decrease
[1]Difference calculated by subtracting 1995 or 1999 from 2003 estimate using unrounded numbers
Note: Countries are sorted by 2003 average scores
Source: International Association for the Evaluation of Educational Achievement (2004).

That science and technology impact greatly on the society is no longer debatable. For example, STM exerts positively on many aspects of human life such as agriculture, health and medicine, law, transportation, communication, comfort, entertainment and welfare, automation, building and construction, to mention a few. Specifically in agriculture, in many nations of the world, scientific and technological efforts have resulted in increased food production, mechanization of operations and emergence of disease-resistant and high quality plant and animal species. Also, man's scientific and technological know-how has brought great improvements in medicine, nutrition and overall health-care delivery. Medical sciences, according to Aniodoh (2001), have reduced death rate of human beings through the discovery of the cure for various diseases such as malaria, diarrhea, dysentery, poliomyelitis, whooping cough and various sexually transmitted diseases. Moreover, through the knowledge of science and technology, man has been able to evolve safer and faster means of transportation such as motor, rail and air transportation systems which have fostered interactions within international communities. In the area of communications, the entire world has been turned into a global village through the emergence of new postal services, radio, television, telephone, internet and other electronic devices which have made communication easier, faster and more efficient.

In spite of these positive impacts of STM on the society, it is not encouraging to observe that the present status of STM education is some how worrisome because of the low science achievement of the students that are supposed to be future scientists, technologists, engineers and mathematicians. Internationally, the trend suggests that students' achievement in science is generally low. For example, the results of the Trends in International Mathematics and Science Study (TIMSS) in 1995, 1999 and 2003 indicated that between 1999 and 2003, there were significant increase in students' achievement in science in only nine (9) out of the twenty-nine (29) countries that participated (See Table 1). Even in America, policy makers and analysts are said (Lips and McNeill, 2009) to be concerned about American students' low achievement in STM fields, the percentage of American college students earning degrees in STM fields and the population of the workforce prepared for science, technology, engineering, and mathematics profession.

It is against the backdrop of low level of achievement in science, technology and mathematics globally and in the Caribbean in particular that the need for this study is established. In other words it has become crucial, therefore, to investigate, based on existing literature, what the causes of low achievement in science, technology and mathematics are, what the challenges are and ultimately how to ameliorate the problems through teacher preparation in colleges and universities.

Oriaifo (2002) and Iheonumekwu (2006) documented reasons for students' low achievement in the sciences in many nations as:

(a) Great plans, wonderful policies but excessive haste, unsatisfactory implementation leading to defective outcomes.
(b) Curriculum of STM was geared in content and procedures towards acquisition of certificates and diplomas. Consequently the STM education becomes extremely examination conscious, rendering the entire education system highly academic and theoretical and far removed from the local environment and local needs.
(c) Stereotyped and ineffective methodology of teaching the STM subjects.
(d) Teaching and learning resources are grossly inadequate for communicating STM education in schools.
(e) Lack of incentives to STM teachers is a very serious barrier to effective science teaching and learning.
(f) Inadequate teacher preparation and the problem of relating science teaching to the socio-cultural environment of learners are barriers to effective communication of science.
(g) Failure to turn the abstract nature of science to hands-on activities in the classrooms and field environment.

(h) Low supply of science teachers to schools e.g. the ratio of teacher to students could be as high as 1:80 or even more in many nations of the world.

Also, Ogunniyi (1996) documented causes of low achievement in the sciences especially in Africa as presented on Table 2 below.

Table 2. Causes of Low Science Achievement

Government-Related Causes	Society-Related Causes	Teacher-Related Causes	School-Related Causes
*Poor policies and/or action plans *Poor funding *Poor institutional set-up *Quality of political leadership *Mismanagement of funds of STM *Poor or lack of mechanism for the training, retraining and upgrading of STM teachers.	*Social class differences *Tribal conflicts and nepotism *Anti-intellectual values and practices *Level of STM literacy *Job opportunities for STM *Status of STM teacher in the community	*Poor preparation of STM teachers *Low morale of STM teachers *Poor salaries & allowances *Lack of adequate knowledge of STM*Lack of critical skills*Overloaded classroom/laboratory *Lack of opportunities for self-improvement. *Frequent transfers of STMteachers*Inadequacy in the quantity and quality of STM teachers at various levels *STM teachers' professional qualification and experience	*Poor physical environment *Poor equipped laboratories/workshops *Poor quality of teaching *Over crowded classroom *Leadership & level of discipline *Lack of career counselors *Inadequate instructional materials viz: texts, teachers' guide, A/V materials *Poor library facilities *Peer influence

Nature of Subject Matter	Examination Related Causes	Family-Related Causes	Student-Related Causes
*Over congested curriculum *Language of STM textbooks *Abstract nature of STM concept, symbols and generalizations *Conflicting learning theories about STM *Nature of STM world-view e.g. mechanism	*Overloaded examination syllabuses*Emphasis on the cognitive domain*Unfavourable mode of setting question schemes*Mechanical marking schemes*Mismatch between students' cognitive level and examination questions	*Family relationship *Nature of cognitive pool *Availability of financial resources*Unavailability of STM related materials *Value placed on formal education*Level of parents'education*Preferences for certain careers other than STM*The language of STM	*Poor attitude towards STM*Physical and health factors *Difficulty encountered in learning STM symbols *Consistently poor performance in STM *Weakness in computational ability *Level of motivation *Truancy*Difficulty with learning

Source: Ogunniyi (1996)

Contributing to what the causes of low student achievement in STM are, Shaikh (2000) submitted that the perception of STM as an irrelevant and often elite, Eurocentric, laboratory-based

subject area demanding higher levels of intelligence and skills, puts many learner groups off from taking the subject or pursuing it further. These include girls and often the less privileged within the learning groups. Also, Soyibo (1986) identified the causes of students' persistent failure or underachievement in STM as being due to the abstract nature of science, quality and quantity of science teachers, teachers' attitude to science teaching and teaching style, inadequacy and lack of science textbooks. Furthermore, Okebukola (1995) added that inappropriate funding, poor teacher training/welfare, shortage of instructional materials, diminishing regard for the value of education, social decadence and political instability, among others are barriers to good quality STM education. On the other hand, Jegede and Okebukola (1998) named authoritarianism, goal structure, the African worldview, social expectations and sacredness of science as socio-cultural factors militating against drift towards science and technology in secondary schools. Other factors as given by other authors (Olarewaju, 1991; Busari, 1991; Ogunkola, 2005; Ogunkola and Olatoye, 2008) include language of instruction, lack of interest in science on the part of the students and quantitative nature of some science subjects.

Interestingly, Oriafo (2000) presented a model for identifying factors influencing quality of STM education in Nigeria, which is applicable in any part of the world. He stressed some major aspects of STM education as critical to high quality and as such very crucial determining factors of the level of its success (Figure 1).

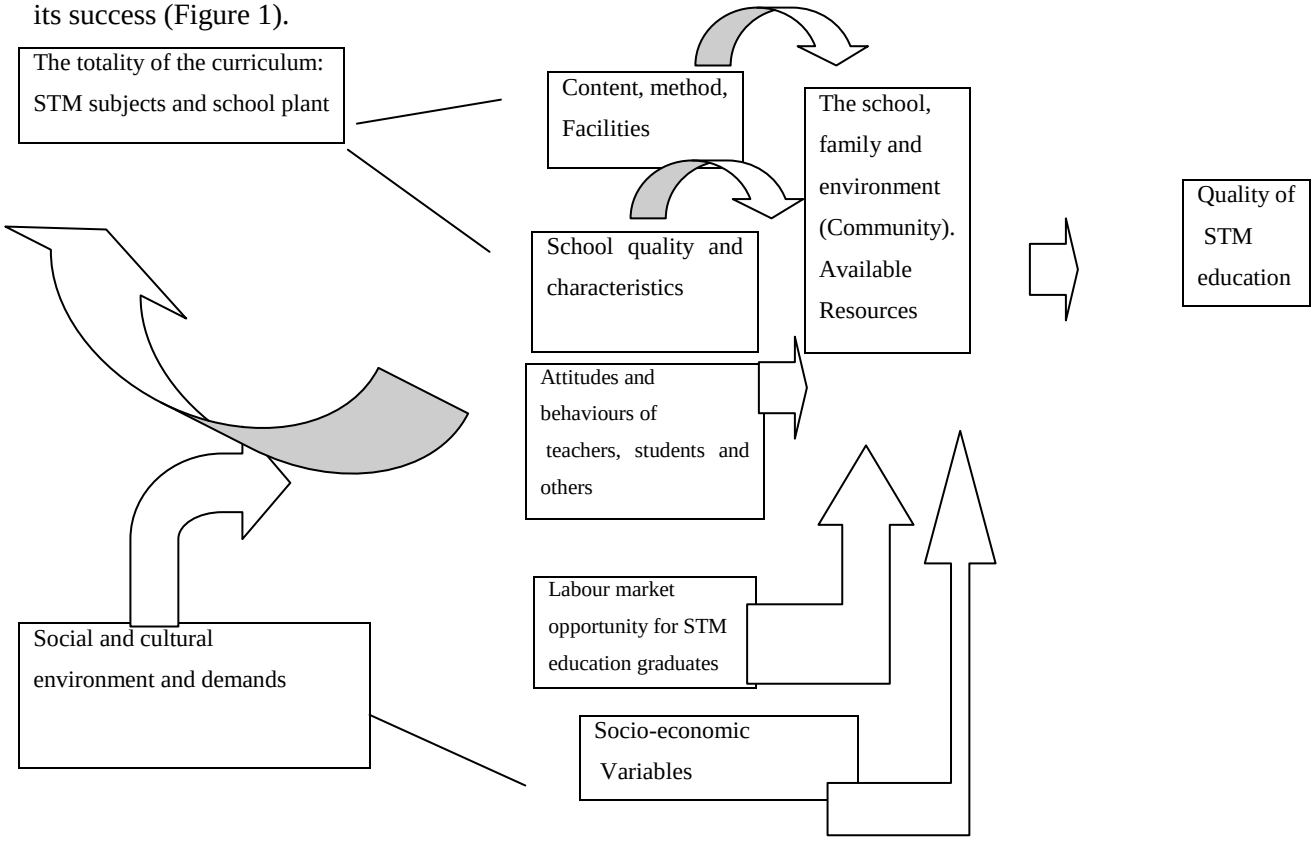

Figure 1. A Model of Factors Influencing Quality of STM Education
Source: Oriafo (2000)

Challenges of STM Education in the Caribbean

The issue of low achievement in science, technology and mathematics is a general problem in the Caribbean. This assertion is supported by Sweeny (2003: 8) who stated that 'Of particular concern is the relatively low extent of science education, as suggested by the number of students who successfully pass secondary level science examinations. He further states that a cursory review of Caribbean Examination Council (CXC) 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'.
In his writing titled 'A panorama of Science Education in the Latin America and the Caribbean', Macedo (2000:11) pointed out that although science and technology education acquires great importance at the middle school level in the region, there are certain major obstacles such as:

- Developing student-adapted and relevant curricula based on life-long science for citizenship.
- Developing curricula that transcend the 'discipline' oriented logic which has resulted in overloaded study programmes full of conceptual contents.
- Transfer to lower levels of higher level curricular matter due to simplification processes starting at the higher and descending to lower levels.
- Lack of global vision on the part of teachers of what is taught, generally leading to the teaching of concepts, skills and aptitudes in an isolated manner deprived of their meaning and purpose.
- Excessive discipline-oriented vision even at secondary school level which accounts for a fractionated and compactmentalised presentation of scientific knowledge. Each discipline being taught by a separate teacher has led to limited coordination and in many cases prevented the students from having a global view of the physical and natural phenomena that they study.
- Difficulty to include technology education in general secondary education and scant relationship between science education and technology education at this level.
- Lack of region-specific educational resource materials related to the needs and concerns of students and the educational community which makes links between school science and daily life difficult.

All these, according to Macedo (2000) led to a science education that is not accessible to all and attractive for only a few pupils. The majority of the students finds it boring and difficult and so loses interest. He further reiterates that the feeling of 'uselessness' that pupils feel in science classes, the feeling of failure experienced by science teachers due to lack of interest /motivation of pupils added to the conviction that science literacy is a necessity for every citizen has pushed teachers, directors and educational authorities of the region to look for new curricular propositions for science education. Cehelsky (2003) of the InterAmerican Development Bank stated that although education in the region (Latin America and the Caribbean) has been undergoing not just growth , but reform as well, moving toward improved quality and greater equity, curricular reform, and also the recognition of the importance of training in science and technology and teacher preparation has emerged as a priority and innovative approaches include incorporation of information technology and distance education, the needs and deficits in the region remain large. He explains that as UNESCO's World Science Report indicates, the region lags in terms of the development of science and does not provide a solid foundation in primary and secondary schools; few countries in the region achieve universal net enrolment at the primary level. With the regional average at 75%, the level of failures and dropouts is high and of those proceeding to the secondary school, only 50% complete their schooling and in rural areas the percentage drops to 10.

Cehelsky (2003) also stated that in the region, teachers are poorly trained and compensated; schools lack the resources for quality equipment- and even basic facilities. Some countries, according to him, have experienced a decrease in enrolment in science and engineering, reflecting the quality of science and mathematics education at primary and secondary levels. Unfortunately, few Latin America and the Caribbean countries have participated in international testing through TIMSS or PISA and those that have, place at the bottom of the rankings (Cehelsky, 2003). Against the backdrop of the challenges provided so far, the science, technology and mathematics workers produced enter the labour force ill prepared for the global economy.

Imperatives for Teacher Preparation in the Caribbean Colleges and Universities

There is a growing international consensus that good teachers are key to the delivery of high quality education and to the reform of education to meeting the new demands of society. The National Commission on Teaching and the America's Future, cited by Miller (2009: 6) in a paper titled 'Teacher Developments in the Caribbean', put forward a three pronged argument with respect to the central role of teachers to good education:

- What teachers know and can do is one of the most important influences on what students learn.
- Recruiting, preparing and retaining good teachers are the central strategies for improving schools.
- School reform cannot succeed unless it focuses on creating conditions in which teachers can teach and teach well.

Evidence from literature (e.g. Ferguson and Ladd, 1996, Ogunkola, 2008) also suggests that teachers' abilities, teachers' knowledge of subject matter and teaching methods and teaching experience along with small class sizes and the positive influences of small schools, are critical elements in successful student learning. However, Cehelsky (2003), pointed out that given the importance of human capacity building for competitiveness and quality of life, the deficits in science, technology and mathematics in the region are particularly worrisome because teachers are largely unprepared to teach their subject matter and access to quality content, to information technology and to innovative approaches, including inquiry based education is limited. This therefore calls for a deliberate effort on the part of the tertiary institutions in the region to rise up to the challenge of raising the standard and quality of science, technology and mathematics teachers. It is expected that this effort will in turn transform the STM education in the Caribbean.

At this juncture, it may be necessary to state that sociologically, teachers in the Caribbean are not a unitary category. Using the social criteria of ethnicity, gender, social class and occupational prestige, Miller (2009) identified five teaching occupations within the region:

- University teaching that is comprised predominantly of males of the middle and upper classes and among whom the minority ethnic groups are over-represented. University teaching enjoys the highest prestige among the teaching occupations.
- High school and college teaching which is comprised of a minority of females and significant minority of males of middle class backgrounds and recent recruits to the middle strata from the lower strata through educational achievement.
- Private preparatory and kindergarten school teaching which is predominantly comprised of females of the same ethnic and social background as the clientele that patronize their schools.
- Public primary school teaching, which is comprised predominantly of females of lower social strata and of the same ethnic groups as the mass of the student population, served by the schools in which they teach.
- Community based pre-school teaching comprised almost totally of poorly qualified females of the lower social strata.

The present composition of the different teaching occupations in social terms, Miller warns, must not be regarded as either a static representation of history or a terminus in the social evolution of Caribbean society or of the teaching occupations. Rather, the social composition of the teaching occupations is reflective of both historical patterns as well as transformation in Caribbean social structure which are continuing. Having presented the above categories of teaching occupations in the Caribbean today, the following imperatives are suggested for colleges and universities training teachers in order to raise the quality of teachers and ultimately improve students' achievement in science, technology and mathematics.

(a) Evolve a unique model of STM teacher education

Miller (2009: 10) highlighted the salient features of Caribbean education with implications for teacher development as follows:

- Caribbean education has been part of Western education for over 350 years and readily adopts and adapts major developments in leading Western school systems.
- Both within and between countries, it is possible to find a wide array of educational reforms being implemented simultaneously.
- Because most reforms are adoptions from the West, there is not a strong indigenous capacity to initiate original approaches derived from the first principles applied to Caribbean imperatives.

Table 2. University of Columbia Teacher Training Model

Phase	Focus/type	Purpose of training
1	Experience the school	A 4 - 8 week apprenticeship to a public school to acquire some practical school experience; No teaching involved.
2	Small group and tutorial teaching by master teachers in a candidate's subject area of specialization. The student has a teaching subject and takes courses in them like those majoring in them.	To expose students to 10 – 20 weeks of experimenting with teaching strategies under laboratory condition
3.	Skill in the use of the inquiry teaching strategy. Each class group experiments teaching under varying conditions but each of which emphasized inquiry approach. Each candidate teaches five or more times using inquiry.	To drill students in the use of the inquiry instructional approach. Episodes of each inquiry teaching are played back, analysed and refined by the group.
4.	Curriculum practicum. Gaining practical experience in curriculum development and usin a curriculum to teach peers.	To provide students with opportunities for an observation – participation experience in curriculum processes and in a variety of ways of teaching.
5.	Simulation of a school and develop an educational programme for the school.	To give inquiry groups/course mates the opportunity to carry out activities designed to ensure that the school is well run.
6	Internship	To provide a unique opportunity for graduating students to function as trained teachers already in service with co-curricular activities. Salary and other remunerations are paid. Candidates go in teams and use inquiry strategy for teaching

Moreover, innovations and developments in pre-service teacher training in the 1990s are also listed but summarized thus:

- Upgrading the academic and professional standing of the pre-service programmes. Colleges training teachers were upgraded to offer pre-service training through degree programmes.
- Changing pedagogical practices in the training of teachers.
- Expanding the modalities used in the delivery of teacher training to include distance education and school based approaches.
- Using information technology to modernize instruction and management in colleges training teachers.

It is good to know that in America and England, various institutions that produce teachers have evolved their unique model of teacher education. See the example of the University of Columbia Model for Teacher Training (Table 2).

Such model is particularly useful during processes of education stocktaking, curriculum planning, and curriculum development. In the Caribbean, it is now very important for tertiary institutions training teachers to evolve teacher education model that is unique, adequate and relevant to the needs, goals and aspirations of the Caribbean community.

(b) Integrate technology into STM teacher preparation programmes

If technology is to be integrated into the classroom and play a significant role in educational reform, teachers need to be prepared to use emerging technological devices in ways that will facilitate teaching and learning. Granston (2007) in agreement with this suggestion declares that teacher preparation programmes in tertiary institutions need to play a more proactive role in preparing new teachers to teach in technology-rich classrooms, or at the very least, classrooms where teachers and students have access to computers. In other words, the issue of professional development of science teachers has become more necessary than ever because of the introduction of the use of computers and other modern instructional materials in teaching and learning processes in science classrooms, which demand new skills of science teachers in handling modern instructional materials and equipment which are aimed at enhancing quality in science education. This posits a new set of requirements on the teachers.

According to Hostmark (2007), in future, teachers will have an even more important role as they increasingly function as learning facilitators, helping students to grasp and select among all information available. The general standard for all teachers therefore has to do with the competency of developing the knowledge and skills in learning technologies to be able to appropriately and responsibly use the tools, resources, processes and systems and to be able to retrieve, assess and evaluate information from various media. The competent science teacher will use that knowledge along with the necessary skills and information to assist learners in solving problems, communicating clearly, making informal decisions and in constructing new knowledge, products or systems in diverse learning environments (Kadijevich, 2002).

However, in his meta-analysis of the factors that are instrumental to promoting the use of computer aided learning, Griffin (1998) found that teacher attitudes towards computer is an important factor related to the teacher's role towards the effective use of computers in education. It is then instructive to advise tertiary institutions in the Caribbean to make provisions for training of their students how to select the materials for teaching based on relevance, adequacy, comprehensiveness etc, and how to handle the equipment in the classrooms or laboratories as the case may be. And this has to be done in a way that will attract the interest of the prospective teachers. By doing this, they are disposed to using the computer and other materials enthusiastically resulting in better understanding and application of concepts on the part of students and ultimately leading to high science achievement.

(c) Introduce research – oriented activities into STM teacher training programmes

STM teachers ought to be well grounded in research – oriented activities in both classroom and laboratory settings. Student-teachers should be exposed to frequent and continuous drills in the use of Inquiry method of teaching and learning. They should also be developed to become action – researchers through which they can discover needs of learners and be able to offer relevant solutions.

(d) Ensure thorough academic preparation

The Universities and Colleges training teachers must equip the pre-service teachers with adequate academic competence and understanding of the relevance of STM education they require and transmit. If the teacher is to be regarded as professional, he/she must acquire adequate knowledge of the subject he teaches. This is crucial because today, an average Caribbean science, technology and mathematics teacher is below the minimum in the knowledge required for his or her discipline. Most of the older teachers do not make efforts to update their knowledge and competence and most of the younger teachers are ill prepared.

(e) Organize short – time programmes for practising STM teachers

Many practising STM teachers were not exposed to computer-aided learning during their time in school, neither were they taught this during their training in colleges or universities and yet they must teach students using various gargets or devices. Therefore they need help from the tertiary institutions to put them abreast of the situation. In this way it is imperative for these institutions to rise up to the challenge.

Conclusion

It is no longer debatable that the world in which we live today is a discovery and knowledge-driven one. Obviously, over the last half century, science and technology have come to occupy a central place as sources of economic growth and social well-being. Discoveries through scientific activities have led to dramatic increases in agricultural productivity, the establishment of new industries with new materials and processes, a revolution in communication and information technology, and improvements in health and quality of life. Therefore, the status of STM education particularly the science achievement of students in schools in the Caribbean should be raised to an acceptable level if the region must achieve the goal of using the STM education as an instrument par excellence for national development.

It is in the light of the above that it is recommended in this paper that the colleges and universities in the Caribbean take the lead in ensuring that students' achievement in science, technology and mathematics at various levels of education improves. This can be done by developing a unique model for teacher training which can be used in monitoring and evaluating teacher preparation at every stage. The tertiary institutions should also ensure ways of integrating technology into STM teacher preparation. The truth is that many teachers that are expected to teach science students using computers and other devices can not handle the gargets, neither do they understand the operations of such devices. For the existing teachers who were not exposed to Information and Communication Technology in their days and yet are expected to use ICT to teach, should be exposed to short – time courses, workshops and seminars along this line. The value of academic competency of teachers, especially in STM cannot be overemphasized. The colleges training teachers should ensure that the teachers they are producing are not only masters of the subject matter of the subjects they are to teach, but must also be sound in

pedagogy. Action research at classroom level by teachers should, henceforth be encouraged by the colleges training teachers during preparation of student – teachers.

The obvious limitation in this study is that the nature of the Caribbean region which comprises of many Islands is such that it is highly heterogeneous and is characterized by a mosaic of cultures, creeds, races and religions. It is a kind of diversity that makes any analysis of the region a very complex enterprise. Therefore, what is presented in this article is the general perspective, rather than an extensive analysis of all of the Islands.

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