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**CAUSES AND CONSEQUENCES OF LOW RATES OF SPECIALISATION
IN SCIENCE AND TECHNOLOGY IN CDCC MEMBER COUNTRIES**

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Abstract

The importance of science and technology (S&T) in Small Island Developing States (SIDS) is clearly articulated in Chapter XI, paragraphs 57, 58, 61 and 62 of the Mauritius Strategy for the Further Implementation of the Programme of Action for Sustainable Development of Small Island Developing States (MSI). At the regional level, the Heads of Government of the Caribbean Community (CARICOM) noted the challenge that CARICOM member States face in competing in this new international economic environment in which the impact of scientific and technological change has created a knowledge-based global economy.

Given the importance of S&T to development of Caribbean SIDS, the Economic Commission for Latin America and the Caribbean (ECLAC) Subregional Headquarters for the Caribbean embarked on a study to determine the causes and consequences of low rates of specialisation in S&T with a view to making recommendations for development of strategies for addressing these challenges. Data on postgraduate (Master of Science, Master of Philosophy and Doctor of Philosophy) enrolment and graduation in agriculture, engineering and the sciences from the three campuses of the University of the West Indies (UWI) as well as from the University of Technology in Jamaica and the University of Trinidad and Tobago (UTT) were examined and analysed. Face-to-face interviews were also held with key personnel from these institutions and a questionnaire was also served to individuals in key institutions. Results of the study revealed that although the number of students enrolled in higher degree programmes has increased in absolute terms, they are decreasing in relative terms. However, enrolment in agriculture has indeed declined while enrolment rates in engineering, although increasing, were not significantly high.

Market forces have proved to be a main reason for this trend while facilities for the conduct and supervision of cutting-edge research, the disconnect between science and industry and societal labelling of scientists as “misfits” are also contributing to the situation. This has resulted in a reduced desire by students at all levels of the school system and faculty to be involved in S&T; lack of innovation; a better staffed private, as compared with public, sector; and poor remuneration in science-based employment. There also appears to be a gender bias in enrolment with more males than females being enrolled in engineering while the opposite is apparent in agriculture and the sciences. Recommendations for remedying this situation range from increasing investment in S&T, creating linkages between science and industry as well as with the international community, raising awareness of the value of S&T at all levels of the education system to informing policy to stimulate the science – innovation interface so as to promote intellectual property rights.

INTRODUCTION

The word science comes from the Latin "scientia," meaning knowledge. It is "knowledge attained through study or practice"¹, or "knowledge covering general truths of the operation of general laws, especially as obtained and tested through scientific method [and] concerned with the physical world". Science refers to a system that uses observation and experimentation through the scientific method to describe and explain natural phenomena for the acquisition of knowledge and to the organized body of knowledge people have gained using that system. Science may be categorized into pure science that produces useful models of reality to differentiate it from applied science, which is the application of research to human needs. Fields of science are commonly classified along two major lines namely the natural sciences, the study of the natural world; and the social sciences, the systematic study of human behavior and society.

The word technology has Greek origins in "techne" meaning technique or skill and "locia" meaning to study. Therefore, technology should denote the study of techniques or skills. "ology" on the other hand is a branch of learning or study and is usually characterized by a more specific part such as biology signifying the study of living organisms. Technology is sometimes interpreted to be applied science or by the general public to be synonymous with computers. Technology is therefore a discipline involved in the systematic study of the creation, utilization and behaviour of technological systems and the impact of these systems on humans, societies and the environment with the purpose of attaining technological literacy. Technology is usually associated with major activities such as manufacturing, transportation and communication. Advances in technology are generally accompanied by social changes as a consequence of changing economies and ways of carrying out life's various activities.

A. The importance of science and technology (S&T)

The importance of (S&T) in Small Island Developing States (SIDS) is clearly articulated in Chapter XI, paragraphs 57, 58, 61 and 62 of the Mauritius Strategy for the Further Implementation of the Programme of Action for Sustainable Development of Small Island Developing States (MSI). The MSI recognises that S&T is a cross-cutting issue and since 1994, some SIDS have been successful in strengthening the S&T support base of their economies while others still require support to achieve this.

At the regional level, the Heads of Government of the Caribbean Community (CARICOM) noted that 'the Member States of CARICOM face the challenge of competing successfully in a wholly new international economic environment in which the impact of scientific and technological change has created a knowledge-based global economy' (CARICOM, 1997). They also noted the recommendation that in human resource development, 'priority should be given to, inter alia, increased productivity; research and development; science and technology and technical and vocational education . . .', and agreed that in all initiatives appropriate emphasis should be given to ' . . . the importance of science and technology . . .'. The policy emphasis of CARICOM governments also finds expression in The Strategic Development Plan (1997–2002) of the regional University of the West Indies (UWI, 1997), which sets explicit

¹ Webster's New Collegiate Dictionary

targets for significantly increasing the proportion of science and technology students in its total enrolment. Developing countries have, in recent times, gone beyond a general commitment to university or tertiary education to an emphasis on science and technology education that they perceive as essential for the development and maintenance of international competitive strength.

Economic growth could be boosted by discoveries made through scientific research and technological development that lead to the commercialisation of products. This, in itself, would promote development and, in turn, create employment opportunities that would serve to further attract both local and foreign experts thereby increasing the possibility of exponential economic growth. This would require significant investment in science and technology both from the human and institutional approaches.

Science and technology could contribute to improving safety and security, including areas such as cyber-security, transport security, environment security, crisis management and infectious disease prevention. Addressing those safety and security issues will require a global approach involving multiple stakeholders. Issues of personal privacy and data protection will also need to be addressed. The role of biometrics in achieving safety and security goals should also be considered. Implementation of biometrics will require significant research and development and generating new biometrics devices would present significant challenges over the next decade.

Utilisation of the results of applied research by the private sector could greatly help in boosting the S&T sector. In the current situation, the private sector transfers technology from abroad as it does not exist nationally and embarks on training local staff in the imported methodologies. If the results of applied research could be made available to this sector then the need for imported technology would be minimised and could significantly boost the specialised area of S&T.

Given the importance attributed to science and technology, the Caribbean Development and Cooperation Committee (CDCC) member countries can derive significant benefits from advances in science and technology in that knowledge creation and diffusion are increasingly important drivers of innovation, sustainable economic growth and social well-being. It would be necessary to ensure the long-term sustainability of the research enterprise and the need to involve civil society and business more effectively in the governance of public research.

Notwithstanding the importance attributed to science and technology, CDCC member countries are faced with low rates of specialization, a situation that does not augur well for security, social and economic growth and development. These countries recognize the importance of developing and maintaining an educated stock of human resources in order to promote scientific research and technological development.

This study, therefore, seeks to examine the factors that may contribute to decreasing interest in S&T and the consequences that may occur. It draws on the experiences of relevant stakeholders obtained through face-to-face interviews on responses obtained from a questionnaire (see annex) as well as an examination of the relevant literature. It builds on a previous study that focused on institutions in Saint Lucia, Suriname and Trinidad and Tobago

that impact the development of S&T nationally and in particular sectors and on the policy issues and process (ECLAC 2006). It will specifically address the areas of engineering, agriculture, physics, environmental management, biochemistry, chemistry, biology and information technology at the postgraduate levels, namely Masters of Science (MSc), Master of Philosophy (MPhil) and Doctor of Philosophy (PhD) and will focus on three countries, namely Barbados, Jamaica, and Trinidad and Tobago. Selection of these countries was facilitated by their strong emphasis on S&T as evidenced by the operations of specialized institutes offering the programmes of interest at the appropriate levels.

I. RATES OF SPECIALISATION

This section examines the rates of specialization in (S&T) at the higher degree levels in regional and national institutes in Barbados, Jamaica, and Trinidad and Tobago.

A. Barbados

The UWI Cave Hill Campus is the only institution in Barbados that offers specialized courses in S&T at the postgraduate level. MSc degrees are offered in natural resource and environmental management (started in 1992) and electronic commerce (started in 2006) and are usually of 12–16 months duration. The MSc in natural resource and environmental management originally offered a limited number of scholarships funded by the Canadian International Development Agency (CIDA) and later on by the European Union (EU). When external sources of funding for this programme had expired, the UWI took over financing but no scholarships were offered. MPhil degrees are offered in biochemistry, biology, chemistry, computer science, electronics, mathematics, microbiology and physics and are usually of 24-months duration. However, after one year many students opt to expand the focus of research and therefore upgrade to the PhD programme. PhD degrees are available in biology, chemistry, computer science, ecology, environmental science, mathematics, microbiology and physics and may be achieved in a minimum of 36 months up to a maximum of 60 months for full-time study.

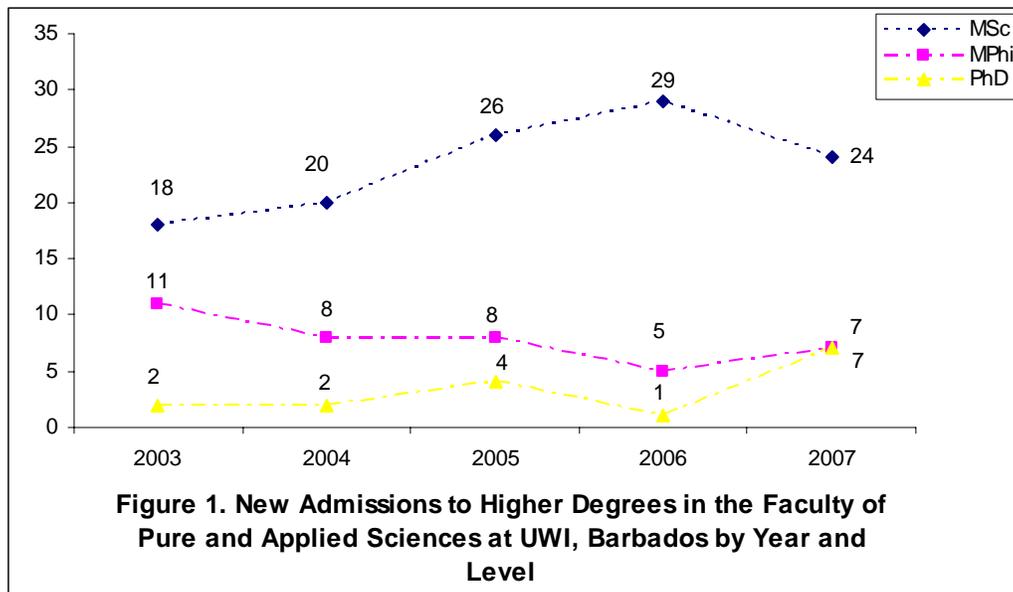
MSc programmes usually comprise courses that are delivered in the taught modality although there may be a limited research requirement of either three or six months duration. However, there is a modern trend to remove the research component from MSc programmes. At UWI, enrolment in MSc programmes appeared to be relatively steady with no significant increases or decreases (figure1). Three important factors should be noted; firstly that the increase in 2006 is attributed to the onset of a new programme in electronic commerce, secondly that there has been no increase in the availability of places in the MSc in natural resource and environmental management and, thirdly, there has been a decreased availability of scholarships for MSc programmes. MPhil enrolment showed a steady decline from 11 in 2003 to 7 in 2007 while for 2003-2006 a maximum of four students was enrolled in PhD programmes with a peak in 2007 when seven new students registered (figure1). Overall, new admissions to MSc courses of study are higher than that to research MPhil and PhD programmes with PhD programmes recording the lowest recruitment levels (figure 1).

Overall, there was a net increase in enrolment despite a reduced number in 2006 (figure 1). Disaggregation of the data by gender over the period 2003–2005 revealed that in 2003 and 2005 more female than male students enrolled, while in 2004 a slightly larger number of males (15) than females (14) enrolled. However, overall, more female than male students entered for higher degree programmes (table 1).

Table 1. New Admissions to Higher Degrees in the Faculty of Pure and Applied Sciences at UWI, Barbados

Year	Male	Female	Total
2003	8	28	36
2004	15	14	29
2005	11	21	32

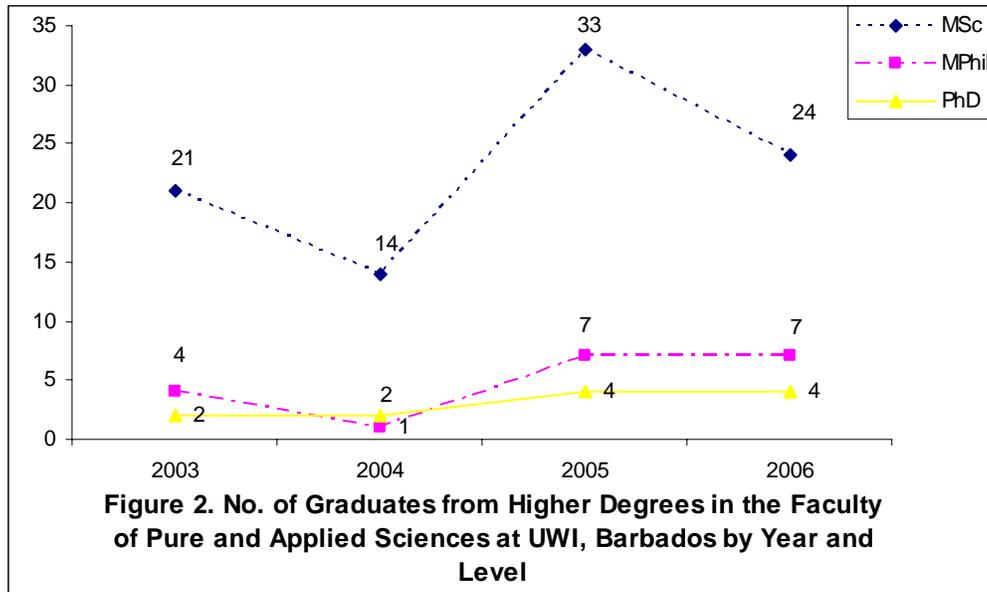
Graduates from MSc programmes ranged from 21 in 2004 to 24 in 2007, with a peak in 2005 (33); for MPhil programmes from four in 2004 to seven in 2007 and with PhD degrees from two in 2004 to four in 2007 (figure 2; G. Carter², *pers. comm.*).



Source: UWI, Cave Hill, Barbados

²Gail Carter-Payne, Senior Assistant Registrar (Graduate Studies), UWI, Cave Hill Campus, Barbados

It should be noted that graduation from these higher degrees does not necessarily occur annually as some programmes are of 18 months duration and some students return to their jobs after the first year so that they tend to complete the research component of the degrees in a longer period of time. In general, there are no significant changes in enrolment and graduation in postgraduate programmes with enrolment being higher in the taught Master's degrees than research degrees, namely the MPhils and PhDs (Figure 2).



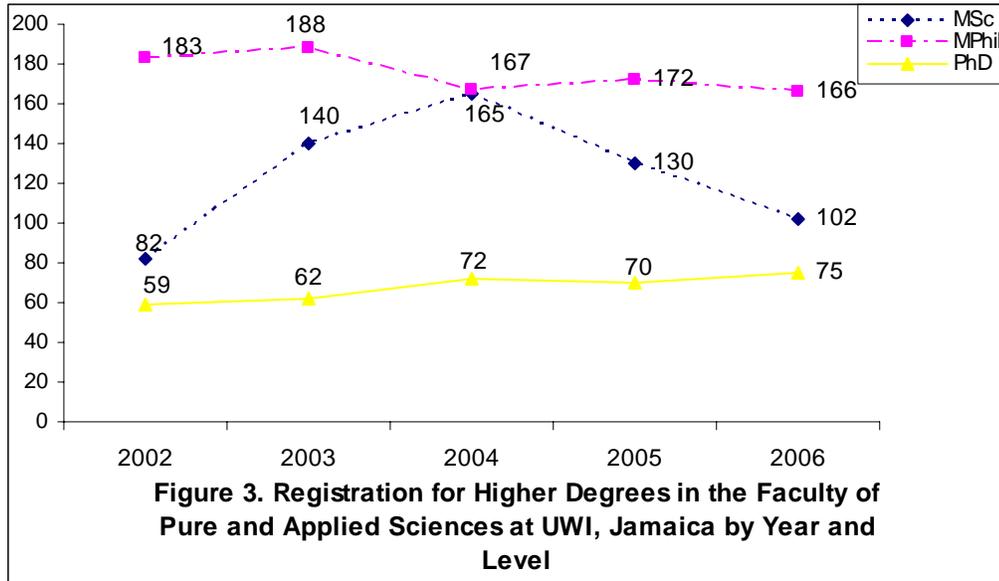
Source: UWI, Cave Hill,, Barbados.

B. Jamaica

The UWI campus in Mona, Jamaica, offers MSc degrees in aquatic science and marine and river systems, computer science, digital technology, mathematics, occupational health and safety, natural resource management, and plant production and protection. MPhil and doctoral degrees are offered in biochemistry, botany, chemistry, computer science, environmental biology, environmental management, geography, geology, marine sciences, occupational health and safety, physics, and zoology. In addition, MPhil degrees are offered in mathematics.

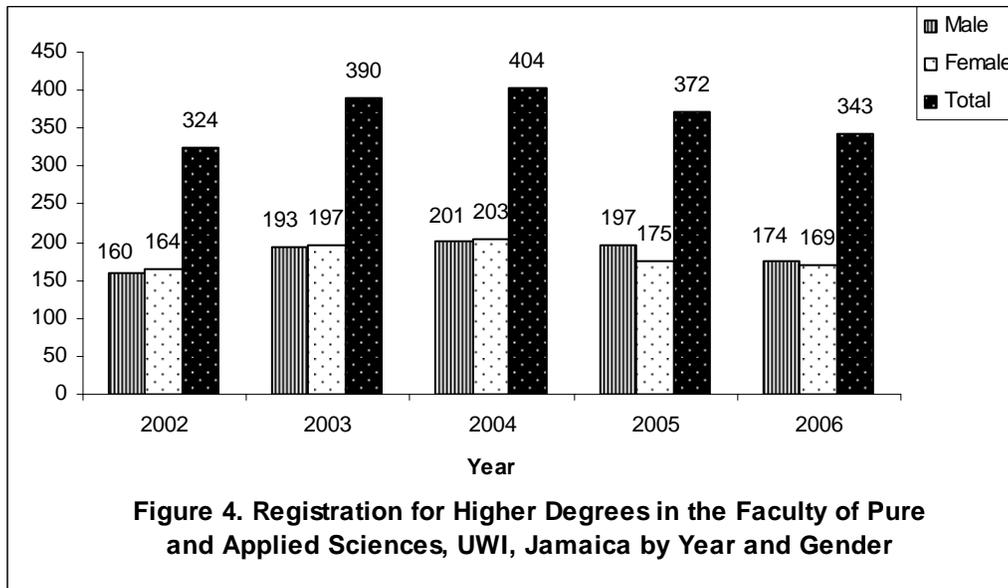
Registration for higher degree programmes over the period 2002 and 2006, in general, showed a net decline (figure 3). In the case of MSc programmes, although there was an increase from 82 students in 2002 to 165 students in 2004 this declined to 102 in 2006 (figure 3). Recruitment to MPhil programmes was high in 2002 (183) and although there was a slight increase in 2003 (188) there was an overall decline in new admissions over this period. Enrolment in PhD programmes showed a slightly upward trend although remaining generally low. Of particular note here is the higher recruitment to MPhil programmes than to MSc courses of study which is different from the case of Barbados and which will be seen in institutions in Trinidad and Tobago. In 2005 registrations in MSc programmes fell by 20 per cent and PhDs by

4 per cent from that in 2004, but MPhil registration increased with overall registration falling by 27 per cent mainly in the area of research degrees (67 per cent) (R. Young 2006).



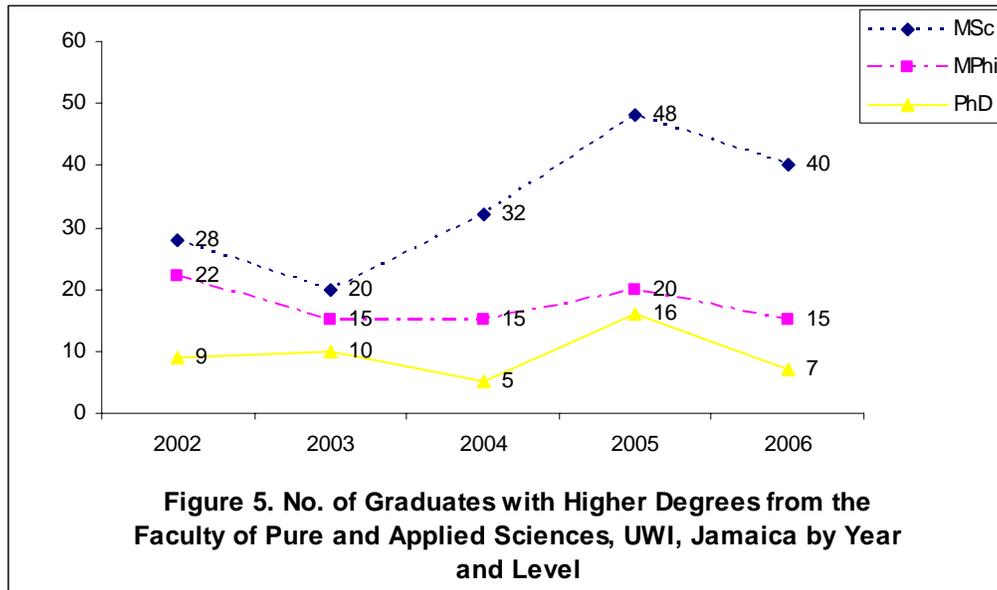
Source: Office of Planning and Institutional Research, UWI, Mona, Jamaica.

Disaggregation of registration data by gender revealed that between 2002 and 2004, females outnumbered males in registration (figure 4). However, this situation was reversed since more males than females enrolled in 2005 and 2006. Nevertheless, overall, there is no significant difference in recruitment by gender over the five-year period from 2002–2006 (figure 4).



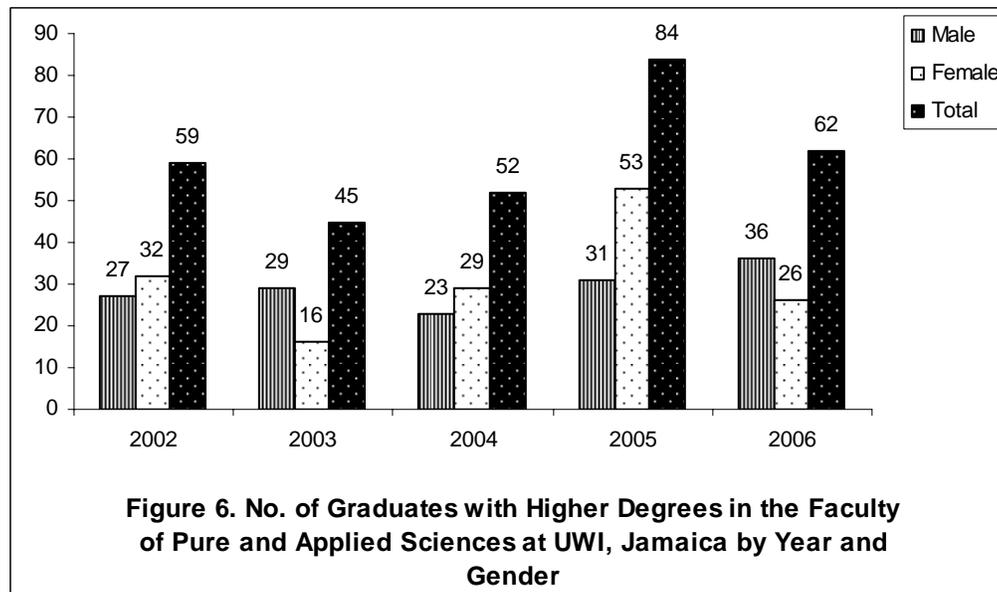
Source: Office of Planning and Institutional Research, UWI, Mona, Jamaica.

With respect to graduation from higher degree programmes, there was some fluctuation in the number of graduates resulting in a net decline over the period 2002-2006 (figure 5). However, overall graduation from MSc programmes was higher than that for MPhils and PhDs although registration for MPhil programmes is higher than that for MScs. This may be explained by the longer time taken to complete research leading to award of MPhil degrees than for achievement of MSc degrees.



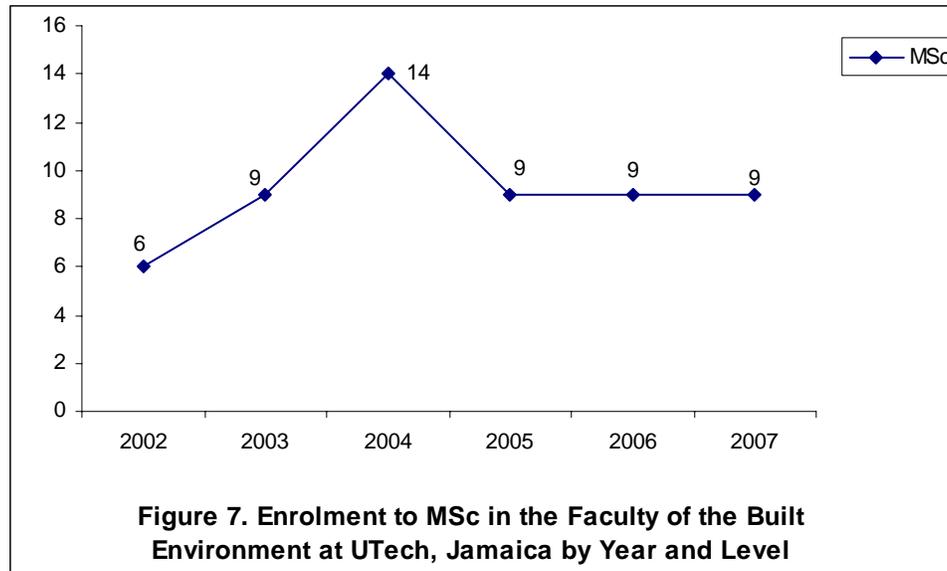
Source: Office of Planning and Institutional Research, UWI, Mona, Jamaica.

Disaggregation of these data by gender revealed that a larger number of females (155) as compared with males (146) graduated with an overall peak in graduation in 2005 (figure 6).



Source: Office of Planning and Institutional Research, UWI, Mona, Jamaica.

At the University of Technology (UTech) in Jamaica, postgraduate programmes are offered in the Faculty of Health and Applied Science where one student is currently registered in pharmacy studies (one has dropped out), the Faculty of Engineering and Computing (FEC) and the Faculty of the Built Environment (FBE). In the FEC, students were informally registered for research degrees (MPhil and PhD) in that they conducted research without being formally recognised as students³. This situation was regularised in 2007 when four MPhil and five PhD students were formally registered. At the FBE, an MSc degree is offered and over the past six years registration seemed to be rather steady with a peak in 2004 (figure 7).



Source: Office of Planning and Institutional Research, UWI, Mona, Jamaica.

An MSc in engineering management of 18 months duration is offered in partnership with the College of Engineering and Computing, Florida International University (FIU), whereby students are responsible for payment of all fees, UWI provides all facilities for conduct of the programme and FIU provides the staff. Profits accrued from the programme are shared between universities (M. Fletcher⁴, *pers. comm.*). Data indicate that enrolment has doubled since the onset of the programme and it is expected that this trend would continue (table 2).

Table 2. Enrolment in MSc in Engineering Management at UTech, Jamaica by Year

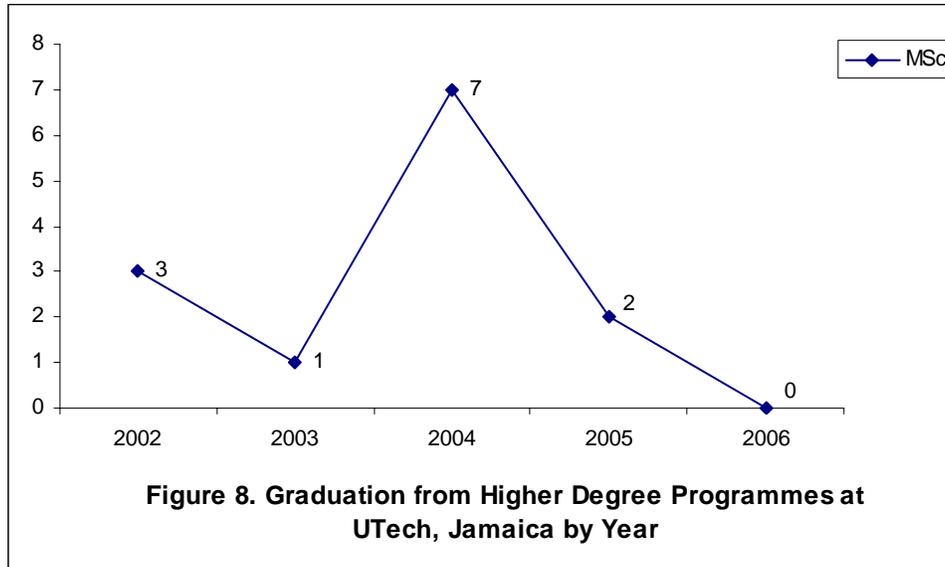
Year	Nos.
2006	19
2007	39

Source: Office of Planning and Institutional Research, UWI, Mona, Jamaica.

³ T. Street, Graduate Studies Assistant, Office of Research and Graduate Studies, UTech, Jamaica.

⁴ M. Fletcher, Principal Lecturer, Department of Mechanical Engineering, UTech, Jamaica

Data on graduation in the MSc in the FBE reveal that all students enrolled do not complete the programme in one year. Of the six enrolled in 2002, 50 per cent graduated (figure 8). In 2006, although nine students enrolled, none graduated. This may be attributed to the fact that many students are in full time employment while being registered for the degree.



Source: Office of Research and Graduate Studies, UTech, Jamaica.

C. Trinidad and Tobago

The Trinidad and Tobago national economic development strategy emphasizes continued high levels of investment and growth in natural gas production and export, growth of the petrochemical industry such as methanol and nitrogenous fertilizers, expansion of iron and steel refining, and establishment of a vibrant information technology sector. The government has stressed the associated demand for S&T graduates as well as for an increase in the overall gross tertiary enrolment ratio, which in 2005 stood at 13 per cent (UNDP 2006) as compared with 8.2 per cent in 1966 (Bourne and Dass 2003) and approximately 25 per cent for Latin America and the Caribbean region as a whole (UNESCO 2003).

In Trinidad and Tobago the institutions that offer specialization in S&T are the UWI St. Augustine Campus and the newly-established University of Trinidad and Tobago (UTT) which is a technology-oriented institution.

1. The University of the West Indies (UWI)

The UWI originally offered postgraduate programmes in the Faculties of Engineering, Agriculture and Natural Sciences. However, owing to a decrease in demand for places in the Faculty of Agriculture this faculty was merged with the Faculty of Natural Sciences and renamed

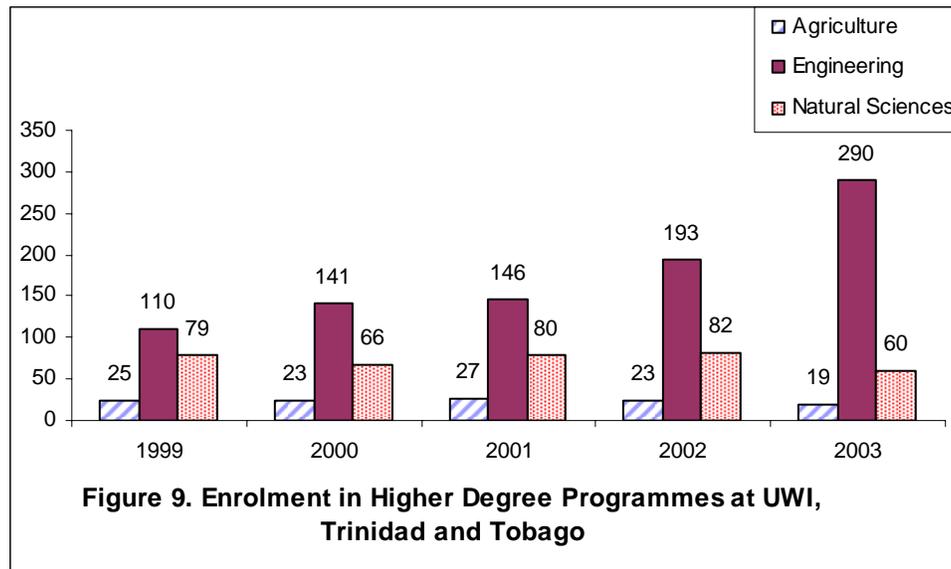
the Faculty of Science and Agriculture⁵. Today, both the Faculties of Engineering and Science and Agriculture continue to offer postgraduate programmes in S&T fields.

At the UWI, during the period 1999–2004, admission of students to higher degrees in the Faculty of Engineering actually increased with more males being admitted than females (table 3, figure 9). In the Faculty of Sciences and Agriculture, over the same period of time, the numbers fluctuated a bit with an overall downward trend with more females than males being admitted (table 3). Although enrolment in this faculty was low, it was even lower in specialist agriculture areas than in natural sciences fields.

Table 3. Enrolment by Year and Gender to Postgraduate Programmes in S&T at UWI, Trinidad and Tobago

Faculty	Year									
	1999		2000		2001		2002		2003	
	Male	Female								
Agriculture	11	14	11	12	12	15	07	16	9	10
Engineering	73	37	81	60	98	48	125	68	123	68
Natural Sciences	27	52	23	43	33	47	33	49	27	33

Source: Niherst 2006a. Science and Technology Indicators 2000-2004.

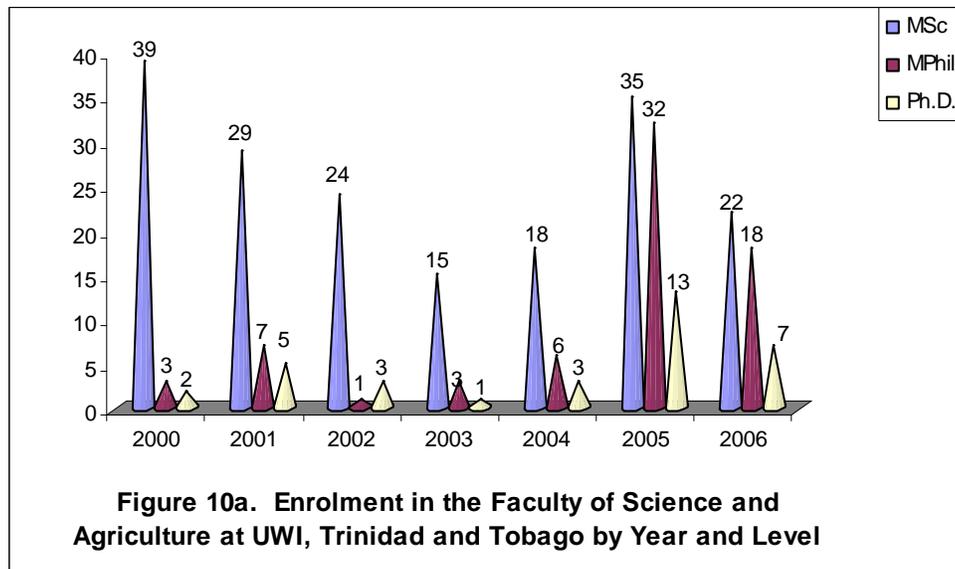


Source: Niherst 2006a. Science and Technology Indicators 2000-2004.

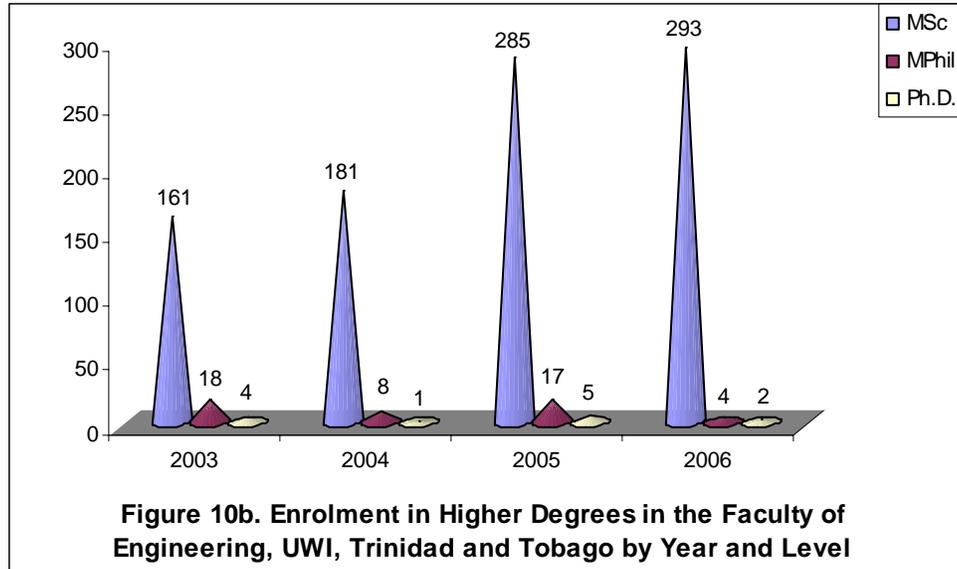
⁵ Professor Clement Sankat, Pro-vice Chancellor, Graduate Studies, UWI, Trinidad and Tobago

An examination of enrolment into specific graduate levels in the Faculty of Science and Agriculture at UWI reveals that generally there are low levels of recruitment and although an increase is apparent in 2005 (80 new admissions) this was short-lived as recruitment again declined in 2006 to 47 (figure 10a). However, engineering is better subscribed than agriculture and the natural sciences as enrolment increased from 214 in 199 to 369 in 2003.

Overall, enrolment in MSc programmes is higher than in MPhil and Ph.D. programmes (figures 10 a, b). MSc programmes are, in general, taught degrees normally encompassing a combination of course work and research. As such, they have a more finite end than MPhil and Ph.D Degrees. MPhil and Ph.D. programmes, which are research degrees, are generally undersubscribed and require specific laboratory facilities especially equipment and investment in research materials which are usually obtained from foreign manufacturers and are expensive. Research leading to award of these degrees tends to be quite specific and therefore requires supervision by experts in the respective fields for successful completion.

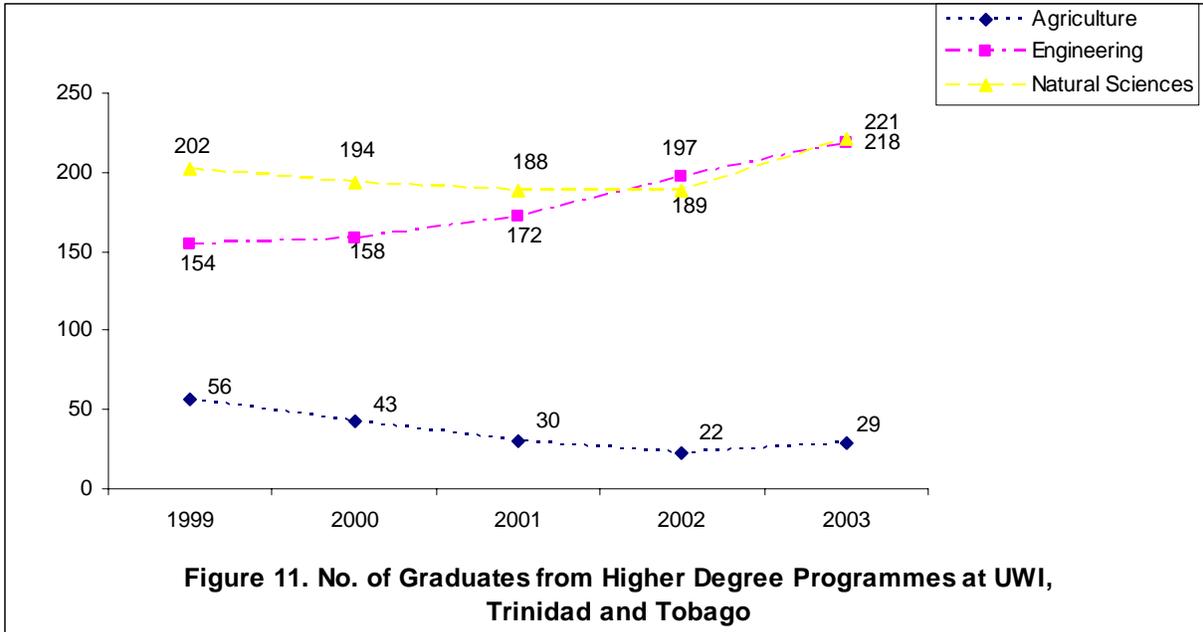


Sources: Niherst 2006a. Science and Technology Indicators 2000-2004 and School for Graduate Studies and Research, UWI, Trinidad and Tobago.



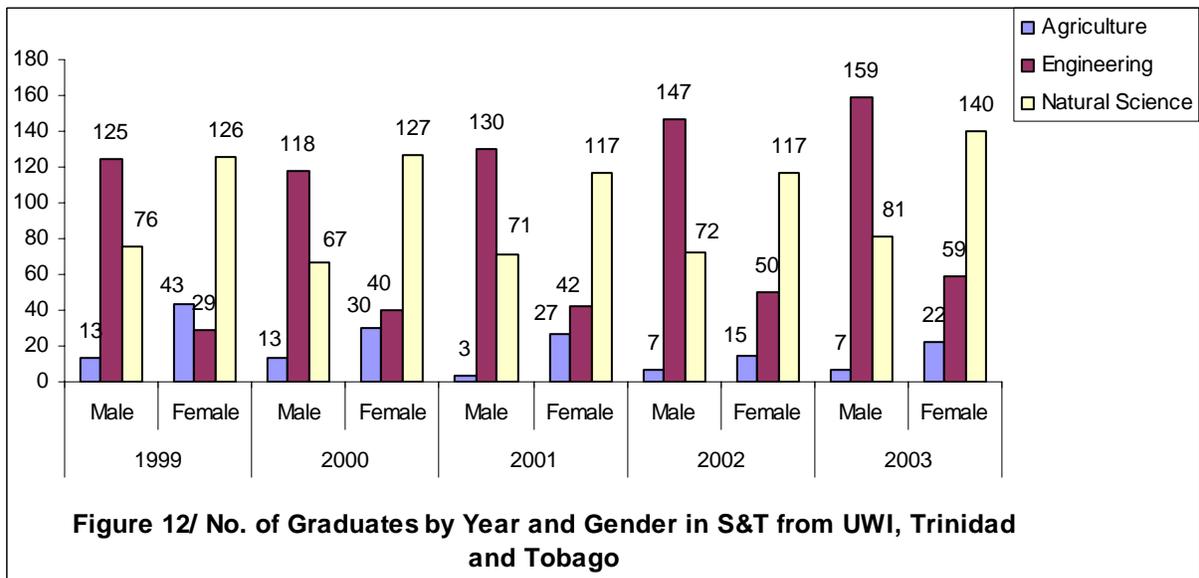
Source: School for Graduate Studies and Research, UWI, Trinidad and Tobago.

Statistics on enrolment are not necessarily representative of the number of individuals who qualify in the specialized areas. Therefore, in determining actual levels of specialization it would be informative to focus on the number of students who have graduated from institutes of higher education. At the UWI St. Augustine Campus there is a great disparity between the number of graduates in agriculture as compared to that in natural sciences and engineering. In agriculture alone, there appears to be a net downward trend as fewer students graduated from the faculty while in the natural sciences there appeared to be a period of stabilization between 1999 and 2002 with a slight increase after that, while engineering graduates seem to steadily increase from 154 in 1999 to 221 in 2003 (figure 11). However, it should be noted that this increase is by no means significant ($X^2 = 7.5399E-187$ $p < 0.05$).



Source: School for Graduate Studies and Research, UWI, Trinidad and Tobago.

In disaggregating the data by gender, it is apparent that more male than female students graduated in engineering while more female students graduated in the fields of agriculture and the natural sciences (Figure 12).



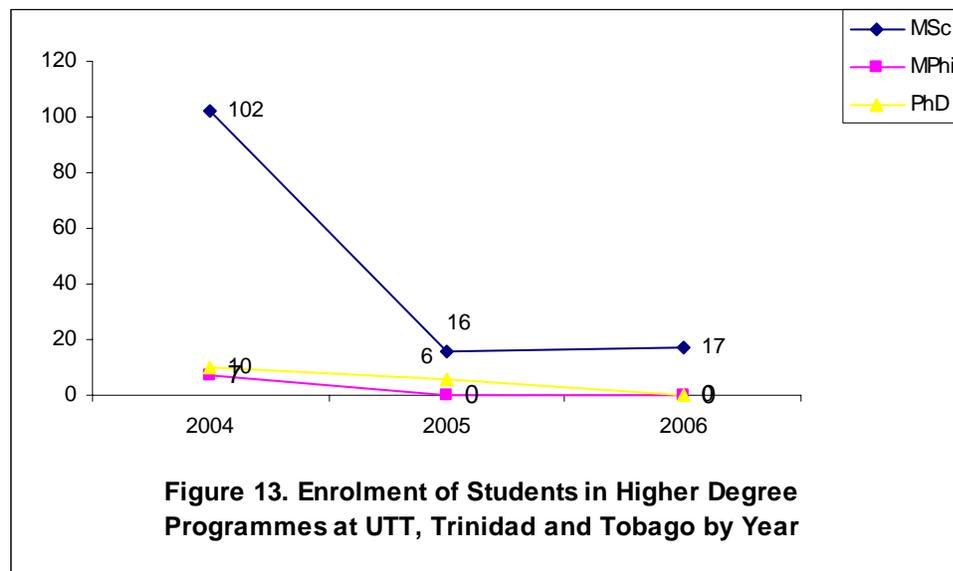
Source: School for Graduate Studies and Research, UWI, Trinidad and Tobago.

2. The University of Trinidad and Tobago (UTT)

The UTT seeks to meet the needs of Trinidad and Tobago for a highly trained and qualified technological manpower base. As technology changed over the years to suit the evolving global environment, so too have the human resource needs of the country. In reviewing these needs, several distinct engineering functions are identified with each function requiring its own set of specialized competencies and, by extension, education, training and qualification. Drawing on the experiences of the various institutions which will fall under its ambit, and the maintenance of established partnerships and arrangements, the UTT is expected to play its part in the development of a sophisticated society with the capacity for the application of cutting-edge information and knowledge.

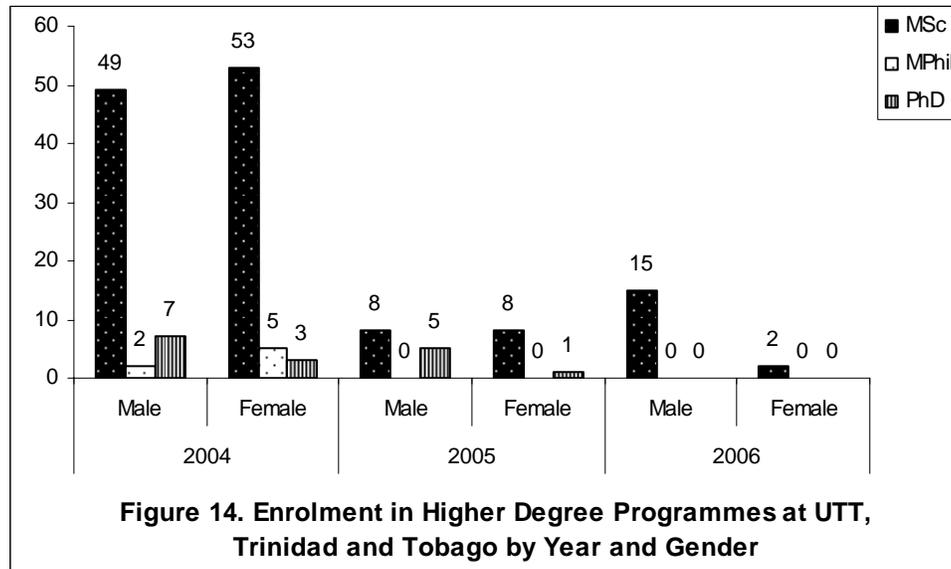
The UTT offers MSc and doctoral programmes in petroleum engineering, process and utilities engineering, information and communications technology (ICT) and industrial innovation, entrepreneurship and management. In addition, doctoral programmes are offered in manufacturing engineering.

Since the UTT has only been in existence for approximately three years, data on admissions is rather sparse but nevertheless show similar trends to that of UWI. With respect to enrolment, a total of 158 students were admitted to MSc, MPhil and PhD programmes over the period 2004–2006. Of this total enrolment, a trend similar to that observed for the UWI campuses is apparent in that enrolment in MSc programmes fell from 102 in 2004 to 17 in 2006; for MPhil programmes seven students registered in 2004 and there has been no registration in 2005 and 2006 and; PhD admissions ranged from 10 in 2004, to 6 in 2005 and none in 2006 (figure 13). A general decline in enrolment is apparent but this is more pronounced in MSc programmes perhaps because initial admission of new students was higher than in other degree programmes.



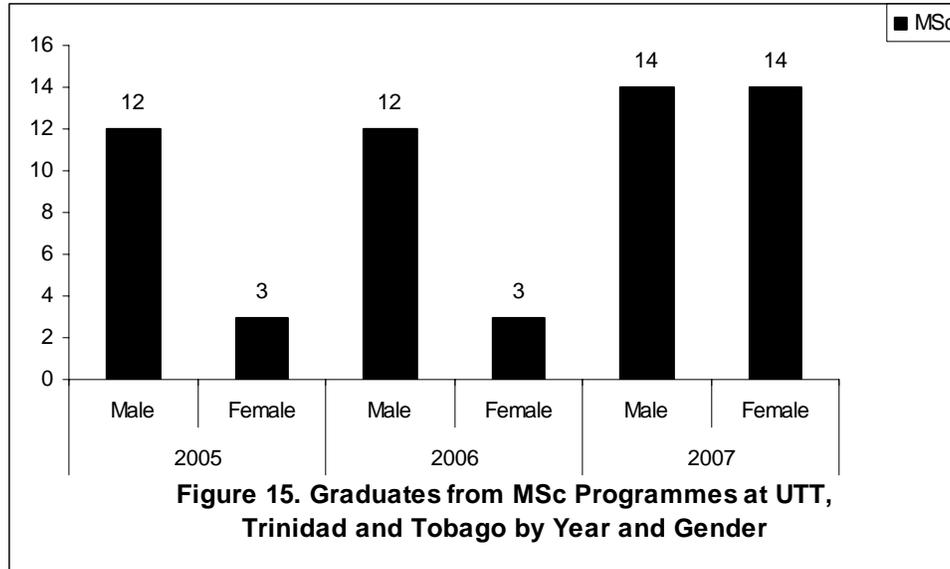
Source: S. Sheppard, Office of Planning, UTT, Trinidad and Tobago.

With respect to enrolment by gender, overall, more males than females registered for higher degrees even though there was a decline in total admissions (figure 14). Of notable interest is the large disparity in enrolment of male students over females in MSc programmes but the situation was reversed for MPhil degrees where more females than males were enrolled (figure 14). However, given the mandate of UTT to encourage and support specialization in S&T fields, the level of incentives to students is high and the institution is able to attract an increased number of students. Other S&T institutions in CDCC member States may well benefit from the strategy used in establishment of the UTT.



Source: S. Sheppard, Office of Planning, UTT, Trinidad and Tobago.

The majority of higher degree programmes at UTT are awarded over a period of two to three years at a minimum, with the exception of MSc programmes that could be achieved in 12 months of full-time study. To date, graduates, from the UTT are mainly those who have read for MSc degrees and the data display an increasing trend in graduates (figure 15). Given the level of investment in the UTT mainly in the provision of scholarships and increased staffing, the number of graduates from higher degree programmes in general should continue to increase with time.



Source: S. Sheppard, Office of Planning, UTT, Trinidad and Tobago.

D. Causes of low rates of specialisation

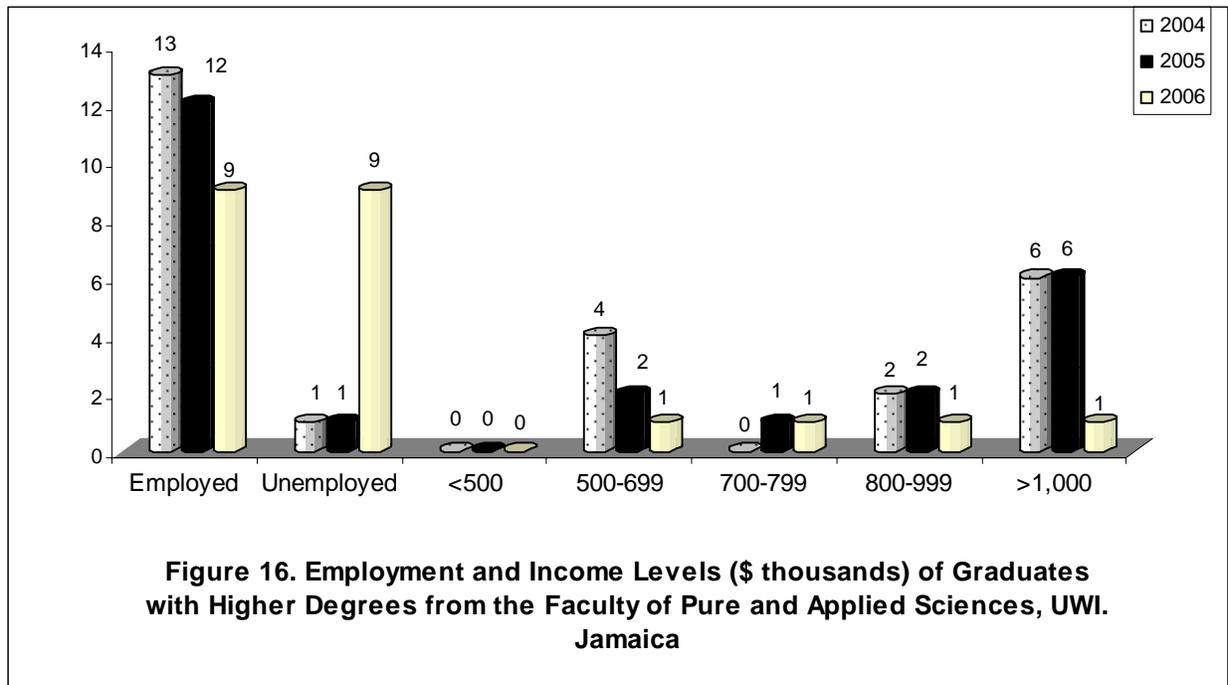
Low rates of specialisation in S&T have been attributed to a variety of factors ranging from economic, such as employment and income, to structural (adequate state of the art laboratory facilities) to the scientific such as the expertise to supervise cutting-edge research and the lack of linkages with industry. Of interest here is the perceived disconnect between S&T and development policy in the wider Caribbean region. The challenge of meeting demand for S&T talent is made all the more difficult by waning interest in science among youth, the gender gap among S&T graduates (notably at the doctoral level), the rapid ageing of the workforce in the public research sector, regulatory barriers and market disincentives to research careers, and the globalisation of higher education and research systems. These factors would be addressed in the following section.

1. Employment opportunities

Although there is a paucity of data from tracer studies conducted post-graduation there appears to be a link between specialization in S&T and employment and income both on the part of students and teaching staff. In the engineering field, growth in the construction sector in Trinidad and Tobago has resulted in a greater demand for civil engineers as well as electrical and computer engineers hence the increase in enrolment and number of graduates at the St. Augustine, UWI Campus and the UTT Campus. However, the move to employment in the public agricultural sector as well as in the physical and life sciences areas in the region is the result of limited employment opportunities in the private sector where remuneration is usually considered high as compared to the public sector. With respect to teaching staff, the security of contracts is a deterrent. In general, faculty staff are recruited on short-term contracts with limited benefits or at times without benefits and therefore seek more lucrative and secure positions in the private sector or in educational institutions abroad.

With respect to student enrolment in Trinidad and Tobago, the data also reveal that in 2000 there were 25,844 persons in occupations of science and technology; this represented 4 per cent of the total labour force 613,400. Technicians and associate professionals comprised the largest group of human resources in S&T (47 per cent), followed by professionals (41 per cent) and managers (12 per cent) (NIHERST 2006a).

Tracer studies conducted at the UWI Mona Campus in Jamaica revealed that in 2004 and 2005 the majority of graduates were employed and gainfully so, with annual incomes in excess of J\$1,000,000, with none earning less than J\$500,000 annually (figure 16). However these studies do not indicate if employment has been obtained in the public or private sector. This is comparable with the situation in Italy, Finland and Ireland where S&T graduates start out at a higher salary level than their counterparts from other disciplines except in teaching (Hamer *et al.* 2005). However, there was a halving of employment in 2006 with only one graduate earning above J\$1,000,000 annually (figure 16).



Source: Placement and Career Services, UWI, Mona, Jamaica.

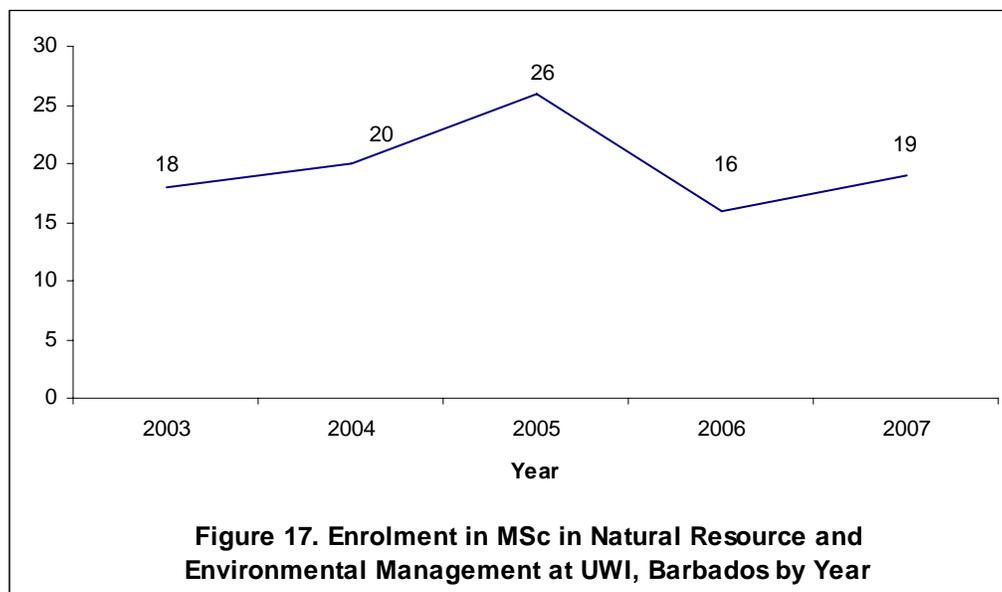
It is therefore evident that there is decreasing employment and financial remuneration for students who have specialised in S&T and this may well account for low enrolment in higher degree programmes. However it should be noted that these data are based on a minority of students (13, 12 and 9 in 2004, 2005 and 2006, respectively)

It is possible to posit that future employment in the field of S&T as well as the use of results of research, which would raise the demand for the conduct of such research by business, may probably be hampered by lack of market knowledge, market uncertainty, risk associated

with adoption of new technologies, absence of standards, and a lack of access to relevant skills and expertise⁶.

2. Availability of places in institutes of higher education

The availability of places for pursuing programmes at the postgraduate level in S&T is linked to access to funding as well as design and supervision of research and the status of enrolment, that is, whether it is full time or part time. The main deterrent to the increase in places stems from the limited availability of funding to facilitate expansion in programmes. Whereas small increases in availability of places could occur at minimal cost, the ability to attract students to enrol may be linked to the offer of scholarships. Scholarships are very rarely available unless international support has been accessed as with CIDA and the EU-funded MSc in Marine Resource and Environmental Management Programme at the UWI Cave Hill Campus. This funding was available for approximately six years and afforded students the opportunity of taking unpaid leaves of absence from employment to pursue specialised studies. However, with the termination of that funding, although the number of applicants remains high, there has been no net increase in enrolment (figure 17).



3. Qualifications and gender bias

Access to higher education is generally defined by the results of final examinations at the secondary school level, and if students are not provided with the opportunity to pursue S&T at this level it is unlikely that they would do so at the university level. Specialisation in S&T is also affected by perceptions of it as being difficult and therefore irrelevant to the careers of women. This is exacerbated by the influence of the school where there is only a small number of female

⁶ Professor Wayne Hunte, Pro Vice Chancellor, Research, University of the West Indies, Cave Hill Campus, Barbados..

teachers to be role models and differential school policies in assigning students by genders to advanced courses in the field where S&T is traditionally male-dominated (Ayalon, 2003).

The majority of female students are still enrolled in the traditionally "female" fields of studies and the highest increase in the number of female graduates has continued to occur in fields such as humanities, fine arts and education. In the United States, where college enrolment of women now exceeds that of men, the majority of women still choose subjects of study that are less likely to lead to higher paying jobs (Commission on the Status of Women, 1995).

Career advice. Specialisation depends on the choices that young people make in the 12-15 year age group and these in turn are determined by the nature and quality of science teaching earlier in their schooling as well as by guidance counselling and academic advisement. It is possible that if students do not receive appropriate career advice at a sufficiently early age they may not be empowered to make informed choices. This may result in selection of careers that are not necessarily in line with career desires and may affect enrolment at the tertiary level in general and, moreso, specialisation at the postgraduate level. For example, the 15–16 age group appears to be the watershed age with regard to choosing an S&T-oriented study path. Although there is no statistical relationship between emphasis on S&T before this age and study choice in higher education, influencing the experience of S&T before this moment would seem essential to counter the outflow of students at this point (Hamer *et al.* 2005).

4. Availability of facilities for research

Many tertiary level institutions such as those at the UWI campuses have not kept abreast of developments in S&T and hence laboratory facilities in terms of infrastructure and equipment for the conduct of cutting edge research are limited. Many research institutes therefore do not generally develop new products from applied research with the result that the region purchases almost all finished products from foreign countries (S. Sheppard⁷ *pers. comm.*). Engineers, for example, are generally involved in either application or maintenance engineering. More specifically, mechanical engineers neither conduct research into sources of alternative energy for cars or houses nor do they design and develop computers and software in any sustained manner. On the contrary, they maintain power stations and telecommunications systems bought in foreign countries and should problems develop a foreign expert has to be accessed to find a solution. Sometimes these same engineers and scientists excel when placed in a foreign environment as they receive the appropriate exposure to new technologies.

This situation could arise from limited investment in research and development in the Caribbean as well as the lack of a collaborative approach by universities, other research institutions and business enterprises in the pursuit of such an agenda.

⁷ Mr. Stephen Sheppard, Director of Student Affairs, University of Trinidad and Tobago.

5. Cost and duration of specialisation

Developing countries which represent nearly 70 per cent of the world's population account for barely 5 per cent of the world expenditure on research and development (R&D) in S&T. More specifically, over the period 2000–2004, total expenditure on R&D remained constant at about 0.13 per cent of the Gross Domestic Product (GDP) of Trinidad and Tobago (NIHERST 2006a).

Taught postgraduate degrees are better subscribed than research programmes. This could be because students perceive that there is a finite end to taught programmes which are structured and managed by a definite programme, while research degrees require greater time management and discipline on the part of the students. Furthermore, the modern trend to restructure taught degrees in a modular manner is increasingly attractive to professionals who are employed and could utilise holiday time to read for one or more courses.

Low specialisation at the regional level may also be caused by the present fee structure at the universities. For example, at the UWI St. Augustine Campus and the UTT, the Government of Trinidad and Tobago covers full economic costs of all nationals; at UWI, Mona, 80 per cent of economic costs are paid for by the Government of Jamaica and; at UWI, Barbados, the government covers economic costs of students with upper second and first class honours only. Students from unsponsored countries are therefore at a distinct disadvantage in pursuing higher degree programmes at any of the regional university campuses. Further afield, in Finland and Sweden all students are provided with grants to cover living expenses, while other countries limit the loans and grant system to specific groups often depending on income (Italy) or hardship (Germany and the United Kingdom; Hamer *et al.* 2005).

6. Lack of flexibility in identifying new areas of research

The lack of synchrony between R&D may be a cause of lack of attractiveness of students to the field of S&T. Tertiary-level institutions have not been successful in keeping pace with developments in industry, and innovativeness is at a minimum. This, linked to a lack of awareness of the limited areas of innovative research that these organizations could offer, may be responsible for low levels of specialisation in S&T as students prefer to be at the cutting edge of the developmental field and are encouraged by the application of research findings to the policy environment. It would therefore be useful to develop strategies to raise awareness of the areas of research, development and innovation that institutions could offer and this may serve to attract an additional number of students.

7. Availability of staff to teach and supervise specialised areas

Student career choices could be determined by their experiences at school. Negative experiences due to uninteresting content or poor teaching are often very detrimental to future choices. Furthermore, curriculum structures can also play an important role in preventing pupils from pursuing their natural preferences. Positive contacts with S&T at an early age can have a long-lasting impact on choice of specialisation at a later age. This is apparent in Sweden and the United Kingdom where high rates of specialisation have been positively correlated with systems where science subjects are an explicit part of the compulsory curriculum (Hamer *et al.* 2005).

At the tertiary level, the decline in S&T enrolment is in part due to a reduction in the number of faculty to teach and supervise research (PMSEIC, 1999a). For example, in the Faculty of Pure and Applied Science at the Mona Campus of the UWI there has been a decline in staff from 104 in 2004 to 78 in 2007 (R. Young⁸, *pers. comm.*). This is related to lack of competitive salaries, poor research facilities and declining investment in S&T research. A consequence of this is that staff that remain become disenchanted and virtually become “high school teachers” limited only to delivering lectures. There is an attempt to address this through the establishment of the New Initiative Fund at the UWI, into which a pool of funds, generated from consultancies, would be available to staff to conduct research.

8. Public’s perceptions of S&T

The public’s perception of S&T could greatly influence student choices in specialization. In 1995, the National Institute of Higher Education, Research, Science and Technology (NIHERST) in Trinidad and Tobago conducted a survey of 1595 respondents (45 per cent male and 55 per cent female) to determine their perceptions of S&T (Niherst 2006b). A relatively large proportion of the survey respondents (74 per cent) felt that they were informed while one quarter (26 per cent) considered themselves not informed. However, it should be noted that being informed showed a positive correlation with educational attainment and that fewest respondents (57 per cent) were interested in agriculture. Again, a small majority (42 per cent) was of the opinion that the benefits of scientific developments would accrue to only a few individuals and that 'society should use expenditure for science in more urgent activities' (73 per cent). These attitudes and perceptions may be among the factors influencing rates of specialization in S&T.

With respect to the relatively low rates of specialisation in agriculture, this may be attributed to lack of knowledge on the part of the public of the importance of agriculture to national food security, national social stability and environmental protection. The underestimation of the importance of food and agribusiness industries in economic development has resulted in “a lack of recognition of the contribution of agriculture and agricultural professionals to national development; under-financing of agricultural research, training and education; low interest in agribusiness as a profession among youth” (Brathwaite, 2003).

9. Accreditation

Lack of accreditation of credentials from national and regional institutions on the global market may result in low recruitment to specialised areas. Accreditation has its roots in “trustworthiness” and is therefore confirmation that such programmes have met or even exceeded the minimum educational requirements for registration of graduates in their respective field to specialised organizations. The Caribbean region has progressed gradually from the offer of secondary level examinations from overseas accredited bodies to national examinations overseen by the Caribbean Examinations Council (CXC). The uncertainty in accreditation of these credentials by prominent institutes of tertiary education for undergraduate studies may be a cause of lack of interest in pursuance of specialised programmes at regional and national universities. This may in turn filter up to interest in pursuing specialised courses in S&T at the

⁸ Professor Ronald Young, Dean, Faculty of Pure and Applied Sciences, UWI, Mona, Jamaica

postgraduate level. Additionally, at the tertiary level students who are interested in specialising at foreign universities may be hesitant to pursue courses in S&T if they perceive that they may be unable to secure places for postgraduate studies at foreign, recognised universities. With respect to postgraduate studies at the regional institutions this is not a tremendous challenge since the practice of having external examiners from recognised foreign universities appraise theses is still in place.

10. Stereotypical image of scientists

As early as primary school, students can be fascinated by S&T, particularly if the teaching is based upon practical experiences. Maintaining this fascination requires an exciting curriculum and teachers who are enthusiastic, adequately informed about the principles of science, and able to deal with practical teaching in a relaxed and competent manner. However, many research studies reveal that the perceived image of the typical scientist and engineer is stereotypical and problematic and aligned along the lines of the “crazy scientist”. They are perceived to be boring and authoritarian, having narrow and closed minds and not working to solve the problems of mankind (Sjoberg, 2000, 2002). These perceived characteristics add to the negative perception of S&T. Also, when students have to choose subjects at the secondary level, the science curriculum has to compete for popularity and attention with other school subjects, many of which have qualities that meet the students’ needs for meaning and relevance. The content of these alternatives appear to be less authoritarian. This is seldom the case in school science as it is presently taught. This situation is well captured in a headline in the *Financial Times* where it was written that “Science attracts fewer candidates. Students switch to newer subjects thought to be more interesting and less demanding” (Financial Times, 15 August 1996).

11. Values and ethos of science

The traditional values of science are meant to safeguard objectivity, neutrality, disinterestedness and rationality (Merton, 1973) and have come to be considered the core ethos of science. In extreme cases, however, these values may seem to justify an absence of ethical considerations and hence a lack of empathy with, and concern for, the social implications of science. The search for universal laws and theories may promote an image of science as abstract and unrelated to, and disconnected from, human needs and concerns. In this regard, S&T may well be perceived to be cold, uncaring and lacking a human face (Sjoberg, 2002).

12. A communication gap between scientists and the “public”

There is need to justify scientific and technological research and development in public forums when confronted with public distrust and criticism on new discoveries and this may make specialisation in S&T unattractive. However, criticism and scepticism are often based on lack of information and are often derived from misunderstandings on the part of the public (Sjoberg, 2002). S&T professionals need to be able to communicate more effectively with the public and to achieve greater acceptance of the results of their research.

E. Consequences of low rates of specialisation

1. Gender bias in employment

In general, the majority of well-educated women with university degrees are employed in lower-level jobs, despite higher educational qualifications than men (Commission on the Status of Women, 1995). The low level of quality of education and the loss of contact between education, training and the modern requirements of the labour market have been noted. Wage differences between men and women are greater among young adults with similar education and women in S&T are more likely to become unemployed than men (Hamer *et al.* 2005). There is a growing distortion between the qualifications and expectations of young women, who are more and more educated, and their effective participation in the labour market (Commission on the Status of Women, 1995).

2. Inflexibility to change to new technologies by society

The lack of interest by society stemming from a “disconnect” between S&T and the public may result in a negative effect on innovativeness in research. If the scientific community perceives that the results of tested and proven research may not be applied in informing national policy in key areas such as food security, ICT and health there may be diminished interest by researchers to design and conduct cutting edge and state-of-the-art research. Positive responses to new methodologies that are based on sound results could enhance the quality of research and serve to attract students to specialise in diverse areas of S&T.

3. Reduced economic benefits

There are clear links between technological progress and economic growth. There is a widely held belief that economic growth in the United States in the past two decades has been propelled by science and technology, as well as evidence that investment by firms and governments in research increases productivity (Boskin and Lau 1992). Low rates of specialisation in S&T may therefore hinder this growth.

A number of economic studies have concluded that there is a clear link between technological progress and economic growth, both at the level of the individual firm and the economy more generally. One analysis estimated that 49 per cent of economic growth came from technical progress and another found that every 1 per cent increase in a nation’s investment in research increased productivity by 0.23 per cent (Boskin and Lau 1992). There is also significant private return on R&D investment at the firm level, but due to spillover benefits there is a much greater social return. A survey of 63 international studies found annual rates of return on R&D in the order of 20 to 30 per cent to firms and approximately 50 per cent to society overall.

The large difference between the private and public rates of return on R&D, leads in the absence of adequate public investment and government action, to underinvestment in R&D. Investing less than the optimal level means that economic growth will be slower than otherwise attainable. In Australia the delivery of public funding for research has been primarily through

universities and public research institutes. In the United States, total funding for research and development grew from US\$100.30 million in 1970 to US\$291.663 million in 2002 (Lynch and Aydin 2004).

The economic significance of publicly funded research is clearly shown through a technique which links patents – as indicators of innovative activity in the economy – to publicly funded research. One study examined 397,000 patents in five industrialized countries and discovered that 73 per cent of the patents cited publicly funded research, 52 per cent cited university research funded through research funding agencies while industry citations contributed 27 per cent. An economic impact model developed by the Association of University Technology Managers (AUTM) shows that, in 1997, \$28.7 billion of United States economic activity, supporting 245,930 jobs, can be attributed to academic technology transfer from the licensing of intellectual property⁹.

Recent empirical research established that corporate R&D is strongly associated with subsequent gains in companies' productivity, earnings and stock prices. The research demonstrated that patent application citations and the links to science in those patent applications are significantly associated, after controlling for conventional financial variables, with subsequent market-to-book ratios and stock returns.

The importance of S&T for economic growth is also illustrated by the Securities Industry Research Centre of Asia-Pacific (SIRCA) which is a research collaboration between the financial services industry and accounting, finance and economic departments from 26 universities across Australia and New Zealand (PMSEIC, 1999b). This is also recognised for Africa where “long-term transformation in Africa will need to be guided by effective science and technology advice” (Ndiho, 2007).

4. Reduced availability of S&T tutors

Low rates of specialisation in S&T have resulted in a reduced availability of science teachers at both the primary and secondary levels and the lack of recruitment of more highly qualified professionals at the tertiary level. At the UTech in Jamaica, only 10 per cent of the staff possesses doctoral degrees (E. Morrison, *pers. comm*) and although there is interest in further education and research, faculty find it extremely difficult to allocate time to conducting research leading to achievement of these degrees (M.Fletcher, *pers. comm*). The effect of this is that students do not benefit from tuition from staff with improved skills as well as possessing a wide range of experiences. This does not augur well in terms of stimulating interest and further contributes to low rates of enrolment in specialised areas of S&T.

5. Low competitive position on the S&T global market

Specialists in S&T would be in a better position than non-specialists (generalists) to compete for positions on the global market. Governments and institutions would prefer to employ highly-qualified individuals and this places tremendous constraints on less qualified

⁹ <http://www.autm.net/>

individuals who then settle for second best, a situation that stems and retards professional development with loss of interest and poor job satisfaction.

6. High drop-out rate in S&T

The high cost of specialisation in S&T together with the length of time this takes may well result in a high drop-out rate from tertiary institutions. This is especially so in research degrees where students consider it necessary to take up part-time employment thereby increasing the length of time required for completion of research and award of degree and sometimes bringing with it disillusionment and resulting in abandoning such programmes.

7. Better staffed private sector as compared with public sector

The few individuals who do specialise in S&T areas are in great demand and are readily employed by the private sector where terms and conditions of employment are usually perceived to be more lucrative than in the public sector. This results in the public sector being understaffed and therefore possibly less productive than the private sector with the concomitant impacts on development and, moreso, on small and vulnerable economies such as those in the Caribbean.

II. CONCLUSIONS AND RECOMMENDATIONS

This study established that there is indeed a decrease in rates of specialisation in S&T although this rate, though insignificant, is not as pronounced in the field of engineering. Market forces have proved to be a main reason for this trend while facilities for the conduct and supervision of cutting-edge research, the disconnect between science and industry and societal labelling of scientists as “misfits” are also contributing to the situation. This has resulted in a reduced desire by students and faculty to be involved in S&T, lack of innovation, a better staffed private, as compared with public, sector and poor remuneration in science-based employment. The gender bias in S&T is also apparent. Recommendations for remedying this situation stem from increasing investment in S&T, creating linkages between science and industry as well as with the international community, raising awareness of the value of S&T to informing policy to stimulating the science – innovation interface so as to promote intellectual property rights.

The practical spectrum of S&T for the Caribbean would range from the factors that affect recruitment of students such as choice restrictions, motivation and the structure of the various educational systems to outflows such as labour market issues and prestige. The recommendations to address these issues include investment in S&T, creating linkages and building awareness of the value of S&T to development (figure 18).

Policy-level changes are required if increased rates of specialisation in S&T are to be achieved. These would range from an examination of the level of investment in S&T both at the level of the students and teaching and research staff to availability of adequately equipped research institutions. Additionally, the development of alliances with international institutions and building of awareness of the value and importance of S&T to national and regional

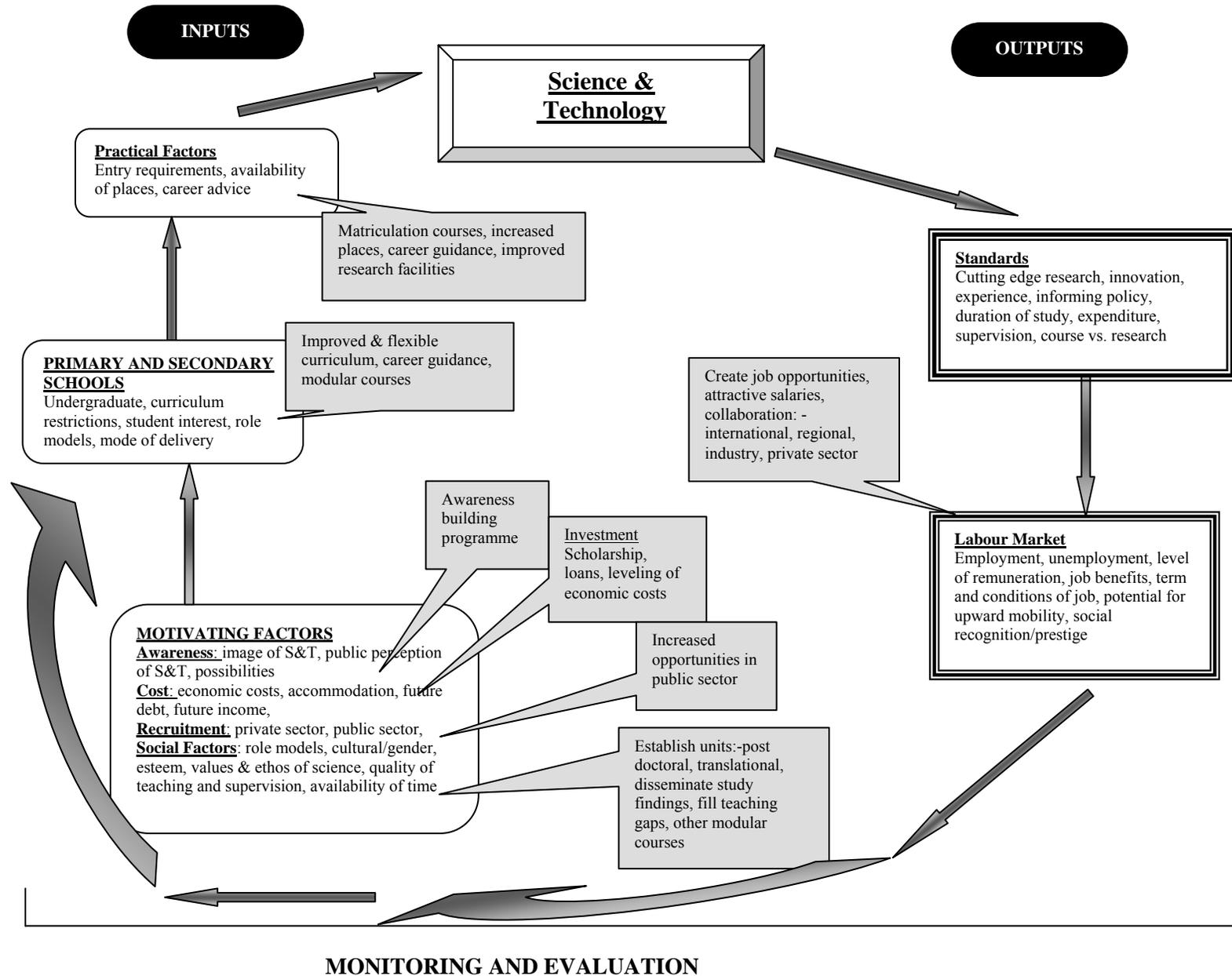
development goals in the Caribbean would enhance the S&T agenda. Recommendations as to the areas in which these changes may be implemented are now examined in more detail.

Investment in S&T at the tertiary levels is required in order to raise levels of enrolment and certification. In this regard, the Government of Trinidad and Tobago, is currently covering 100 per cent of economic costs at UWI campuses for its nationals pursuing postgraduate degrees, while the Government of Jamaica covers 80 per cent and the Government of Barbados covers these costs only for students who have matriculated with upper second class or first class honours degrees. This presents a problem for students from other CDCC countries studying at these institutions for whom economic costs are unpaid. It is recommended that this challenge may be overcome by exempting these students from economic costs (W. Hunte¹⁰, *pers. comm.*). This is evident in Ireland where the Office of Science, Technology and Innovation will invest € 6.1 billion in several areas of science, technology and innovation inclusive of human capital in order to achieve its vision of excellence in research by 2013 (Department of Enterprise, Trade and Employment 2004). Also, in Australia in 2001 the government allocated US\$3 billion to science, research and innovation (Science and Innovation Task Force, 2003). In Britain, the Confederation of British Industry made a call for students to be offered £1000 annually as a “golden carrot” to study science and engineering at university¹¹. However, in Brazil, the situation is different, as federal investment in S&T has stagnated from US\$2.32 billion in 1990 to US\$ 2.36 billion in 1999 (Pinheiro-Machado and Oliveira, 2001). This has been offset by an increase by private investors with a concomitant increase in graduate enrolment but has not materialised in an increase in development of patents for innovation which is the main aim of private investment.

¹⁰ Professor Wayne Hunte, Pro Vice Chancellor, Research, University of the West Indies, Cave Hill Campus, Barbados.

¹¹ The Independent, 13 August 2007.

Figure 18: Conceptual Framework of Causes and Consequences of Low Rates of Specialisation in S&T in the Caribbean. Callouts represent recommendations.



Scholarships are one means of encouraging and enabling females to pursue their education and of guiding them into non-traditional fields and in this regard it is recommended that sources of funding for scholarships be identified. Some developing countries criticize the attribution of scholarships by donor countries on a purely merit basis for those priority areas of study identified for future labour needs. Traditional attitudes often prevail in decisions concerning whether female students should be sent abroad to study. In some countries senior women scientists mentor schoolgirls and young scientists on how to develop career strategies and paths and how to sustain motivation and inspiration. Vocational counselling and guidance are additional means used to encourage girls to opt for non-traditional career paths. France, for example, launched important campaigns in 1992 and 1993 encouraging girls and young women to pursue technical specializations and professions. In Pennsylvania, United States, The Clare Boothe Luce Program provides grants for undergraduate scholarships for women studying science, engineering, and mathematics (4000 Years of Women in Science, 1992).

Offering of courses in modular form, as is currently being done in the MSc in Marine Resource and Environmental Management at the UWI, Cave Hill Campus, may be an incentive for students to enrol as each course is generally of two-weeks duration and may well be read during holiday time. This is currently being done in graduate programmes at the School of Geography, Geology and Environmental Science at the University of Auckland, New Zealand¹², the Department of Science and Technology at the University of Malaysia¹³, at Cranfield University in the United Kingdom¹⁴, and at the Cologne University of Applied Sciences¹⁵. However, this raises the issue of fee structure (H. Oxenford¹⁶, *pers. comm.*). The UWI needs to examine the current fee structure for all students and to arrive at amicable solutions. With the rationalisation of these matters modular courses should indeed contribute to increased levels of specialisation.

Raised awareness of the benefits of S&T is essential to support a knowledge-based ‘can-do’ society in the twenty-first century and it is recommended that such programmes be developed. In promoting science awareness, however, it is vitally important that the community is able to relate science to everyday life and in this way appreciate how science can improve economic, social and cultural well-being. In this regard, Finland, Ireland and the United Kingdom have implemented specific curriculum reforms aimed at improving the image of S&T before this choice-moment and prevented an early “lock-out” of potential S&T students (Hamer *et al.* 2005). Improving S&T education through specialisation (United Kingdom) or a more practical orientation (Ireland) or including a “remedial” year to improve S&T skills (Sweden) are all proven methods to attract students to specialised areas of S&T (Hamer *et al.*, 2005). Additionally, the House Science Committee of Cornell University in its “no child left behind” programme seeks to marry the talents of higher education with the needs of elementary and secondary education particularly in math and science (Marikar, 2005). This committee

¹² http://sges.auckland.ac.nz/postgraduate/courses/envsci_pg_courses.shtml

¹³ <http://sts.um.edu.my/Postgraduate.html>

¹⁴ <http://www.courses-careers.com/graduates-courses/articles/materials-science.htm>

¹⁵ <http://www.international-office.fh-koeln.de/english/study/entire/u/01721.php>

¹⁶ Professor Hazel Oxenford, Professor of Marine Ecology and Fisheries, Cermes, UWI, Cave Hill Campus, Barbados)

recognises that “you don’t create a Ph.D. just by taking someone from undergraduate to graduate school” but the process needs to start in kindergarten.

In conjunction with raised awareness of S&T at the primary level and greater flexibility of the curriculum so as to increase participation, is the need to improve the quality of teachers at both the primary and secondary levels. Without sufficiently qualified teachers, students will lack the necessary incentive to follow S&T-related studies. High-quality teaching often requires teachers, students and organizations to examine their perceptions and beliefs about teaching and teaching practice. This needs to be considered by policy makers in the design of new educational policies and in providing incentives to facilitate this reflection (Hamer *et al.* 2005).

National strategies to target gaps and overlaps, and make existing awareness activities more focused and effective is recommended. This strategy will target key audiences with key messages using specific delivery techniques. The formation of a coordinating body and the implementation of a national strategy are essential prerequisites for an increase in national science awareness. This approach is being tried in Australia and a strategic framework has been worked out (PMSEIC, 1999b). The Confederation of British Industry has proposed that the brightest 40 per cent of 14-year olds should be told that they must study three science subjects at the local General Certificate of Secondary Education (GCSE)¹⁷. The Caribbean region may well benefit from becoming acquainted with this approach.

If the Caribbean region is to be competitive in a global market of ideas and skills, public support for scientific research is essential. Industry requires a community with a better understanding of S&T to provide a labour force with adaptable skills and the flexibility to deal with ongoing rapid technological change. An understanding of research principles and a science and technologically literate community are essential for investment in new and technologically high value added industries, and therefore critical to innovation and wealth creation. R&D are also vital drivers for industry to develop innovative ideas. It is therefore important that society's awareness and understanding of science be improved in government, business and industry, the media and the community as well as for students and the education sector.

At present there is a perception that regional universities are focused on delivering taught Masters programmes and that they are not involved in innovative research that could inform policy decisions and are therefore unattractive. This is particularly pertinent to UTech (E. Morrison¹⁸, *pers. comm.*) It is recommended that projects geared towards upgrading of existing infrastructure and installation of laboratories in which cutting edge and state-of-the-art research may be conducted should serve to attract both staff and students in moving forward the research agenda in S&T. Furthermore, promoting greater international cooperation in S&T is vital in meeting a broad range of global challenges related to economic growth, better health, sustainable development, and enhanced safety and security, as well as in implementing large science projects in a growing range of disciplines. For example, staff would benefit from exchanges with university staff in developed countries to allow for the opportunity for keeping abreast of new technologies which would greatly enhance research design and supervision and reduce the time taken for completion of research and award of degrees.

¹⁷ The Independent, 13 August 2007.

¹⁸ Professor Errol Morrison, President, University of Technology, Old Hope Road, Jamaica.

At the institutional level, in order to attract the student body to specialist fields in S&T it is important to have programmes of study accredited to foster interest in pursuance of higher degrees. Accreditation is the tool that is used to monitor, assess, and evaluate the standards and quality of the education a student receives at a college, university, or other institution of higher learning. This process of accreditation can ensure that the education for which students are paying is valuable and worthwhile and it is the job of the accreditation organization to review colleges, universities, and other institutions of higher education to guarantee quality and improvement efforts. Accreditation should involve a periodic audit of courses and programmes provided by educational institutions with a view to maintaining required and acceptable standards. However, there are costs associated with accreditation which may be prohibitive but every effort should be made to invest in this exercise in order to maintain standards which, in turn, may serve to attract students to specialized area in S&T.

Related to this are the benefits to be derived from forming relationships with national and regional institutions as well as institutions in developed countries. At the national level, the UTT in collaboration with the Faculty of Engineering at UWI, Trinidad and Tobago, offers a Bachelor's Degree in Engineering Technology (BTech) in the major engineering disciplines (Sankat, 2004). At the regional level, the MSc in engineering management that is offered at UTech is shared with the FIU. Students pay fees, UTech provides all facilities for conduct of the programme, FIU staff deliver the lectures, the arrangement is profitable and the profits are shared. Also, the University Consortium of Small Island States (UCSIS) which comprises the University of Malta, University of Mauritius, University of the South Pacific, University of the Virgin Islands and the UWI is in the process of developing an MSc in Sustainable Development of Islands and Small States (W. Hunte, *pers. comm.*)¹⁹. This organizational method could be promoted among other university campuses so that increased financial independence may be obtained. This would greatly enhance opportunities for both staff and students and make S&T more attractive. However, data on formal partnerships show that the vast majority of them involve participants from developed countries (UNCTAD, 2002) and Caribbean regional institutions need to guard against this in the recruitment process.

The establishment of units for translational research is recommended to promote the applicability of the research agenda. Translational research is the application of the resulting knowledge and discovery for the benefit of society and was previously limited to medical research. Investment in such units could create research value, visibility and additional opportunities. This is currently being proposed at Northeastern University in Boston, Massachusetts²⁰ and has been described as "the Academic Initiative". It is also being recommended for use by networks where results of studies may be shared and collaboration in the application of these results encouraged (Ruttenberg *et. al.*, 2007). In the Caribbean region such units could serve a two-fold purpose. Firstly, they could embark on market scoping with a view to identification of changing market forces that would inform research. Secondly, they could translate research findings into policies in support of national development plans and relieve teaching staff of the burden of designing, conducting and also applying the research findings.

¹⁹ Professor Wayne Hunte, Pro Vice Chancellor, Research, University of the West Indies, Cave Hill Campus, Barbados.

²⁰ <http://www.neu.edu/planning/draftplan/index.html>

As distinctions between fundamental and problem-oriented research have blurred, demands to make public research more responsive to the needs of business and civil society have mounted. Also, changing innovation processes and the evolution of the relative contribution made by the private and public sectors have emphasised the need for strong industry-science linkages (M. Fletcher²¹, *pers. comm.*). A well-functioning interface between the innovation and science systems is more necessary than ever to reap the economic and social benefits from public and private investments in research, ensure the vitality and quality of the science system, and improve public understanding and acceptance of S&T and the importance of innovation.

Research has shown that collaboration between industry and science has increased (Geuna *et al.*, 2004). In this regard, several countries including Brazil, Argentina, Mexico, Chile and Costa Rica are moving in the direction of developing incentives for innovation in industry and are reviewing policies and institutional frameworks to transform them into supportive mechanisms for innovation. For example, the Government of Chile is preparing a law to finance R&D through the imposition of a royalty on mining. Brazil has recently approved a new law removing constraints that discouraged collaboration between universities and industry (IDB, 2004).

The increased use of public-private partnerships could well promote science-based innovation, improving mobility of research personnel, and create a business environment in which both established and start-up firms demand new scientific and technological advances. In this regard, it is recommended that tertiary education institutions should have the necessary autonomy and incentives to adapt curricula to changing skill demands, including for interdisciplinary knowledge and managerial/entrepreneurial skills, and to develop partnerships with industry to meet these goals. However, because it has not traditionally been in the interest of private companies to share their resources and creative competencies with the public sector, incentives are needed. This can be accomplished through the award of tax advantages to firms for cooperative research, commercialization of publicly financed research, 'scientist-in-industry' programs, joint or specialized training, and technology parks and publicly supported 'incubators' for providing start-up companies with assistance such as office and laboratory facilities and technical support (InterAcademy Council 2003). Also, the award of tax breaks and concessions to industries that form alliances with universities by governments might assist in promotion of this venture.

A strong science and innovation system could contribute to economic growth, environmental sustainability and social well-being (Science and Innovation Task Force, 2003). Science-innovation linkages can take many forms, from contract and collaborative research and personnel transfers to technology licences and creation of spin-off firms. These linkages should include the changing role of intellectual property rights in stimulating knowledge creation and diffusion. Patent regimes play an increasingly complex role in encouraging innovation, diffusing scientific and technical knowledge, and enhancing market entry and firm creation. It is recommended that university staff be provided with the time and resources to conduct state-of-the-art research so that innovation would be promoted and new, useful and marketable products

²¹ M. Fletcher, Principal Lecturer, Department of Mechanical Engineering, UTech, Jamaica

might be produced that might be patented. These established patents might then be made profitable through the issue of user licences without the need for duplication of research efforts.

To further the S&T agenda, the use of masters, doctoral and post-doctoral students may be critical given the shortfall of funding at many institutions. This approach may be two-pronged. Firstly, master's and doctoral students could be encouraged to provide support to core staff in the conduct of tutorials, marking of scripts as first markers and in co-supervising research. Doctoral students could also be employed as teaching assistants. Secondly, a postdoctoral unit could be established whereby the staff could provide critical support to core staff as well as postgraduate students thereby easing the workload of lecturers who would have additional time for research and publication (H. Oxenford²², *pers. comm.*).

The establishment of networks to promote north-south cooperation would have a significant impact on narrowing the widening research gap between north and south (UNCTAD, 1999). Strengthening research capacities in the south, pooling of resources through various forms of north-south and south-south research cooperation and improving global access to the scientific research information that is available in the north have been given high priority on international policy agendas. Such research networks have been in existence for a long time, and often form "invisible colleges". In this regard it is recommended that alliances be formed with the United Nations Commission for Science and Technology for Development (UNCSTD) that has identified north-south research networks as one of the issues to be addressed in its "Common Vision for the Future of Science and Technology for Development" (UNCTAD, 1999).

Continuation of the conduct of studies such as assessing trends in supply and demand for S&T graduates; identifying successful policy measures for increasing participation, in particular of women, in scientific and technological education and careers; analysing recent changes in the international mobility of students and personnel in S&T fields, and their implications for policy would greatly enhance the S&T agenda and foster a diverse and mobile workforce for the promotion of S&T. It would also be important to conduct studies that seek to evaluate the effectiveness of new measures that are being implemented to increase inflow to the S&T field.

There is a tremendous stock of skill and expertise that exists within the community of CDCC nationals that live overseas. NIHERST has commissioned a study to create a database that profiles Caribbean professionals in S&T fields and this database could be used in the formation of strategic alliances in promotion of a regional approach to S&T.

There is no question that science and society will continue to co-evolve. The nature of this evolution will certainly be affected by the extent to which governments set funding priorities. Societies whose governments recognize the dependence of the development of successful novel technologies on broadly supported basic research are more likely to be healthier and economically prosperous in the future than those that do not. There is therefore a need in the developing countries to bring about more meaningful and deliberate interaction between science and society if technologies are to be generated that would be useful to them.

²² Professor Hazel Oxenford, Professor of Marine Ecology and Fisheries, Cermes, UWI, Cave Hill Campus, Barbados)

However, the real challenge is revival of the agricultural sector given its strong links to S&T from the point of view of the contribution of applied research to food security. In this regard, it is recognised that the conduct of research into new strains and varieties of plants could have considerable impact on productivity and therefore food security. Increase in supply would result in price decreases and increased availability to the populace thereby making a contribution to poverty reduction. In this regard, it is recommended that the universities could upgrade and redesign existing research programmes towards the applied areas and work in collaboration with institutes such as the Caribbean Agricultural Research and Development Institute (CARDI) to conduct state-of-the-art research. Results of this research could well serve to boost the agricultural sector, raise awareness of the importance and value of such interventions and serve to attract students to specialised areas.

Finally, it should be stressed that because the problems of recruitment to specialised areas of S&T are deeply embedded, there are no quick and easy solutions. It is necessary to recognise that change requires a long-term perspective and long-term commitment of resources. There is need for reforms that are context specific, embracing multiple approaches and that are implemented over long periods of time. Monitoring of any such initiatives need to be ongoing and subject to continuous evaluation that is informed by evidence and careful analysis.

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Annex

3 October 2007

QUESTIONNAIRE**CAUSES AND CONSEQUENCES OF LOW RATES OF SPECIALISATION IN
SCIENCE AND TECHNOLOGY CDCC MEMBER COUNTRIES**

Information provided by:	
Country:	
Name of Ministry/Office:	
Date:	
Submitted by:	
Mailing address:	
Telephone:	
Telefax:	
E-mail:	



UNITED NATIONS

ECLAC

Introduction

The importance of Science and Technology (S&T) in Small Island Developing States (SIDS) is clearly articulated in Chapter XI, paragraphs 57, 58, 61 and 62 of the Mauritius Strategy for the Further Implementation of the Programme of Action for Sustainable Development of Small Island Developing States (MSI). The MSI recognizes that S&T is a cross-cutting issue and since 1994, some SIDS have been successful in strengthening the S&T support base of their economies while others still require support to achieve this.

Science and technology could contribute to improving safety and security, including areas such as cyber-security, transport security, environment security, crisis management and infectious disease prevention. Addressing those safety and security issues will require a global approach involving multiple stakeholders. Issues of personal privacy and data protection will also need to be addressed. The role of biometrics in achieving safety and security goals should also be considered. Implementation of biometrics will require significant research and development and generating new biometrics devices would present significant challenges over the next decade.

Caribbean Development and Cooperation Committee (CDCC) member countries are faced with low rates of specialization in science and technology a situation that does not augur well for security, social and economic growth and development. These countries recognize the importance of developing and maintaining an educated stock of human resources in order to promote scientific research and technological development. The Economic Commission for Latin America and the Caribbean (ECLAC), cognizant of the need to assess and evaluate the current situation with respect to S&T conducted a study on the operation and management of agencies and institutions working in the field of science and technology in selected CDCC member countries. One of the findings of this study is the low rates of specialization that are apparent in S&T programmes and courses. ECLAC seeks to continue this work by examining the causes and consequences of these low rates.

In this regard, ECLAC has prepared a short questionnaire in order to obtain relevant information that would inform the study. We are essentially investigating student enrolment and success in postgraduate studies in the areas of Engineering, Agriculture, Natural Sciences and Information Technology. We would, therefore, appreciate if you would assist us in the conduct of this exercise by providing replies to the questions that seek to investigate the causes and consequences of low rates of specialization in S&T. This survey would be complemented by face to face and telephone interviews. All of the results will be compiled and analyzed and incorporated in a publication that would be made available to participating countries and will also be used to provide policy support in the area of S&T to these very countries.



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A. CAUSES OF LOW RATES OF SPECIALISATION IN SCIENCE AND TECHNOLOGY

i. Employment opportunities		PLEASE TICK APPROPRIATE BOX <input checked="" type="checkbox"/>	
No.	QUESTIONS	Coding Categories	
		Yes	No
1.	Do you think that students are hesitant to pursue courses and programmes in science and technology (S&T) owing to the lack of employment opportunities?		
1a.	What do you consider as some of the more lucrative employment opportunities that may be obtained in the field of S&T? a. _____ d. _____ g. _____ b. _____ e. _____ h. _____ c. _____ f. _____ i. _____		
ii. Availability of places in institutes of higher education			
2.	Do you consider the availability of places in Institutes of Higher Education to be a limiting factor in student recruitment and therefore low rates of specialization?	Coding Categories	
		Yes	No
2a.	If more places become available in your institutions would this increase enrolment?	Yes	No
2b	How many students could be accommodated in your institution? _____		
iii. Qualifications and gender bias			
3.	Do you agree that there is a perception that S&T is irrelevant to the careers of women?	Coding Categories	
		Yes	No
3a.	Do you consider that areas of S&T are regarded as difficult and therefore too challenging for women?	Yes	No
3b.	Would it be fair to say that there are fewer female teachers of S&T courses than there are males?	Yes	No
3c	Do you think that school policy tends to assign male students to S&T courses	Yes	No



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rather than female students?

iv. Availability of infrastructure

4.	How many laboratories does your institution possess? 1 ____ 2 ____ 3 ____ 4 ____ 5 ____ 6 ____		
4a.	Do you consider that this infrastructure is adequate to support flagship S&T research and programmes?	Yes	No
4b.	Are the laboratories sufficiently modern to attract high calibre students?		
4c.	Are the laboratories sufficiently equipped for the conduct of cutting-edge research?	Yes	No

v. Specialization is long-term and expensive

5.	Do you view that the cost of specialization in S&T as a deterrent to enrolment in courses and programmes?	Yes	No
5a.	If cost is a deterrent, what could be the possible solutions? i. increased government subventions ii. increased support from the private sector iii. other _____		
5b.	Do you think that the physical sciences are underfunded as compared with the natural sciences?	Yes	No
5c.	In your opinion, is low enrolment a consequence of the long time it takes to specialize?	Yes	No

vi. Flexibility in identifying new areas of research

6.	Do you consider that identification of new areas of research is a challenge in promoting interest in S&T?	Yes	No
6a.	How do you think this may be addressed? i. Working with international organisations <input type="checkbox"/> ii. Liasing with policy makers to identify areas of national interest <input type="checkbox"/> iii. Developing a regional approach to research programming <input type="checkbox"/> iv. Other <input type="checkbox"/> a. _____ b. _____ c. _____		



6b.	Does the research agenda include innovation in terms of national sovereignty and intellectual property rights?	Yes	No

vii. Availability of staff to teach and supervise specialized areas

7.	Would the availability of staff to teach and supervise specialized areas of S&T be a deterrent in attracting students to S&T?	Yes	No
7a.	Could low availability of staff be linked to small remuneration?	Yes	No
7b.	Do you think that the terms and conditions of service is a cause of lack of attraction of staff to institutes of S&T? E.g the offering of short-term contracts with no tenure?	Yes	No

viii. Perceptions of Science and Technology

8a.	Do you consider that children have a negative perception of S&T as being:	Yes	No
8b.	If yes, why do you think this is so? i. boring ii. difficult iii. unpopular		
8c.	Can S&T courses and programmes compete with more “fashionable subjects” such as management, marketing and media studies?	Yes	No

ix. Values and Ethos of Science

9a.	Would postmodernist attacks on S&T contribute to making it unpopular?	Yes	No
9b.	Do you consider that students have difficulty accepting the values of S&T?	Yes	No
9c.	Do you think that students have difficulty accepting the ethos of science? i.e. that scientific knowledge is public, unprivileged, original and proven.	Yes	No



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x. Stereotypical image of scientists

9.	Do you think that there is a perception that scientists are social misfits?	Yes	No
9a.	In your opinion, are scientists no longer regarded as “heroes”?	Yes	No

xi. Communication between scientists and the public

10.	Is there a disconnect between scientists and the public?	Yes	No
10a.	If yes, do you think that this would influence the level of student recruitment and therefore specialization in S&T?	Yes	No

B Consequences of low rates of specialization in Science and Technology**xii. Gender Bias in Employment**

11.	In the field of S&T, do you perceive a gender bias in employment?	Yes	No
11a.	Are there fewer women than men in high positions in the S&T field?	Yes	No
11b.	If yes, would you attribute this to: i. low recruitment of females in S&T fields? ii. selection of males over females		

xiii. Inflexibility to change to new technologies by society

12.	Do you think that the inflexibility of society to change and adapt to new technologies may be a deterrent to the pursuit of research and therefore recruitment in S&T fields?	Yes	No

xiv. Reduced economic benefits

13.	Do you think that there is a connection between low rates of specialization in S&T and reduced economic benefits to countries?	Yes	No

xv. Reduced availability of teachers in Science and Technology

14.	Do you see the low levels of specialization in S&T resulting on a reduced availability of specialist teachers in S&T?	Yes	No

xvi. Competitive position of S&T professionals on local and foreign markets

15.		Yes	No
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	Do you think that the migration of experts in S&T to foreign countries has resulted in reduced availability of teachers and other professionals in S&T?		
15a.	In your opinion, the movement of S&T professionals to foreign markets has resulted in the influx of foreign professionals into local markets?	Yes	No
15b.	Do you perceive that competition for S&T professionals on the global market is low?	Yes	No

xvii. High drop-out rate in Science and Technology

16.	Do you think that there is a high drop-out rate in S&T courses and programmes in academic institutions?	Yes	No
16a.	If yes, has this resulted in low rates of specialization in S&T fields?	Yes	No

xviii. Better staffed private sector

17.	In your opinion, has the low rates of specialization in S&T fields resulted in a better staffed private sector than the public sector?	Yes	No
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