Implementation Strategy and Action Plan to Promote a STEM Education, Innovation and Employment Program for Barbados

Final Report

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Executive Summary

The specific objectives of this consultancy, carried out by the Caribbean Science Foundation (CSF), were to review the current status of STEM (Science, Technology, Engineering and Math) education and STEM-related employment in Barbados, and establish a comprehensive Blueprint for a STEM education, innovation and employment program for Barbados. The review of the current status of STEM education and STEM-related employment in Barbados comprised a survey of about one hundred Barbadians from several different sectors. The major recommendations of the STEM Blueprint incorporate perspectives from respondents to the survey.

This STEM Blueprint addresses Pillar 5 of the Barbados Human Resource Development (HRD) Strategy which has a primary goal of promoting research, entrepreneurship, and innovation in primary through tertiary education with a view to increasing the number of STEM-based small and medium size enterprises (SME) contributing to economic growth. Whereas Barbados has in the past invested a considerable amount of its GDP in supporting micro and SME development, the results have not led to significant changes in the economic development of the country. Unemployment remains at very high levels. This Blueprint lays out the challenges, proposes a strategy, and makes a set of specific recommendations for implementation to promote STEM education and STEM-related employment in Barbados.

In particular, the Blueprint points out that expansion and diversification of the private sector is key. It recommends both attracting and home-growing more technology-based companies, removing unnecessary bureaucratic hurdles and creating a more business friendly environment, and reforming STEM education at all levels to increase the number of young people pursuing STEM-related careers. To assist the Government with the planning and implementation of this private-sector expansion and diversification strategy, the Blueprint recommends the formation of a Science and Engineering Advisory Board (SEAB) for Barbados, with membership comprising international and Caribbean experts in science, engineering and business. The chairman of the SEAB would report directly to the Prime Minister.

To attract more technology-based companies to Barbados, the Blueprint offers several recommendations, including an aggressive recruitment campaign to bring new and established technology companies to Barbados, and encouraging Caribbean nationals abroad with interests in technology entrepreneurship to consider setting up shop in Barbados. Business plan competitions (run by the government or private sector institutions) that are open to anyone willing to locate their business in Barbados are recommended.

An aggressive promotion of technology-based entrepreneurship in small businesses is recommended, including providing mentorship and identifying sources of capital for new businesses. Participation by an actively-engaged scientific and business Caribbean Diaspora is critical. The establishment of a Diaspora Science Relations Committee that has intimate knowledge of the Diaspora and strong connections and influence within the Diaspora is suggested. Such a committee would contribute expertise, especially science and engineering advice, and facilitate business and academic connections and collaborations for the people and institutions in Barbados.

Building a strong STEM research environment is central to the strategy. It is noteworthy that the Blueprint does not recommend the creation of a science and technology park or an innovation center, even though these concepts resonate well with many Barbadians. This Blueprint does, however, recommend: (a) the establishment of the Shared National Research Laboratory (SNRL) of the Caribbean which will house state-of-the-art equipment and services that are critical for modernizing research in Barbados, (b) much more investment in university research infrastructure and technology transfer, (c) increased collaboration with the Diaspora to keep pace with cutting edge STEM research, and (d) the establishment of a Small Business Innovative Research and Development program (SBIRD) modeled after the US SBIR (Small Business Innovative Research) Program.

Strong leadership is critical for successful implementation of the above efforts, so the Blueprint recommends the establishment of a new position - a Director General for Science and Engineering (DGSE) who would have overall authority and responsibility for the Government's science and engineering programs in Barbados, and would report to and receive guidance from the SEAB. The DGSE, among other tasks, would be expected to implement the recommended policies pertaining to the aggressive formation of technology-based SMEs, thereby leading to expansion of the private sector.

A primary responsibility of the DGSE would be to reform and lead a re-engineered version of the National Council for Science and Technology (NCST), to be renamed the National Council for Science and Engineering (NCSE). In addition, the DGSE would have oversight of: (a) the proposed state-of-the-art shared Scientific National Research Laboratory (SNRL), (b) the proposed Tertiary Education Scientific Advisory Committee (TESAC) which assists the tertiary institutions with science and engineering curriculum and research reform, and (c) the proposed Diaspora Science Relations Committee (DSRC) which engages and leverages the Diaspora for science and business advice as well as networking connections and funding.

Reforming STEM education for primary through tertiary levels will be key for providing future leadership and the workforce for the STEM business sector. Enriching the curriculum with computer programming (coding), robotics, science, and concepts in entrepreneurship beginning at age 8 is absolutely necessary. Engineering and engineering principles are weaknesses in the Caribbean educational system. Adding robotics and coding will allow all Barbadian students to be exposed to engineering concepts at an early age. The recommendation is that Barbados adopt computer programming and robotics within its primary, secondary and tertiary education institutions, immediately.

To further reinforce this recommendation, science questions should be placed on 11+ exam, which seems to be a permanent fixture of the educational system. In addition, it is recommended that Barbados reinstate its science fairs and science competitions, get started on the opening of a science museum, and start implementing robotics camps, coding clubs, hackathons, and math Olympiads as these will also play a key role in raising the bar for STEM education and will make sure that Barbadian children are being educated at the highest global standards.

Additional educational recommendations include providing more opportunities to the citizens for second chance and continuing education. The planning and the management of these programs should be the responsibility of the Ministry of Education, and the content of the courses offered should be determined jointly by the Ministry, the private sector, and NCSE.

It is recommended that teachers be trained to discourage rote learning in the primary, secondary and vocational schools, and instead promote a culture of logical and analytical approaches to problem solving, and a focus on the understanding and mastery of fundamentals in all STEM subjects. To strengthen research and innovation skills, it is further recommended that beginning at the primary school level, all science subjects include some project-based work with a design component and teamwork. Particularly in the technical and vocational training curricula, Barbados must promote more basic STEM training and the applications of STEM to wider cross section of these students.

Primary and secondary school teachers should be required to undergo much more mandatory basic science and math training and continuing education, with a focus on the use of Problem Based Learning (PBL) and Inquiry-Based Science Education (IBSE) teaching methods and exercises. Inquiry-based teaching and learning methods are imperative for incorporating and reinforcing basic STEM and entrepreneurial concepts and skills. All students beginning at age 8 should be exposed to a STEM syllabus that employs the above teaching methods. Innovation, along with logical and analytical thinking must be strongly encouraged from primary through tertiary education. The focus must be on creating well-rounded technologists to move the economic development plan forward.

Given that Barbados needs to urgently introduce coding, robotics and the elements of entrepreneurship into the curriculum, the trainers at Erdiston Teacher's Training College will need to be trained. Erdiston will also need to teach more basic science principles to more primary school teachers, and then teach them how to teach STEM subjects using PBL/ISBE approaches. Substantial investment at Erdiston will be needed in order for the training college to carry out its expanded role.

It is important for Barbados to modernize the management of its primary and secondary educational system. It is recommended that Barbados put in place a comprehensive Learning Management Systems (LMS). Such a system would include: (a) a Website featuring high quality STEM teaching materials (with lots of culturally relevant examples), (b) online teacher training components where teachers can learn/practice skills at their own pace, (c) a system to measure teacher performance and effectiveness, and (d) a system to provide feedback and suggestions to teachers so they can improve their performance. Merit-based pay for teachers is the best way forward for Barbados. The LMS system can be easily set up to show which teachers are the most effective. Merit-based pay will draw more highly qualified teachers into the profession.

Tertiary-level institutions must develop centers of excellence in key areas of science and engineering, and these institutions must also be able to provide strong technology-transfer support to the private sector. To be effective, the tertiary institutions will need to: (a) have a critical mass of expert researchers, (b) leverage the scientific expertise in the Diaspora, and (c) be supported with significantly increased funding for laboratory equipment, research staff and teaching. The formation of a Tertiary Education Scientific Advisory Committee (TESAC) is recommended to assist the tertiary institutions with science and engineering curriculum and research reform.

To get people on board with the new HRD strategic plan for Barbados, the government must be able to explain the plan in simple terms, and the people must be able to see how it will benefit them. Promoting a culture of STEM awareness, innovation and entrepreneurship through science popularization and awareness programs that are promulgated through the media (including print, TV, radio and social) is recommended for immediate implementation.

It will be critical to establish a budget for implementation of the recommendations of the Blueprint. Thus, the Blueprint recommends increasing the allocation for science and engineering research and development (R&D) within the next 5 years towards an annual goal of 1% of the GDP. For efficiency and effectiveness purposes, all science and engineering R&D funding programs should be consolidated under the NCSE.

In light of the current weakness of the Barbados economy, this Blueprint proposes that the focus of early implementation must be on low-cost, low-risk, high payoff approaches that address some of the more urgent challenges. For the more expensive initiatives, suggestions are made on how to acquire the financial means to implement those recommendations. The full set of recommendations is described in detail in Section 5, and summarized with priorities for immediate implementation in Section 6.

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List of Acronyms and Abbreviations

BEF	Barbados Entrepreneurship Foundation
CADSTI	Caribbean Diaspora for Science Technology and Innovation
CSF	Caribbean Science Foundation
DGSE	Director General for Science and Engineering
DSRC	Diaspora Science Relations Committee
HRD	Human Resource Development
IBSE	Inquiry Based Science Education
ICT	Information and Communications Technology
LMS	Learning Management System
NCSE	National Council for Science and Engineering
NCST	National Council for Science and Technology
NGOs	Non-governmental organizations
NREN	National Research and Education Network
PBL	Problem Based Learning
R&D	Research and development
S&T	Science and technology
SBIRD	Small Business Innovative Research and Development program
SEAB	Science and Engineering Advisory Board
SJPP	Samuel Jackman Prescod Polytechnic
SME	Small and medium size enterprises
SNRL	Shared National Research Laboratory
STEM	Science, Technology, Engineering and Math
TESAC	Tertiary Education Scientific Advisory Committee
TVET	Technical Vocational and Educational Training
UWI	University of West Indies

1. BACKGROUND - ECONOMIC AND SOCIAL ENVIRONMENT

The Barbados economy is relatively small by global standards. The 2014 Gross Domestic Product (GDP) was roughly BDS $7,422M [1], and as in other developing countries, it has been impacted adversely by the recent global economic downturn. It has become clear that tourism revenues are no longer sufficient or reliable enough to sustain the levels of GDP required for stable economic growth. Furthermore, the financial services sector, which form another pillar of the Barbados economic structure, is experiencing increasingly difficult-to-navigate and onerous international regulations, and may no longer provide reliable support. A significant number of jobs has been lost in the last five years and the 2015 unemployment rate was by some estimates around 12% [2]. The growing debt level and economic outlook is such that the 2015 Moody's rating for Barbados was "B3" and its S&P rating was "B" [1]. Thus, Barbados does not qualify for the most favorable borrowing rates on international markets. Because of limited resources, economic recovery is proving to be difficult and painful.

There is broad agreement that any strategy for future sustainable economic development must include aggressive promotion of a culture of research, innovation, and entrepreneurship in science and engineering. One of the major issues for small businesses continues to be lack of access to operating funds and start-up capital. Unfortunately, the mode of funding has traditionally been debt capital. The government has made attempts to stimulate SME formation and growth in many areas, most of which were not focused on developing an economic pillar based on creating more science and engineering companies. For example, in 2003, US $2.5 million was specified for an Innovation Fund, managed by the Enterprise Growth Fund Limited. This initiative provided small amounts of seed capital to assist entrepreneurs with the implementation of commercially viable project ideas, and with improving the competitiveness of their businesses. The vast majority of the local enterprises that gained assistance were micro and small scale in size [3].

Also around that same time, the government established the Youth Entrepreneurship Scheme (YES) which caters to people between the ages of 18 and 35 and provides a range of educational courses in areas such as personal development, English for business, accounting, financial planning, customer service and customer management etc. Expansion of YES into schools could support the development of a culture of entrepreneurship at much earlier ages. Also, adding focus on more practical work attachments, business processes, financial processes and scenario planning would further enhance the program's effectiveness [3].

Other government programs have included the Barbados Small Business Association (BSBA) youth-focused pilot project titled *Enterprise in Action* which encourages students at both the primary and secondary level to examine entrepreneurship as a viable career path option. Within the small number of schools that participated in the pilot, the students received training in business skills and demonstrated those skills in business projects that involved planning and implementation. Today, education and training are still taking place, although in a more limited capacity, with support from sources such as the Education Training Fund (TVET Council) and the National Productivity Council [3].

Barbados has never had a focus on the development of companies that produce goods and services based on the applications of science and technology, let alone technology-based companies that can be globally competitive and earners of substantial foreign exchange. Thus, it is not surprising that despite government interventions and investments, the innovative mindset in the country remains weak, unemployment remains high, and foreign exchange earnings remain too low to accelerate economic development. The technology sector is where substantial economic development gains can be realized [3]. This Blueprint recommends steps towards building this sector.

Barbados has an extensive technological infrastructure, including high levels of Internet penetration, and mobile and land-line telephones, but the costs for connectivity are too high. This is a disincentive to the formation of competitive Internet and knowledge-based businesses. The country is rightfully proud of its high literacy rate which is a tremendous asset, but it often loses sight of the fact that the labor supply is lacking in highly skilled technology persons who are necessary for creating the type of technology companies that could successfully compete in global markets and bring in the levels of foreign exchange necessary to facilitate debt relief [3].

1.1 Social and Cultural Challenges

Generally speaking, Barbadians are culturally very risk averse. The fear of failure is rampant throughout the society, and the society is not very forgiving or sympathetic to persons who have tried and failed. This continues to be a great deterrent to risk taking and, therefore, to technology entrepreneurship. Then, there is lack of vision within some government bureaucracies, and the fact is that far too many civil servants are resistant to change in the manner and timeliness of how and when they provide service to the citizens.

In Barbados, there seems to be almost no penalty for under performance or lack of performance, and it seems that there are little or no incentives in place for government workers to improve job performance or offer improved services to the public. Furthermore, since government systems and services are slow to modernize, it understandable that complacency reigns, and efficiency and speed of service are not priorities. Among the people, too many have either a poor work attitude, low esteem, or lack the self-discipline and the will to change their living conditions. Not surprisingly, the productivity of the average Barbados worker is low by standards in the developed world.

Barbadians are quick to look to the Government for the solutions to all problems, but the Government often does not have the budget, the right talent or the mechanisms in place to: (a) collect novel ideas, (b) distill out the best ones, and (c) assemble the teams and gather the resources to implement the best and most practical ideas. The private sector is profit driven, as it should be, and often not concerned with solving large societal problems that do not serve its interests directly or indirectly.

These are huge social problems, and though outside the scope of this report, these items will all require serious attention if the overall HRD strategy is going to be successful in creating the new jobs that Barbados so desperately needs. Thus, stimulating an entrepreneurship and innovative

culture in Barbados will be more difficult than in most places in the Region, but not impossible. Clearly new cultural attitudes need to be cultivated. Such a change will not be readily realized, and could easily take a generation or more if evolutionary rather than revolutionary approaches are adopted.

1.2 Role for the Religious Organizations

Regarding the cultural challenges, it seems that there is a clear role for the religious sector in the economic development plan for Barbados, and the importance of this sector should not be overlooked. With crime and unemployment on the rise, more than ever this sector needs to step in and contribute more to the creation of a progressive Barbados.

The religious organizations in Barbados have a large following, so they are a key asset. The government needs to work with these organizations to help: (a) rebuild the social fabric, (b) disseminate to the people the government's message about the promotion of a culture of science and engineering, and (c) persuade the masses to get on board with the HRD strategic plan. Reinforcement of ethical and moral values can only help to support a peaceful society, as investment and economic development will not thrive in a in a turbulent and unsafe environment.

2. OBJECTIVES OF THE BLUEPRINT

This Blueprint addresses Pillar 5 of the Barbados Human Research Development (HRD) Strategy [3]. The primary goal of this pillar is the promotion of a culture of research, entrepreneurship and innovation in primary through tertiary education with a view to increasing the number of STEM-based SMEs contributing to economic growth. This pillar, therefore, has been frequently referred to as the STEM pillar. Thus, the objectives of this Blueprint are to establish a comprehensive implementation strategy and action plan with a set of specific recommendations for implementation to promote STEM education and STEM-based businesses in Barbados. In doing so, it cuts across the other 4 pillars of the Barbados HRD Strategy.

Much can be learned from examples in the international community, and hence there is no need for Barbados to reinvent the wheel in most cases. Every attempt is made not only to identify the challenge, but also to provide concrete suggestions for implementation, especially those that have high payoff with minimal investment. Thus, in light of the current weakness of the Barbados economy, this Blueprint proposes that the early implementation focus must be on low-cost, low-risk, high payoff approaches that address some of the more urgent challenges. For the more expensive initiatives, suggestions are made on how to acquire the financial means to implement those recommendations.

3. SURVEY AND SUMMARY OF FINDINGS

In the work leading up to the preparation of this Blueprint, a review was conducted of the current status of STEM education and STEM-related employment in Barbados. Several town-hall style meetings were held at which a brief presentation was made by officers from the Ministry of Labour and Human Resource Development, followed by a presentation on STEM by Prof. Cardinal Warde (the consultant charged with conducting the review) and a question and answer session.

In other cases, interviews were conducted formally, many informally, some in groups, and some individually. In all cases the participants were requested to fill out a questionnaire of up to 144 questions which asked for their impressions of the current status of STEM in Barbados, as well as their advice as to what should be done in a multitude of different scenarios.

About one hundred Barbadians participated between February 2015 and February 2016. The participants included teachers and principals, lecturers and professors from the local university and community college, private sector business leaders, civil servants in several government ministries, and politicians. A presentation of the preliminary recommendations was made to the Cabinet on February 11, 2016. Appendix A is an attempt to summarize the myriad of responses. The results were not surprising. A brief summary of the findings follows.

The persons surveyed, for the most part, seemed to be unaware of the development of the Barbados HRD strategic plan to promote more STEM-based employment in Barbados. Most were fully aware of the economic decline of Barbados and were supportive of a sound strategic plan to increase employment, restore economic vibrancy, raise the standard of living, and expand the middle class life to which many have become accustomed. However, all participants were excited that the government was taking the initiative to develop this Blueprint as a first step to implementing change.

Many of the persons interviewed gave Barbados low marks for efforts to-date on a STEM-based model for economic development. Over and over again, fingers were pointed at the government (past and present). Also, not surprisingly, the survey revealed that most participants believe that policy, planning, development and leadership of the required science and engineering initiatives for Barbados are missing. There was general agreement that economic diversification to supplement tourism and financial services is essential for the future economic growth of Barbados. There was broad consensus that cultivating more STEM and more STEM-based jobs would reduce unemployment, raise the standard of living of the people and diversify the economy.

The Barbadians surveyed were able to consistently and correctly identify the challenges facing the nation, and could speak eloquently, at a high level, about what needs to be done to solve the problems. However, few were able to provide enough specific practical details on how their ideas could be implemented to solve the problems.

Many participants in the survey agreed that there is not a prevalent culture of science and engineering in Barbados, and that not enough students are pursuing advanced degrees in science and engineering. Several persons said that Barbados needs to create a greater interest in science and in the STEM-based disciplines within its schools, and not stifle the innate creativity in its youth, who are the engine for future economic growth and development. Most people interviewed seem to think that the tertiary educational institutions in Barbados are not effectively serving the needs of Barbados. They agreed that there is substantial untapped talent in our youth who could be groomed into the next generation of technology entrepreneurs and leaders in science, engineering and business. There was almost unanimous agreement that

Barbados Scholars must give back to Barbados in some tangible way at the end of their university education.

Modernizing government services was cited by some participants as a priority. Some complained that the old fashioned, paper-intensive methods of collecting, processing, sharing and disseminating information are still too frequently the norm in many governmental agencies, and so access to and sharing of information between government agencies and with the public is still too slow and cumbersome. There was agreement that a more business-friendly environment, increased engagement of the private sector in the educational system, and increased assistance from the Diaspora are absolutely essential to help more Barbados businesses compete successfully at a global level.

On the positive side, the survey revealed that Barbados already has in place several of the agencies necessary to develop and maintain a vibrant research and innovation culture. However, existing resources and institutions are not being effectively used to improve science, technology and innovation as a tool for development. There was some agreement that the plan must include re-engineering, redesigning, reorganizing, combining or eliminating, and most certainly refinancing some of these current entities for cost/benefit purposes.

4. OVERALL STRATEGY FOR A STEM-BASED ECONOMIC PILLAR

Assuming that Barbados can get its social challenges under control, it is clear that to pave the way for economic recovery, Barbados must diversify its economy by adding a new economic pillar to complement tourism and financial services. To turn around the economy, among other initiatives, Barbados must cultivate a supply of highly skilled scientists, engineers and technicians capable of carrying out research and developing and adapting new and existing technologies critical for the development of the country. However, what is particularly lacking is the infrastructure to support the research needed. The university is woefully lacking in basic scientific instruments, equipment, materials and supplies, hindering its ability to contribute. Any proposal to solve the research challenge must address this problem.

To create more and better paying jobs, and to significantly increase foreign exchange earnings, it is imperative that Barbados take the steps necessary to strengthen, expand and diversify the private sector so it includes more companies and organizations engaged in producing goods and services based on science and technology. This must be the focus of the strategic plan. To implement the plan, clearly innovation and entrepreneurship stimulation within the university and in the private sector will be critical for success. Similarly, aggressive STEM education reform in the 91 primary and 33 secondary schools in Barbados [4], and a modernization of its technical vocational education curriculum are equally important.

Figure 1 illustrates a proven pathway to the development of a science and engineering-based economic pillar that could work for Barbados to complement its tourism and financial services pillars. In promoting and encouraging technology-based research, Barbados must be very selective and focused. What may look like new research for Barbados may have already been done elsewhere. Far too many of the research projects proposed in the Region (not only Barbados) fail the novelty test. This is an area where leveraging the expertise resident in the Diaspora for proposal and project review can be most valuable. This means that entrepreneurs and university staff submitting proposals and business plans must do the necessary diligence before proposal submission to make sure that time and funds are not wasted rediscovering that which has already been done. In cases where the research has already been done, to the extent possible, Barbados should simply build upon that research to move forward. If necessary, Barbados companies should negotiate a license to practice the art. Of course, novelty is not a necessary condition for success in entrepreneurship. In a case where Barbados can bring substantial improvements in quality, performance and/or cost to the product or service, a successful business venture may still be possible.

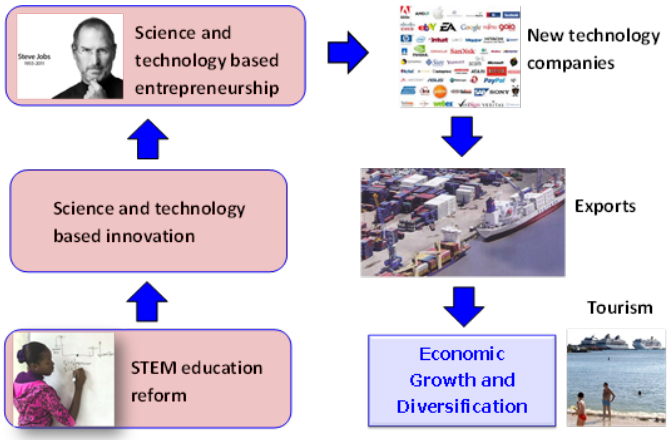

Fig. 1. An Economic development growth model

Given the financial constraints of the government, implementation of the strategic plan must begin with of a coherent set of robust, practical low-cost, high-return strategic initiatives. The Diaspora and the international community must be called upon to help. A new leadership structure for science and engineering for Barbados is recommended. Over the long term, with progressive and visionary leadership, and practical policy and planning initiatives, the country should be able to lift itself up by its bootstraps and become a model for the rest of the Caribbean. In the process, the leaders will need to take calculated risks and think outside the box, so that the government does not continue to do the same things that have produced the same undesirable results with which Barbados is now faced.

At the highest level, the strategy can be summarized as follows:

- Establish strong and competent leadership for science and engineering
- Establish a substantial budget for science and engineering research programs
- Promote a culture of innovation and entrepreneurship
- Fully engage the scientific Diaspora of the entire Caribbean
- Facilitate world-class research
- Diversify and expand the Private Sector
- Reform STEM education at all levels
- Implement legislation for business-friendly reforms

5. IMPLEMENTATION DETAILS FOR THE WAY FORWARD

5.1 Establishing Leadership with Budget and Authority for Science and Engineering

Figure 2 shows the organizational structure recommended for carrying out the above strategy, and ensuring that science and engineering are effectively harnessed to develop and sustain a new economic pillar for Barbados. Clear leadership with authority will be needed to drive the process. Thus, this Blueprint recommends the appointment of a standing Science and Engineering Advisory Board (SEAB) that serves the people of Barbados, and whose leader (chair) reports to the Prime Minister. The SEAB would be charged with providing critical input and perspective on all science and engineering in Barbados, and appointing a Director General for Science and Engineering (DGSE) who would have overall responsibility for implementing the Government's science and engineering programs within the agencies shown in Fig.2. The DGSE would report to and receive his/her guidance from the SEAB.

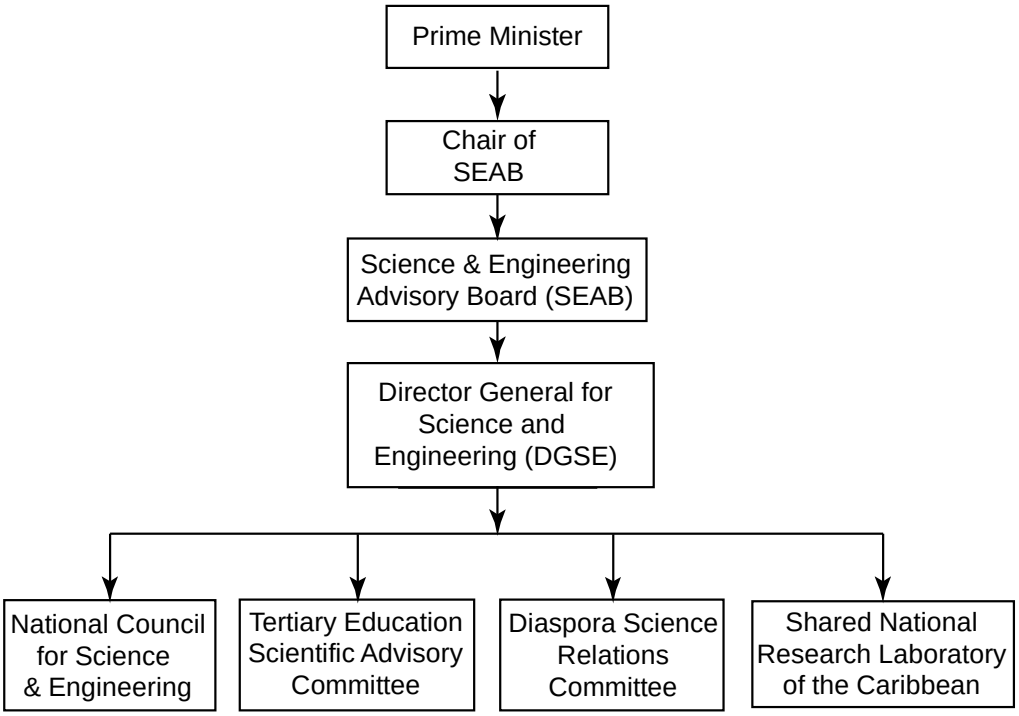

Fig. 2. Proposed responsibilities and reporting structure for the Director General of Science and Engineering

The Barbados Government should demonstrate its commitment to developing an economic pillar based on science and engineering by making funding for all research, development and innovation in science and engineering a permanent line item in the budget, each and every year. This overall allocation for science and engineering agencies and projects should be increased until the internationally recommended target level of 1% of GDP (Johannesburg Declaration) is reached. A 5-year goal to reach this target level is recommended. Reaching across the aisle to get agreement from both parties to tie the science and engineering research and development budget to a fixed percentage of the GDP for the long term is strongly recommended, for the good of Barbados.

5.2 Science and Engineering Advisory Board

The primary role of the SEAB would be to provide guidance on all science and engineering in Barbados. The SEAB could be established with input from the Governing Council [7] of the Caribbean Science Foundation (CSF). SEAB members would include influential and highly experienced individuals from Barbados, the wider Caribbean and the Diaspora. The mix on the Board would include scientists, engineers, technology business leaders, finance experts, and venture capitalists. In particular, the agricultural sector would be represented. Engaging such experts on the SEAB will also allow our leaders to stay ahead of the curve on upcoming technology trends. Appointment of the SEAB is a very high priority, and should be implemented immediately, as the Board's wisdom and input will be critical in the planning and the execution of all the STEM-based components of the HRD Strategy.

An important function of the SEAB would be to assist the Government in creating more sound policies and in making more informed decisions related to STEM, especially in areas such as telecommunications, energy, food security and agriculture, and biotechnology. The existence of the SEAB would strengthen the interface between science, technology, innovation, and the decision making powers of the Cabinet, since the Ministers will have greater and easier access to science and technology experts.

While the Chair of the SEAB will report to the Prime Minister, incoming governments should not have the power to dissolve the Board. When government changes, the succeeding government tends to dismantle, reshuffle, redirect the path of, or significantly change the operations and responsibilities of institutions and organizations set up by the outgoing government. The SEAB should be established so that it takes an act of Parliament to dissolve the SEAB, thus ensuring continuity and durability of the strategic science and engineering plans and initiatives of Barbados. Thus, it is important that this Blueprint be embraced and adopted by both political parties.

The Barbados Government must create a more-friendly ecosystem for innovation and entrepreneurship, as this will be needed to rapidly stimulate technology entrepreneurship. To address this challenge, it is recommend that the Chair of the SEAB be an honorary member of the Cabinet and also hold an honorary role in Parliament so as to be able to bring awareness of pressing economic development challenges that have roots or solutions based on science and engineering to the attention of legislators in a timely manner for swift action.

5.3 Director General for Science and Engineering

As illustrated in Fig. 2, it is recommended that the position of DGSE reporting to the SEAB, be created. The DGSE would have overall responsibility for implementing the Government's science and engineering programs in Barbados. In particular, she/he would be charged with (a) leading the National Council for Science and Engineering (NCSE, re-engineered NCST), (b) overseeing the proposed state-of-the-art Shared National Research Laboratory (SNRL), (b) guiding the proposed Tertiary Education Scientific Advisory Committee (TESAC) which assists the tertiary institutions

with science and engineering curriculum and research reform, and (c) chairing the proposed Diaspora Science Relations Committee (DSRC) which engages and leverages the Diaspora for science and business advice as well as networking connections and funding.

The DGSE would also create ad-hoc science and engineering panels of regional and international experts in specific scientific disciplines, as appropriate, to help with the review of research and development proposals and business plans submitted for consideration to Government-funded business development programs. Similarly, highly specialized scientific advisory subcommittees should be constituted for the Government by the DGSE in consultation with the SEAB, as needed, when thorny challenges are faced by the Government.

Clearly, identifying the right person for this important leadership role is crucial. The DGSE should be a renowned scientist or engineer, with corporate leadership experience, political savvy, and a vision for the future of STEM in Barbados. The SEAB (not the government) would have the responsibility of searching for and appointing the DGSE, thereby taking this responsibility away, indirectly, from the political process.

5.4 Tertiary Education Scientific Advisory Committee

The Barbados tertiary education institutions (UWI and the Community College) must re-engineer themselves to play a more critical role in stimulating technology-based innovation and entrepreneurship. Because the task may appear daunting, the SEAB should work with the leadership of these institutions to put in place a Tertiary Education Scientific Advisory Committee (TESAC) as shown in Fig. 2. The TESAC would comprise science and engineering academic leaders and business visionaries from the Diaspora and the Region who would assist with strategic planning and implementation of university research and teaching programs. At least one member of the SEAB should sit on the TESAC, so that representation, input and reporting back to the SEAB takes place.

The TESAC would bridge the communications gap between the government and the university, so the university can better address the economic development needs of Barbados. The TESAC would also ensure that there is more collaboration between the two tertiary institutions in Barbados, providing for a better sharing of scarce resources. With its international connections, the TESAC would also help to build linkages and collaborations with universities and industries in the Region and the Diaspora, thereby avoiding a re-invention of the wheel, and bringing much needed expertise to Barbados.

5.5 Diaspora Engagement

Much has been made and said about assistance from the Diaspora in this Blueprint. The reason is that many within the wider Caribbean Diaspora have been successful entrepreneurs or hold influential and leadership positions in corporations, and collectively have vast amounts of corporate experience and wealth. Many of these people care deeply about the Region and want to give back.

Remunerations from the Diaspora at the individual level continue to be of significance to a large number of Barbadians living at or below the poverty line. These funds represent an important contribution to the Barbados economy, and strategies for scaling up these contributions should be explored. At the institutional level, most Caribbean Diaspora organizations have a social focus, not a technology focus. However, most members of these organizations do want to collectively assist the Region with its health care, medicine, and education challenges.

Regarding the harnessing of STEM for economic development, the challenge that Barbados faces is that a large fraction of the Island's scientists and engineers reside in the Diaspora. It is believed that there are as many as 100,000 Barbadians living abroad, and that Barbadians abroad not only have a particularly high interest in giving back to Barbados but also have the relevant expertise and financial means to do so [5]. Naturally then, the most viable solutions should involve harnessing the science, engineering, and entrepreneurial talent and expertise that resides in the Diaspora. Investments from abroad could be better facilitated if there were a mechanism for identifying and vetting start-up business plans, and then linking potential investors in the Diaspora to vetted technology ventures that have a significant probability of success.

As pointed out throughout this document, contributions from the Diaspora could include: (a) providing advice and consultations on science and engineering projects, (b) suggesting candidates for leadership positions in science and engineering, (c) giving guidance related to start-up concepts and their feasibility, (d) setting up angel and venture capital financing for early-stage companies, (e) facilitating business and academic connections to potential sources of funding, (f) helping to launch companies, (g) sourcing technical staff for companies, (h) connecting Barbados's entrepreneurs to large-scale manufacturing expertise, (i) providing guidance on accessing markets, (j) advising on business development strategies, (k) providing assistance with primary, secondary and tertiary education reform, and (l) helping to establish collaborations between the tertiary academic institutions in Barbados and institutions in the Diaspora.

What Barbados needs now is a set of professional Diaspora organizations with a focus on helping with the above-listed items and a government organization that coordinates the efforts of the various Diaspora groups. Given the critical role that Diaspora engagement should play, this Blueprint (as shown in Fig. 2) recommends the establishment of a Diaspora Science Relations Committee (DSRC) that is chaired by the DGSE. The role of the DSRC would be to ensure that there is a continual focus on engaging and maintaining the active participation of the scientific and business Diaspora (from Barbados as well as other Caribbean countries) in promoting STEM in Barbados. As such, the DSRC would be charged with developing a strategic plan for engaging the scientific Diaspora, and overseeing the plan's implementation. The Caribbean Diaspora for Science Technology and Innovation (CADSTI - see http://cadsti.org) with its branches in the UK, New England, Silicon Valley and the Southeastern US is willing to offer some assistance to the Government on Diaspora engagement.

While the Ministry of Foreign Affairs hosts a Diaspora conference every two years, not much focus has been given to the scientific Diaspora. Much of the conference should be devoted to

science, engineering, technology innovation and entrepreneurship, and at least 25% of the conference should be focused on how the Diaspora can help to implement the new HRD strategy for Barbados. This will show the people of Barbados and the Diaspora that the Government is focused on and serious about a transformational change based on STEM to develop the economy.

5.6 Re-Engineering NCST

Creating a separate Ministry of Science and Engineering is not recommended. Instead, it is recommended that the NCST be re-engineered to become a new semi-independent quasi-government agency. It is recommended that the word "Technology" in the title be replaced with "Engineering" (NCSE) primarily for conscious-raising purposes. Engineers create more companies and generate more jobs than any other technology-related profession, and the recommended change sends a clear message that Barbados is serious about developing its human capacity in the engineering sub-disciplines.

The organizational chart of Fig. 2 shows where NCSE fits into the new strategic plan. The SEAB will also serve as the Advisory Board for the NCSE. To ensure its independence and its sustainability, and to make NCSE the permanent and premier science and engineering agency of Barbados, it is recommended that: (a) NCSE be managed by the DGSE, and (b) NCSE be allocated an annual budget that is a fixed percentage of the proposed overall budget (1% of GDP proposed) for science and engineering.

It is further recommended that to increase efficiency and reduce redundancy for economies of scale, and to tap into the technical and business expertise of the new NCSE and its advisory Board (the SEAB), the Government consolidate all funding for all science and engineering research and development under the NCSE. This will ensure improved selection of projects worthy of funding, because of accessibility to the world-class technology and business experts who will act as reviewers. It will also eliminate the confusion in the minds of Barbadians as to where, when and to whom to apply for funding for their creative ideas.

The reconstituted NCSE, with its share of the line item budget for science and engineering research and development, would also be charged with responsibility for science popularization. It should also conduct math Olympiads, coding camps, hackathons, robotics camps (several levels), science fairs, and other summer science camps. It should participate in operation of the government-owned incubators, offer training to technology entrepreneurs on how to write business plans and find financing, and assist Erdiston Teachers Training College with STEM Teacher training, just to mention some of its responsibilities. The CSF is willing to assist with the programs.

NCSE should also be a Barbados platform for the dissemination and the sharing of scientific knowledge and breaking news in science and engineering happening anywhere in the world. Its primary audience would be the general public and the research community in Barbados.

5.7 Establishment of a Shared National Research Laboratory of the Caribbean

Because of the high cost of cutting edge scientific research, the government should begin immediately to establish a Shared National Research Laboratory (SNRL) of the Caribbean as a 5-year project. Figure 2 shows where the SNRL fits into the overall strategic plan. The SNRL will be a shared facility (see Fig. 3) that would house state-of-the-art equipment, machines and tools that are too expensive to be purchased, maintained or operated by any one institution in Barbados, but would be found in any leading research institution in the world.

Fig. 3. Artist's concept of the Shared National Research Laboratory of the Caribbean with its large windows to allow move in of large research equipment

The SNRL should be operated on a fee-for- service basis in a manner somewhat similar to major scientific national research laboratories in some developed countries. By operating the SNRL as a shared facility, it will be easier to garner financial assistance for its establishment and on-going operations from the international community, and its overhead costs (including equipment maintenance) would be shared by a larger user base. This user base should include not only researchers from Barbados, but also all other Caribbean countries (French, Dutch and Spanish-speaking included) and Central America.

As an example of the structure, the facilities and services that could be offered by the SNRL:

- The ground floor could house machine and woodworking shops, metal, wood and plastics stockrooms.
- The 1st floor could house scanning and transmission electron microscopes, an atomic force microscope, optical tables and optical measuring and characterization equipment such as spectrometers, ellipsometers and interferometers, and electronics test equipment such as multichannel analyzers, and a supercomputer.
- The 2nd floor could house a clean room outfitted with fume hoods, spin coaters, mask aligners, a Heidelberg mask-less writer, evaporator, sputtering machine, reactive ion etching system, and other standard semiconductor device fabrication equipment.
- The 3rd floor could house biology and biochemistry test equipment such as a mass spectrometer, NextGen sequencing machine, a Biacore biomolecular interaction machine, a confocal microscope, and analytical and preparative fluorescence activated cell sorters.
- The 4th floor could house the administrative offices, conference rooms and classrooms.

- This facility would be tied into the fiber-optic CaribNET as part of the Barbados National Research and Education Network (NREN).

No other Caribbean country has such a facility or is planning to install such a facility. The expensive test equipment listed above, their upgrades and eventual replacement would be procured as gifts from other governments, the international community, corporations and universities abroad, the Diaspora, friends of Barbados, and wealthy individuals seeking tax relief.

The SNRL would be owned by the Government and administered by a Director who reports to the DGSE. Ideally, it should be located in close proximity to the University of West Indies (UWI) - Cave Hill campus, and would operate in close collaboration with all the tertiary institutions in the Region. The daily research operations of the SNRL would be run by research professionals with specialized skills who are experts in the use of the machinery and equipment. Each of the 3 laboratory floors should have 4 or 5 such well-trained experts who are intimately familiar with principles of operation of the machines and are capable of operating them and carrying out the required low-level maintenance and calibration. Some of these operators will hold masters and Ph.D. degrees, and some could ideally have dual appointments at UWI. These operators should be encouraged to carry out their own grant-funded projects using the specialized equipment in the SNRL.

Major maintenance and repairs of the machinery and equipment is a challenge that must be properly managed. Thus, it will be important to: (a) purchase service contracts for the major pieces of equipment and keep these service contracts up to date, (b) perform the routine daily or weekly maintenance on the machines, and (c) ensure proper usage of the equipment. This will be the responsibility of the full-time technicians working in the facility. Maintenance of the building itself can be a second challenge, and so the financing of both equipment and building maintenance must be budgeted at the very outset. Each month, a fraction of the fees recovered from the use of the facilities should go into the maintenance budget that is managed by the Director of the Laboratory. To cover the shortfall, Government should set aside an inflation-compensated amount for maintenance that is calculated based on each piece of equipment, taking into consideration its age, frequency of use and cost of the service contract. The Government's component of the maintenance budget for the SNRL would come out of the proposed 1% of GDP that would be set aside for science and engineering. If properly operated and maintained, the SNRL should break even as far as operating and maintenance costs are concerned.

The SNRL will make Barbados significantly more attractive to Caribbean students with advanced degrees in engineering, physics, chemistry and the biological sciences who wish to return to the Region to make a contribution in scientific research or to start technology-based companies. Such an institution would help to ignite and fuel the research culture that Barbados has been speaking about for many years, and has yet to realize. The existence of this facility will also solve a problem that the UWI system has been grappling with since its inception: how to attract and retain world class scientists and engineers. It is well known that world-class scientists and engineers want and need access to state-of-the-art equipment, tools and resources. For most

distinguished scientists and engineers, it is not necessarily the highest salary that binds them to an institution, but often it is the ease of conducting research and working with the brightest students and post-docs, so that the quality and quantity of their research can be maintained at the highest level. This is why the US has been so attractive to many of the brilliant minds from around the world. Salaries would need only to be competitive, not excessive, to attract these top-notch scientists and engineers.

Another source of international brain power for Barbados is through scientific exchange programs that the EU, the US and Canada have in place. The Caribbean rarely participates in the experimental research component of these programs because of the lack of world-class facilities in the Region. The SNRL will bring many more researchers from Europe, Canada, the US and Latin America to Barbados year after year. Also, professors from high ranking universities should be lured to Barbados to spend their sabbatical years at the SNRL. Additionally, such high-profile scientists and engineers will sometimes add significant additional pieces of equipment and tools purchased through their research grants and contracts.

In turn, having the top scientists and engineers in the world on the UWI - Cave Hill science faculty will attract the brightest students from around the world to come to Barbados to work with them. Furthermore, with the home-trained superstars and the senior professors that will be attracted to the SNRL, the international raking of UWI - Cave Hill will begin to rise sharply within 10-15 years.

Of course, the primary spinoff from having all of this scientific brain power concentrated in Barbados, will be the entrepreneurial endeavors that will place Barbados in the fast lane towards building its new economic development pillar based on science and engineering. The spin-off technologies and firms, and hence jobs, from the activities of this research facility can be expected to stimulate tremendous growth to the economy of Barbados and the greater Caribbean region.

5.8 Private Sector Expansion and Diversification

Expansion and diversification of the private sector is the key to the development and growth of the economy of Barbados, and hence to the production of new jobs. Unfortunately, for Barbados, the largest private sector companies are engaged in trading, and developing science and engineering talent is not critical to their existence or survival. Currently, many of the new companies that register to do business in Barbados are financial services companies, and while more of such companies are good for the Barbados economy, the fact remains that to propel Barbados forward and to significantly grow its GDP, these types of companies will not suffice. Science and engineering companies will create many more jobs, and will spin-off secondary companies that will create yet more jobs than the typical financial services company. So Barbados has no choice but to find ways to attract more science and engineering companies to its shores. For reference purposes, simply take a look at the skyline of Singapore and count the number of international companies operating there. The focus in Barbados must be on building a dynamic and diverse private sector by adding new technology companies year after year. In fact, the

number of new technology companies added each year would be one important indicator of the vibrancy of the economic development plan.

Further, to strengthen the private sector through SME formation and growth, the HRD Strategy must support the delivery of workshops on financing, intellectual property protection, business operations for individuals and businesses, as well as technical conferences to boost communication and share information. The government should create a new small business research fund targeted at the private sector for building or developing technologies, products and services based on science and engineering as proposed below in Section 5.8.1. It should undertake expansion of the frameworks that provide mentorship for small businesses and entrepreneurs, and that assist small businesses with institutional strengthening, workforce training and capacity building with a system of incentives [3].

To further support and maintain private sector expansion, Barbados must keep the pipeline full of STEM talent. Thus the country should aggressively expand the development of an appropriate curriculum for the teaching of entrepreneurship at the postsecondary and tertiary levels as discussed below in Section 5.9.1.

More regional and local private sector influence and involvement with the tertiary education institutions is recommended. Technology-based private-sector companies should have input on curriculum reform discussions at the secondary and tertiary education levels, and also have a voice in research directions. Then, as tertiary education partners, the private sector would be more enthusiastic about funding research projects in academia. Additionally, the technology-based private-sector companies would be eager to provide more internships, support more science clubs in schools, participate in national science and technology events that are intended to excite and motivate young people, track students, and establish bonds to recruit the best students as future employees.

5.8.1 Establishment of a Small Business Innovative Research & Development Program

As suggested in Section 5.4, Barbados should consolidate all of its government-funded science and engineering research under the NCSE. The major funding vehicle should be a new Small Business Innovative Research and Development (SBIRD) program. Such a model was proposed to Caribbean governments as far back as 1998 [6]. Most of the funds now scattered throughout multiple agencies should be combined and used to kick start this program. Consolidating these funds to get SBIRD off the ground will allow the government to better control costs and minimize additional outlays to initiate this important program. In year 2 and beyond, the budget allocated to the SBIRD could grow slowly until a desirable funding goal is reached. Initially, the program would be open to applicants from anywhere in the world whose companies have at least 51% ownership by Barbados citizens and who would be willing to locate their business to Barbados. A smaller pool of funds should still be dedicated to the micro and SMEs and to the cottage industries that the government currently supports.

The SBIRD program should be modelled after the US SBIR program which has been highly effective in increasing the number of successful small technology businesses. The proposed

Barbados SBIRD program would be a three-phase initiative. Phase I of the Barbados SBIRD program would make grants to small companies (less than 50 employees) on a competitive basis to establish the feasibility of development of high-tech and biotech commercial products and services. Successful Phase I companies would be immediately eligible to use the services and the facilities of the SNRL. Those Phase I awardees that successfully meet the technical feasibility milestones would be invited to update their business plans and resubmit them for possible Phase II funding to develop pre-manufacturing prototypes or almost market-ready products and services. Many of the successful Phase II winners would be expected to form alliances with larger companies (in the Caribbean or the Diaspora) and in some cases these larger companies could be expected to cost share in or add to the level of the Phase II award from the government. As an example, Phase I grants could be approximately BDS $100,000 with a six-month period of performance, and Phase II grants could be approximately BDS $750,000 with a two-year period of performance. The Barbados SBIRD program would differ from the US program in that the Barbados government (NCSE) would take an equity stake in the company if the company accepts Phase II SBIRD funding.

Under SBIRD, business plans involving joint product or service development between industry and universities would be encouraged. The business plans would be evaluated based on a general overall ranking of the probability of success of the venture that includes: (a) technical merit, (b) the competence and experience of the management and technical teams, (c) the go-to-market strategy with a feasible work plan and timeline, (d) realism of the proposed market share and the commercial potential (including global competitiveness), (e) the potential for scaling to significant annual revenues (for example, about BDS $40M within 5 years), and (f) relevance to the needs of Barbados. Phase III would be the full commercialization phase where the funding would come from angels and institutional investors facilitated by the government, if necessary.

The Phase I and II evaluations would be carried out by a committee of experts selected by the SEAB that includes members from the Diaspora. There would be no nepotism and no special-interest advantages in the selection process. Committee members with conflicts of interest would excuse themselves from the evaluation process.

Since NCSE would take a small equity stake in the companies that are awarded Phase II funds, if these companies go on to be highly successful, then the government should eventually sell its equity back to the founders or other interested investors, and re-invest the proceeds realized into the basic pool of SBIRD funds. In this way, the pool of funds could actually grow after about ten years. Thus, in a well-managed program, taxpayers could be repaid their initial investment into the program, for a truly self-sustaining program.

To be successful, the SBIRD program should be part of the national entrepreneurship culture and dialog. The people and the politicians must always be talking about the program. The program must continually be refined as the economy evolves so it remains efficient and effective. This program would need to be very heavily advertised well in advance of its launch to make sure that potential applicants are aware of the availability of the funds and that the government is soliciting business plans for the development of new products and services or to upgrade the quality of

existing products and services. In parallel, it will be necessary to develop an angel and venture capital network in Barbados with assistance from the Diaspora as discussed in Section 5.5.

5.8.2 Bringing in Technology-Based Companies for Private Sector Expansion

At a minimum, an adequate level of know-how in science and engineering must reside in the Barbados workforce in order to attract and retain foreign science and engineering companies to Barbados. STEM education reform that includes the integration of disciplines such as computer programming, science, robotics and entrepreneurship into curricula starting as early as age 8 would help to address this challenge.

While Barbados should continue to encourage and support micro-business development, many of which focus on local markets, the new HRD policy should have its main focus on the stimulation, creation and development of companies that would employ large numbers of Barbadians, have the potential to be globally competitive, and could be significant foreign exchange earners. For example, special emphasis should be placed on the development of companies that have the potential to grow to about BDS $40 million within 5 years.

Today, students who hold degrees in the STEM disciplines have great difficulty finding suitable employment in Barbados. The problem is that technology jobs are just not available in significant numbers in the private sector, and therein lies the initial challenge. Most of the Caribbean nationals holding advanced degrees in science and engineering are trained abroad and do not live in Barbados. These technologists do not return to Caribbean in large numbers after being trained, because there are few technology jobs, and they do not return to start companies that would create such jobs.

Figure 4 is one model that breaks this cycle. The process begins with government programs designed specifically to attract as many foreign technology firms as possible to Barbados. It would be ideal for Barbadians to hold high-level management positions in these companies. Caribbean youth who are trained abroad will begin to return to Barbados in small numbers initially to fill some of the new technology jobs created within the foreign firms. Of course, the government should also encourage Caribbean STEM students and technology entrepreneurs in the Diaspora to set up their businesses or branches of their businesses in Barbados, as shown in Fig. 4.

Expansion of the number of private sector technology companies can be further enhanced by encouraging more university, community college and TVET (Technical Vocational and Educational Training) students to start their own technology-based business and create jobs rather than asking others for a job. Additionally, non-scientists should be encouraged to focus their companies on products and services derived from the application of science and technology in areas such as the arts, agriculture, niche agricultural products, fashion and value-added products and services. It will be important to make sure that such persons can get the help they may need with the relevant science and engineering principles. Of course, helping them to identify projects that could lead to large regional and global markets will be essential.

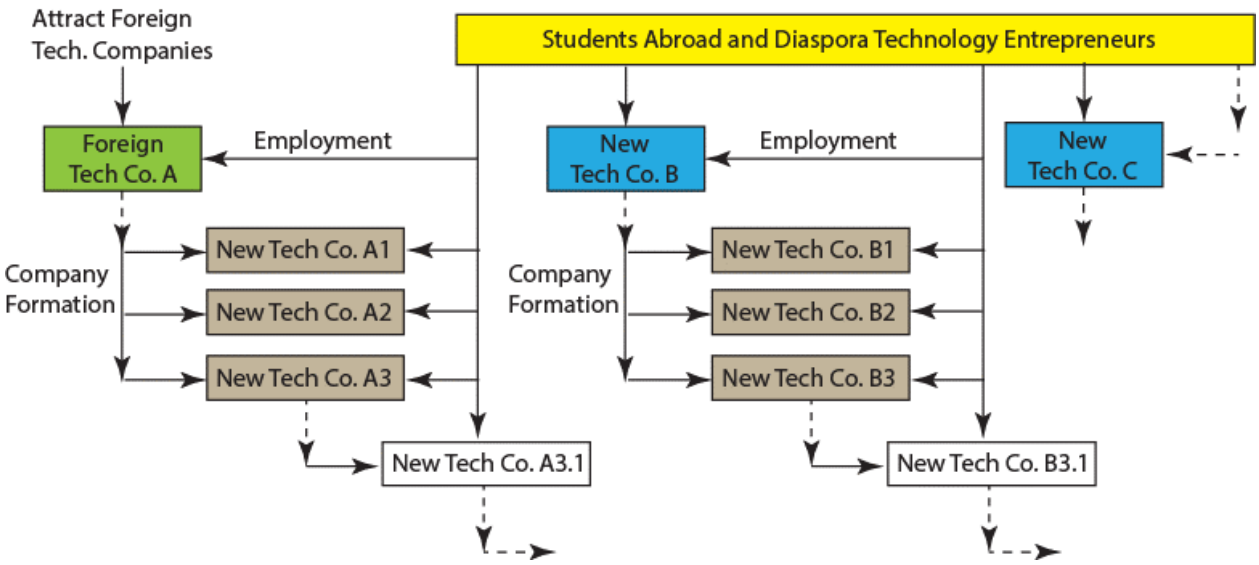

Fig. 4. A technology jobs creation model

To promote the formation of such new home-grown companies, incubation harmonization and mentorship strengthening will be needed to assist the entrepreneurs. Thus, Barbados should re-engineer its science and technology incubators so that only companies with viable business plans and plausible strategies for exit in a reasonable period of time from the incubator are admitted and nurtured in the incubators.

The private-sector expansion process continues, when one of the locally and/or foreign-trained persons who are employed in these early technology companies, leave to start their own technology business, most likely in a related area, as is still the case in Silicon Valley. The goal is to have this process repeat itself over and over again until Barbados is replete with technology companies, as well as companies in the arts and agriculture that employ cutting edge technologies. In short, it is the spin offs from the first cohort of technology companies established in Barbados that will fuel the exponential growth of more technology and technology-related companies in Barbados, as shown in Fig. 4.

To implement this model, Barbados must also make itself much more attractive to technology companies that are looking for a place to relocate, or are interested in starting up in Barbados. This focus on attracting technology companies must be a national priority. An active recruitment strategy will be necessary. A variant of the Chile model is one approach. In this model, Government and private venture capital institutions would open up business plan competitions to any small business in the world, with the understanding that winners would be required to locate their business in Barbados and that the total Barbadian citizen ownership exceeds 51% during the first 5 years. The proposed SNRL of the Caribbean (see Section 5.7) should help to make Barbados a very attractive option for such young emerging technology companies. The business plans will be vetted by a selection committee set up by the SEAB, and management of the program will be the responsibility of the NCSE (see Section 5.6). The selection criteria will be the same as those listed in Section 5.8.1.

To help attract and retain foreign science and engineering companies to Barbados, at a minimum, adequate level of know-how in science and engineering must reside in Barbados workforce. Therein lies the need for education reform in the STEM disciplines, including the integration of entrepreneurship, and disciplines such as computer programming and science into curricula starting as early as age 8.

Another very important action that Barbados must take to attract and retain these companies, is to foster a more progressive and supportive small business environment, where the government removes unnecessary hurdles to starting and maintaining a business. It is recommended that the promotion of an entrepreneurial culture includes more access to multiple sources of capital as well as in-kind capital for entrepreneurs by engaging the Diaspora, as there is very little venture or angel capital in Barbados. The facts are that investments tend to follow good projects based on sound business plans, often times irrespective of location. This can be done via partnerships between the angel networks in Barbados, the few venture capital sources in the Region, and similar entities in the Diaspora. The World Bank has been offering assistance with the formation of such networks in the Region, so Barbados should explore the possibility of such assistance.

Areas of focus for company attraction and formation could include the broad areas below:

- Information and communications technology
- Software (especially animation, processing of big data)
- 3-D display technology
- Renewable energy
- Nanotechnology
- Electronics circuit design
- Semiconductor chip design
- Specialized manufacturing of electronics, optical and biological components
- Biotech contract lab services (followed later by biotech companies)
- Niche food and agricultural products
- Technology enhanced arts, crafts and services

5.9 STEM Education Reform Considerations for All Levels

It is readily acknowledged that across the developed world and in many developing countries, science and engineering continues to be exploited as a major platform for the creation of innovative products and services, the advancement of economic development, and wealth creation. Developed countries generally have the resources and well-developed infrastructures within which science, engineering, and technology innovation can flourish. However, Barbados, like many other developing countries, has the desire to use science and engineering as a vehicle for economic development, but at the present time lacks the capacity and resources to make the necessary investments in research and development. The approach recommended to address these challenges begins with STEM education reform.

During the survey, most participants had lots of opinions and advice to offer on primary, secondary and tertiary education. One thing was clear; Barbadians felt that the education system

was not serving them well. Some felt that creativity was too often stifled in the classroom at an early age, and that teachers who had outmoded classroom practices were teaching as they were taught, and were not giving students enough freedom or space to express their ideas and their thinking. Teacher training was seen as a key area that needs addressing.

Barbados needs to urgently embrace STEM education reform to: (a) increase the level of interest in the sciences, (b) encourage more youngsters to pursue careers in science and engineering, and (c) promote more awareness in the teachers and in the general population of the link between science and engineering, and national economic development.

5.9.1 STEM Curriculum Reform at the Primary and Secondary Levels

An adequate level of know-how in science and engineering must reside in the Barbados workforce in order to attract and retain foreign science and engineering companies to Barbados. Curriculum reform and STEM teacher training in inquiry-based teaching and learning methods are imperative for teaching science and engineering principles as well as entrepreneurship. The focus must remain on creating well-rounded technologists.

In particular, to keep up with the developed world and have a well-trained modern workforce, it is recommended that Barbados add computer programming (coding), robotics, science, and concepts in entrepreneurship to its primary and secondary school curriculum, beginning at age 8. The CSF recommends Python, not Pascal, as the entry-level coding language of choice today for primary, secondary and tertiary students. Other modern languages would suffice also. The hope is that CXC will drop Pascal and adopt Python as its computer programming subject within the next two years. Engineering and engineering principles are weaknesses in the Caribbean educational system. Adding robotics and coding will allow all Barbadian students to be exposed to engineering concepts at an early age. Such coding baseline knowledge coupled with good communication skills will become expected of all knowledge workers, just as spreadsheet and word processing skills are expected today of many entry-level workers.

In general, Information and Communications Technology (ICT) training is important because it can serve as a catalyst for the development of innovative businesses, products, and services while providing enhanced productivity and a competitive advantage for companies in many sectors, including the government [3].

Placing science education in the Barbados school curriculum at such an early age, will allow science questions to be included in the 11+ exam (which appears to be a permanent and robust fixture of the Barbados educational system). The use of the exam is more the problem than the exam itself. The exam unintentionally excludes the late bloomers from attending the schools that are more prestigious. Whether or not the 11+ exam is eliminated in the near term, it is recommended that the Ministry of Education implement a continuous assessment solution that: (a) emphasizes a teach-test-correct-teach approach, and (b) strengthens the lesser performing secondary schools by deploying, as soon as possible, a more even distribution of resources across all secondary schools.

Modification of the primary and secondary school curriculum at all levels to include the fundamentals of entrepreneurship is worthy goal, as a cultural shift is needed in Barbados with regard to the way entrepreneurship is viewed and practiced. A basic entrepreneurial education would complement STEM education, and should cover the fundamentals of finance, how to start a business, the various types of capital, intellectual property concepts, how to write proposals and business plans, market place competitiveness, ethics, and negotiation skills. Development of communication skills (listening, written and oral) and competency in one foreign language must also be part of the basic curriculum required for well roundedness.

To complement the formal in-school curriculum, it is further recommended that Barbados: (a) reinstate science fairs, (b) start annual math Olympiads, computer programming clubs, hackathons and robotics competitions, (c) get started on the opening of a science museum, and (d) follow the example of Guyana and weave some of the high-visibility project based exercises (such as the Sagicor Visionaries Challenge) into the science fair for cost effectiveness and implementation efficiency. The Ministry of Education must convince its education officers that they should not feel threatened or overwhelmed by the myriad of proposed curriculum changes.

5.9.2 STEM Teacher Training

Too many of the Barbados primary school teachers who are called upon to teach science do not fully comprehend the material, or have never taken a science course themselves. All teachers at all levels should be engaged in continuous training and continuous education, even if for a one- or two-day supplemental workshop annually. Such a policy is consistent with continuing education which has become the norm in other professions such as accounting and medicine, and is considered part of the life-long learning experience. STEM teacher training can yield huge returns on the investment. While a poor teacher can turn off an entire class of students, a good teacher can arouse passion, excitement, and create the will to learn in that same classroom.

Given that Barbados needs to urgently introduce coding, robotics and the elements of entrepreneurship into the curriculum, the trainers at Erdiston Teacher's Training College will need to be trained. Further, Erdiston will need to train more primary school teacher on basic science principles, and then teach them how to teach STEM subjects using PBL/ISBE approaches. Substantial investments at Erdiston will be needed in order for the training college to carry out its expanded role.

The "science is cool" factor also needs to be sold to children (e.g., more science and engineering programs on TV, more science exhibits, and more math Olympiads and science fairs with winners celebrated more in the media). STEM teachers need to be trained on how to get this message across with conviction and persuasiveness. Additional on-line STEM Teacher training can be done within the comprehensive Learning Management Systems (LMS) system described in Section 5.9.6. With this system, teachers can teach themselves new material, find examples of science and engineering phenomena that they can demonstrate in class, and get feedback on the effectiveness of their teaching.

The proposed increases in the budget for Erdiston, the costs of installing the LMS and the modest increases in teacher salaries should come out of the overall budget (up to 1% of GDP recommended) that is set aside for science and engineering in Barbados.

5.9.3 Inquiry-Based Teaching and Learning Methods

One of the first steps for Barbados in developing a culture of innovation in science and engineering, is to place much emphasis on the stimulation of creative thinking beginning with primary school and continuing through the tertiary level and beyond. This can be achieved by adopting Problem Based Learning (PBL) and Inquiry Based Science Education (IBSE) teaching methods. The PBL/IBSE inductive approach emphasizes observation, experimentation and teacher-guided construction, and draws on the student's own knowledge and ideas. This is also consistent with good research and scientific practices which begin often with a hypothesis, the design of an experiment, conduct of the experiment, and an analysis of the observations to test the hypothesis. Research scientists and engineers would then further refine the hypothesis, conduct further experimentation and analysis, and repeat this process until sound conclusions are reached (positive, negative or inconclusive). This is the kind of analytical, logical, critical and creative thinking that Barbados needs to perpetuate in its schools to develop the next generation of scientists and engineers.

The PBL/IBSE methods also provide an excellent environment for teamwork. The ability to be a good team member is a very important asset when charged with solving large complex interdisciplinary problems. Resources for such STEM education initiatives need not be expensive as the educational system can draw upon indigenous and everyday materials, and use examples from the home, workplace, school, farm and the community in its inquiry and project-based learning activities. Clever use should also be made of the World Wide Web and online information and teaching modules, many of which are freely available. Using these electronic media, students can learn and review material at their own pace, with the teacher and/or parent clarifying concepts and answering specific questions.

It is anticipated that the above-proposed approaches will promote more student interest and excitement in science and engineering prior to their entering secondary school. Further, the successes gained at the primary level will lead to a stronger focus on the sciences in the secondary level. Ultimately, this should lead to higher numbers of students pursuing advanced degrees and careers in science and engineering, and should help develop the Region's next generation of technology leaders.

5.9.4 The Value of the Design Experience in STEM Education

Barbados must place the student at the center of the learning experience not only in its tertiary institutions, but in all its schools. A balance needs to be struck between theoretical and hands-on learning, as both are important. Cramming followed by regurgitation must be discouraged. Instead, there must be a strong focus on mastery of the fundamentals of science and engineering, so students can draw upon their fundamental knowledge and use their creativity and inventiveness to solve complex problems that they have never encountered before. How else can

Barbados train students today for the jobs of tomorrow, many of which do not exist today? In fact, we want our students to be creating those jobs of tomorrow.

STEM education reform should be multi-faceted and encompass learning both inside and outside the classroom. One of the obvious flaws in the education system, is that not enough attention is paid to the design component of learning in the Barbados educational system (primary through tertiary). The value of project-based assignments and team work seems to be missing in too many schools, especially in science and engineering. The imagination of each and every student needs to be exercised in and out of the classroom. The design component draws on the creativity of the student, and so project-based learning is critical for stimulating imagination and creativity which can then manifest itself in the design of new experiments, products or services.

5.9.5 Discouraging Rote Learning: A Bold Initiative for Barbados?

It is natural for students to cram for exams. Cramming is perhaps the worst way to learn new material. Students with the best memories, not necessarily the most creative, perform best on such exams. What Barbados needs more of are the creative geniuses, who think outside the box. To measure this kind of genius, open ended exams are better suited, where students can express their ideas and prove the viability of their ideas by theory, experiment, or computer simulation (the three basic tools that scientists and engineers use to do research). Coding (computer programming) then has to be an essential tool in the educational quiver of all students of all ages.

In addition to adopting the PBL/IBSE approaches, it is recommended that, in the classroom, Barbados lead the Caribbean by adopting a revolutionary method of classroom teaching. The below-proposed methods would create a learning environment in which students are trained to think critically and to develop analytical and logical problem-solving approaches in several disciplines. Rote learning would be discouraged. The focus would be on understanding the concepts and fundamental principles in each discipline, and to gain mastery. Grades, though important, would not be emphasized over and above mastery.

In this bold new initiative, to discourage rote learning, students would be given zero marks for correct answers arrived at with faulty reasoning, and more than 90% credit for incorrect answers that are based for the most part on logical and analytical thinking. Of course, although arriving at the correct answer to a given problem is important, it is the analytical and logical thinking, the methodology and the problem-solving approach that are most highly valued, as getting these right will lead to correct answers every time.

In order to implement this approach, Barbados would need to cultivate a risk-free learning environment in its schools, that is, an environment in which students are encouraged to have no fear, insecurity or hesitation in asking questions. In such a classroom, there would be no penalty for statements such as "I do not know" or "I do not understand", and there should be no such thing as a stupid question. Since there would be minimal competition between students, students would naturally help each other to learn and understand the material, and would be encouraged to do so. Grades in assignments would reflect self-improvement and mastery. The

above assumes that the teachers are well grounded in the fundamentals which is often not the case today.

5.9.6 Establishing a Learning Management System for Primary and Secondary Schools

Regarding primary and secondary education, Barbados could make a quantum leap forward in the way it manages the educational processes in its primary and secondary schools. Many parts of the world are instituting comprehensive Learning Management Systems (LMS) in their primary and secondary schools, and Barbados should do the same. These systems include: (a) a website featuring high quality STEM teaching materials (with lots of culturally relevant examples), (b) online teacher training components where teachers can learn/practice skills at their own pace, (c) a system to measure teacher performance and effectiveness, and (d) a system to provide feedback and suggestions to teachers so they can improve their performance. Despite potential push back from the unions, merit-based pay for teachers is the best way forward for Barbados. The LMS system can be set easily up to show which teachers are the most effective. Increasing their pay will draw more highly qualified teachers into the profession.

5.10 TVET Education Considerations

Going forward, Barbados must meet the needs of its old and new technology-reliant employers while maintaining its historical excellence in the liberal arts. With the implementation of this HRD strategic plan, Barbados's new employers will need to find sufficient numbers of skilled workers, especially in key tech-intensive and growth-oriented industries like information technology, healthcare and advanced manufacturing. The education system must be the engine that nurtures the talent, grooms our leaders, and prepares our technology workforce. Thus, it is widely agreed that educational institutions must develop programs which respond to employer needs and provide students with the skills most likely to enable them to make a significant contribution to the workforce immediately upon graduation. Barbados secondary and tertiary education systems, for the most part, are still operating in "old economy" modes, in terms of services, practices and strategies for preparing students for career transitions and employability in the new economy.

TVET education has a major role to play in training of the new workforce, and therefore in the economic development of Barbados. TVET must provide alternative credentials, training, mentoring and career services that complement those provided by the university. A new and re-ordered credentialing system will be needed. Barbados would benefit from expert assistance to reform its credentialing system. The experts should among other criteria, assess the quality and relevance of the current credentials, and also explore the need for stackable credentials and certificates in the new workplace.

It was observed during the survey that the Samuel Jackman Prescod Polytechnic (SJPP, the premier TVET institution in Barbados) does not presently emphasize a design component in it courses. If Barbados is truly going to embrace a culture of research in science and engineering, then this institution must immediately incorporate curriculum reform, where each and every student, as a requirement for graduation, must complete a project as part of a team that designs and implements an idea from the student's own imagination. Teamwork would help build the

values of respect, listening, suppressing ego, and placing the good of the whole before interest of self, and will heighten the realization of the enormous accomplishments that can be achieved when a team, working under good leadership, tackles a complex or daunting challenge.

A further weakness of this institution is that its students are very narrowly trained. A student coming to SJPP for a certificate or diploma in cabinet making will not normally have access to computer programming, for example. Even within the engineering disciplines, mechanical engineering students receive very little training in electronics. The fact is that in today's world, many machines are a complex arrangement of electronics, optics, and mechanics and chemistry all working seamlessly together, and technicians narrowly trained in one discipline with no knowledge of related disciplines will be completely overwhelmed if faced with the repair of such a machine. Today's automobiles are an excellent example where this interdisciplinary approach to engineering education is essential.

It is recommended that the SJPP devote most of the first year of its program to giving all of its students a broader education in cross disciplinary subjects such as coding, basic electronics and basic mechanics, and then spend the second year on specialization. Such students would be much better prepared for the modern knowledge-based workforce.

The SJPP is in dire need of more modern equipment for its teaching laboratories. It is also lacking in basic components, materials and supplies for electrical and electronic engineering, mechanical engineering, computer engineering and software. It is further recommended that investments be made to address the proposed curriculum changes, infrastructure deficiencies, and operating costs challenges.

5.11 Career Counseling for STEM Students

To convince our young students of the value of a science-based education, we must expose them, from an early age, to the myriad of technology-based career options that are available with a STEM education beyond traditional paths such as medicine, law and accounting. Some schools are already bringing role models from the Region and the Diaspora, who have a STEM education and are changing the world, into the classroom to accomplish this goal. More schools should do the same. Strengthening career planning and guidance and counselling services needs to become an integral part of the services offered by both secondary and tertiary education systems. In addition to encouraging students at all levels to think more broadly about technology entrepreneurship careers, students should also be encouraged to "ask not who can give me a job, but for whom can I create a job".

Today, both Barbadian parents and students have a growing preoccupation with career readiness and are concerned by the lack of post-university work opportunities. Career services at the secondary and tertiary education institutions must offer students better help in building their careers and transitioning to work. University-employer partnerships are essential if Barbados is to move forward efficiently in training its new knowledge-based workforce. Government legislators, business leaders, employers, education leaders and national and international experts need to better align with speed and unanimity on the demands of the new economy.

They must also work together to install public policies to address these issues. These actions will permit Barbados to determine which skills and credentials its employers really care about, to identify skill gaps that exist, and then with innovative thinking and planning, to address these gaps.

5.12 Second-Chance and Continuing Education Programs

Both second chance and continuing education need to be encouraged much more in Barbados not just in science and technology, but for all disciplines. Second chance programs are designed for those who have not satisfactorily completed their secondary education, or those with disabilities, youth who are vulnerable and at-risk, and adults who are unqualified or under qualified for employment. While Barbados can boast a good primary and secondary education system, there are still too many persons not adequately certified to move into the labor force or into tertiary education. Continuing education programs can assist those seeking to upgrade skills and trade/occupational qualifications, or to transition or re-qualify for a change in career. These programs should especially cater to those people most reticent to opt for learning, such as retrenched workers, unemployed youth, retired persons, widows and widowers, and mothers who have been out of the workforce for a few years. To provide incentives to such groups, certificates of participation, diplomas and letters of commendation should be provided to participants who successfully complete these second-chance and continuing education courses [3].

Although many private and public institutions provide adult and continuing education opportunities, there remains a need to strengthen this provision. Second chance and continuing education need to be encouraged much more in Barbados not just in science and technology, but for all disciplines. Fostering the ability to think logically and creatively, develop talents and skills, and solve problems, will in general enhance opportunities to achieve personal goals and aspirations. Importantly, we must provide an avenue for continuing education in business and entrepreneurship principles for those who have already left the school system and need help getting their businesses off the ground, or in making the transition from a prototype to a globally competitive product. The goal should be the development of a learning culture in which all Barbadians can play a part. [3]

It is recommended that Barbados increase the scope of second chance and continuing education in multiple disciplines, using the facilities of the tertiary education institutions. The Ministry of Education should have full responsibility for implementation, but the prioritization of subject areas in STEM should be jointly decided by the private sector, NCSE and Ministry of Education.

5.13 Further Tertiary Education Considerations

The Barbados tertiary education institutions must play a key role in the implementation of this HRD Strategic Plan. Barbados must demand that the students in its tertiary institutions be trained today to create and fill the jobs of tomorrow, many of which do not exist today. Barbadian students are as intelligent as students in other parts of the world, so why are Barbadian students not actively involved in creating the jobs of tomorrow? What is missing is the research culture – the teaching and continuous exposure to creative and innovate STEM research environments in

the physical, biological and computational sciences. In addition, the tertiary institutions lack the human capital and the laboratory infrastructure to carry out the expected mission. Significant investments in both areas over the next ten years are recommended to broaden the scope of the university and community college from primarily teaching institutions to research and teaching organizations.

Roughly 80% of university research should be driven by the economic needs of the Region. This is not to say the university should abandon all theoretical research. In fact, theoretical research that can be shown to have a clear link to future product or service development should be encouraged. Technology transfer from university to industry and from industry to university should be more strongly encouraged and rewarded. Furthermore, the university must help businesses sustain their competitive advantage through joint research projects.

Engineers create far more jobs than most professions, and so to accelerate the development of a STEM-based economic pillar, Barbados needs to urgently place more focus on the training of high-technology women and men engineers and scientists to rapidly fill the void. At this time, very little engineering is taught or practiced in Barbados or the Region. Perhaps for this reason, the language in the Region is more often about "science and technology" than "science and engineering".

It is necessary to make clear here, the distinction between the terms “engineers” and “technicians” as used in this document. Engineers often work in research and development environments and combine the STEM disciplines with art and agriculture to design, model, simulate, develop and build their innovative products and services for the betterment of mankind. They are the creators of our cell phones, pacemakers, photovoltaic solar cells, spacecraft, robots, software, microprocessors, and special-purpose materials, to mention a few. Such high technology engineers are superb physicists, chemists, biologists, computer scientists and mathematicians, and many hold Ph.D degrees in related engineering fields. On the other hand, technicians (often referred to as engineers in Barbados and the Region) are trained to repair, copy, or install products and systems that were originally designed and built by engineers. Technicians usually do not have the theoretical knowledge and have not done the research to invent cutting edge devices, systems and services that are globally disruptive.

Market and foreign exchange opportunities are being missed because Barbados is not sufficiently exploiting the STEM talent in Barbados, stimulating entrepreneurship, and grooming our students into the science and engineering professions. Here are three examples: (1) Barbados could begin to train electrical engineers who would develop new niche and innovative low-power circuit designs for cell phones and computers (to extend battery life between recharges) and market them to the big manufacturers of these products; (2) our software engineers could be parsing, sorting and preprocessing big-data for sale on the global markets; (3) our biotechnologists could be developing more contract laboratories to provide services for biotech companies in North America and Europe. The latter is, perhaps, the fastest way to attract new biotech industries from overseas to set up shop in the Region.

Sometimes it is one or two individuals within the university or a research laboratory (not necessarily the big companies) who come up with the next disruptive innovation (like Facebook invented by Mark Zuckerberg, his roommates and colleagues while at Harvard university, and Google started by Larry Page and Sergey Brin while students at Stanford University). Ironically, the first evidence of a search engine is credited to Alan Emtage of Barbados while he was a student at McGill University; however, he never benefitted from his invention. Such inventions can also be hatched within the tertiary education system in Barbados if Barbados could put an effective research ecosystem in place. The Emtage story points to the fact that students, professors and university technology transfer officers must be savvy enough to recognize the potential value of disruptive inventions, and act swiftly to seek appropriate intellectual property protection. Barbados needs technology transfer experts who can provide business, intellectual property, and commercialization advice and guidance. Such persons would have the skills to identify potentially interested companies and negotiate deals that would move university research into the private sector. The SEAB and the Diaspora can help with finding leaders with such experience.

Key research areas based on the needs of the Barbados and on the identification of technologies with low financial barriers to market entry should be prioritized through careful consideration of the probability of commercialization success. These technologies, products and services should be developed within new or existing research and development centers of excellence in the tertiary educational universities and in the SNRL. Note that both research and development must be present. The most competitive niche products and services emerging from these centers should be targeted for growth and development, and should be nurtured in well-run incubators.

Some of the research funds for development of more and better research capabilities in the tertiary institutions would come from the proposed up to 1% of GDP set aside annually by the Government for research and development in science and engineering as described in Section 5.1. The remainder would have to come from the international community and the Diaspora, and the local private sector.

5.14 Science Popularization

For a country such as Barbados to implement a significant cultural shift such as the development of a culture of research and innovation in science and technology aimed at implementing social and economic development, the people must be onboard with the policy. Thus, the government must be prepared to sell the strategic plan to the people. To fully engage the general population and to get the necessary buy in, the population should be made scientifically literate and culturally savvy about the benefits of the plan to them. That is, the science and engineering strategic plan must be communicated to the people in simple, clear and concise terms over and over again until the general population understands the plan and can readily see how it will benefit their lives and national development, in that order.

Science popularization is an effective way to engage the people in the strategic plan. At the very least, a basic STEM education up to the high school level for most of the population will make a big difference. Disseminating information on science and technology to all Barbadians will help

to garner support and engender a greater understanding of the role of science and technology. The government should use all media, such as radio, TV, social media, websites, and print media over several years to raise awareness and create the cultural shift. Barbados could also establish an annual STEM week (as is done in the Dominican Republic) that includes STEM talks aimed at the youth and the general public, along with demonstrations of ongoing science and engineering projects in Barbados.

Barbados should, as standard practice, feature children who have won the science fairs, research and innovation awards, math Olympiads, hackathons, and robotics competitions on TV, radio, social media, and print media. In addition, the country should establish special national science innovation awards to recognize technology innovators and companies whose products reach global markets at several different revenue milestones, and feature such champions in the media.

Barbadian youngsters also need more exposure to role-model scientists and engineers to motivate and excite them about careers in science and engineering, and to make them aware of the diverse career opportunities available to scientists and engineers. It is recommended that more of this be done in the schools and at the science fairs, and that role models be featured also in all forms of media such as TV, YouTube videos, educational Websites, Twitter/Facebook, and smart phone apps.

An important benefit from science popularization and awareness raising about the benefits of a basic STEM education for all, will be that more people (including many nonscientists) will become involved in the development of companies based on the application of science and technology to the arts and agriculture. Some of these arts and agriculture companies should be selling their products and services to global markets in addition to serving local markets. Such initiatives must be encouraged, so that more jobs (not just high tech and biotech jobs) are created in Barbados. Science popularization is a low-cost, high-return initiative and its programs should be implemented immediately after NCSE is restructured.

5.15 A Note on Workforce Training

Because technology changes very rapidly today, the technologists must continually retrain themselves or be trained to stay competent and relevant. In general, Information and Communications Technology (ICT) training is important because it can serve as a catalyst for the development of innovative businesses, products, and services while providing enhanced productivity and a competitive advantage for companies in many sectors, including the government [3]. In particular, to keep up with the developed world and have a well-trained modern workforce, Barbados must adopt a computer programming (coding) culture within its secondary and tertiary education institutions. Such coding baseline knowledge coupled with good communication skills will become expected of all knowledge workers, just as spreadsheet and word processing skills are expected today of many entry-level workers.

Creativity is vital in the modern job market, and Barbados must engage in education reform that does not stifle innate student creativity. The links between creativity, innovation, entrepreneurship, global competitiveness, national economic growth, wealth creation and the

improvement of the quality of life for all, have been well established. Creativity is not just confined to the realm of artists. In an Adobe report "Seeking Creative Candidates: Hiring for the Future", it was noted that 94% of hiring managers in the US believe that creativity is key when evaluating candidates and prefer applicants with creative skills versus conventional skills by more than 5:1. Barbados must prepare its students to be competitive in today's job market by cultivating creativity, unconventional thinking, and oral and visual communication skills. The Adobe report goes on to say that 75% of those hiring for businesses agree the job market will change significantly in the next five years. Furthermore, it states that greater than 80% of hiring managers consider the ability to communicate through digital and visual media to be an essential skill. The upshot of this is that 82% of hiring managers seek candidates who can creatively apply core skills to business and technical problems. The same will be true for Barbados within 10 years.

6. SUMMARY OF RECOMMENDATIONS

Throughout this STEM Blueprint, over three dozen specific recommendations have been made. The detailed recommendations and action items are collected and sorted below. The dagger (†) indicates those recommendations that relatively low cost and low risk and for which implementation should begin immediately.

A. Establish strong leadership and budget for science and engineering programs

1. † Establish a Science and Engineering Advisory Board (SEAB) (with input from the Governing Council of the CSF [7]) whose chair reports to the Prime Minister.
2. Appoint (by the SEAB) a Director General for Science and Engineering who reports to the SEAB.
3. Transform NCST into a quasi-government agency and consolidate all research and development funding under new NCSE.
4. Rename NCST the "National Council for Science and Engineering" (NCSE).
5. † Begin now to increase the budget allocation of science and engineering research and development support, and set a goal of 1% of the GDP (Johannesburg Declaration) over a 5-year period.

B. Promote a culture of STEM awareness, innovation and entrepreneurship

1. † Introduce science popularization programs targeted at the youth and to the wider Barbadian community, including daily TV and radio science popularization shows, and the promotion of websites that offer such programs.
2. † Reinstate science fairs and introduce robotics camps (at least 3 levels), math Olympiads, hackathons and coding clubs (with help from the Caribbean Science Foundation, the private sector and the Diaspora). Weave some of the high-visibility project-based exercises (such as the Sagicor Visionaries Challenge) into the science fair for cost effectiveness and implementation efficiency. Celebrate competition winners over and over again in the popular media.
3. † Further promote a culture of innovation and research, by encouraging each high school to have student participation in at least one high-visibility project-based exercise each year (e.g., a science fair, Sagicor Visionaries Challenge, or a robotics camp).

4. † Open a science museum (start small).

C. Diaspora Engagement

1. † Develop and implement a strategy for Diaspora engagement (with help from the Caribbean Diaspora for Science, Technology and Innovation) including the establishment of a formal organization (Diaspora Science Relations Committee, DSRC) which would work with the Diaspora to facilitate contributions of talent, expertise and resources such as science and engineering advice, business and academic connections and collaborations, STEM-focused seminars, contacts for students aspiring to attend university abroad, and funding, as well as to assist with the growth of STEM and STEM-based businesses.
2. † Assign at least 25% of the agenda of the biennial Diaspora conference to exploring how the Diaspora can help with the implementation of the new HRD strategy for Barbados.

D. Private Sector Expansion and Diversification

1. Recruit foreign technology-based companies to locate or relocate to Barbados.
2. Recruit Caribbean Nationals in the Diaspora to return to Barbados for employment or to start technology businesses in Barbados.
3. Identify sources of seed capital needed by emerging new ventures, such as from the private sector, the government, NGOs (non-governmental organizations), the international community, and the Diaspora, and facilitate access to these sources.
4. † Set up a Small Business Innovation Research and Development (SBIRD) program that would increase the amount of grant seed funding for technology startups, and fund the best and most viable technology business plans in a two phase program on a competitive basis (funding can be within the suggested 1% of GDP allocated for the overall science and engineering budget). Open the SBIRD business plan competition to applicants from anywhere in the world whose companies have at least 51% ownership by Barbados citizens and who would be willing to locate their business to Barbados.
5. Re-structure the current incubators in Barbados so that more technology companies graduate within 3 years and become commercially viable.
6. † Continue the monthly entrepreneurship forum initiated by the Barbados Entrepreneurship Foundation (BEF) for entrepreneurs to share ideas, meet mentors/angels/lawyers/accountants etc.
7. † Provide opportunities for continuing business and entrepreneurship education. Explore the use of UWI and community college facilities for these courses.
8. Foster a more friendly and supportive small business environment, including legislation to remove unnecessary red tape.
9. † Sensitize civil servants to the needs of small businesses.

E. STEM Education Reform

Curriculum Reform

1. † Introduce science education to all students, beginning at age 8 with a syllabus that employs Problem Based Learning (PBL) and Inquiry-Based science Education (IBSE) teaching methods and exercises, which:
   - Includes project based courses with a design component and teamwork
   - Discourages rote learning in the primary, secondary and vocational schools, and instead promotes a culture of logical and analytical approaches to problem solving, and a focus on the understanding and mastery of fundamentals of STEM.
   - Strengthens research skills at all levels beginning at primary school level.
   - Promotes more basic STEM training and the applications of STEM in the technical and vocational training curricula.
2. † Add computer programming (coding) and robotics and entrepreneurship to the primary, secondary and tertiary education curricula. Begin at age 8.

Reform of Teacher Training and Teaching Methods

1. † Aggressively implement primary and secondary school STEM education reform to teach more science and to teach it more effectively, including the use low-budget science "labs". These "labs" would be furnished in part with every-day materials found in the home and the office. The "labs" would include the natural biodiversity environment of local plants, crops, insects, animals, the natural geological laboratory of rocks, minerals and soil, the environmental laboratory of our atmospheric and marine environments, and the cosmological laboratory of our solar system and galaxies.
2. † Require all primary school teachers to undergo mandatory basic science and math training, and all primary and secondary school science teachers to undergo continuing education including the use of Problem-Based Learning (PBL) and Inquiry-Based Science Education (IBSE) methods.
3. Require all teachers to be trained on how to include and more effectively use technology tools to teach STEM inside and outside the classroom.
4. † Provide continuing education and training for staff at Erdiston Teacher's Training College in the areas of robotics, coding and entrepreneurship, so Erdiston can train teachers in these subjects
5. † Strengthen/re-engineer and increase budget so Erdiston Teacher's Training College can carry out much of the above PBL/ISBE training in science, robotics and entrepreneurship to teachers
6. † Adopt a syllabus that employs Problem Based Learning (PBL) and Inquiry-Based science Education (IBSE) teaching methods and exercises.
7. Implement a comprehensive Learning Management System (LMS) across all primary and secondary schools that includes: (a) a website featuring high quality STEM teaching materials with lots of culturally relevant teaching examples, (b) an online teacher-training component where teachers can learn and practice skills at their own pace, (c) a system to measure teacher performance and effectiveness, and (d) a

system to provide feedback and suggestions to teachers so they can improve their performance.

8. Provide performance-based incentive pay for teachers as part of the LMS, and thereby attract and retain more talented individuals in the teaching profession.

Reform Teaching at the TVET Schools

1. † Introduce more of the basics of STEM in the vocational training schools, and invest in modern tools, software and hardware so that the Barbadian workforce is more ready for the new STEM based jobs that will be created.
2. † Foster an environment in the vocational training schools where all students are encouraged to adopt analytical and logical thinking as the norm, think innovatively about creating new products and services, and consider entrepreneurship as a career path.

Tertiary Education Operations

1. † Establish a Tertiary Education Scientific Advisory Committee (TESAC), comprising visionary educators and business leaders from Barbados, the wider Caribbean and the Diaspora, to provide advice on the reform of STEM teaching and research programs at these institutions.
2. Re-engineer tertiary educational institutions to establish research centers of excellence in areas of immediate relevance to the needs of Barbados.
3. Hire the appropriate staff to secure funding for the research centers of excellence at the university.
4. Invest in university research infrastructure and meaningful syllabus reform to increase the quantity and quality of research output, thereby enabling the university to recruit and retain top notch science and engineering talent from anywhere in the world.
5. Staff university and community college with a single experienced and highly effective grants and technology-transfer coordinator employed full time to: (a) help find more grant funding opportunities, (b) work with lecturers and professors to support assembly of persuasive application packages for grant funding, (c) provide business, intellectual property, and commercialization advice to faculty, staff and students, (d) identify companies potentially interested in licensing technology from the university/community college, and (e) negotiate with companies for licensing the technology.
6. † Increase collaboration between the tertiary institutions and the Diaspora so as to help the university keep pace with cutting edge STEM research (with the assistance of the TESAC).

Encourage More Private Sector Contributions to Education

1. † Encourage more private sector engagement and collaboration with all levels of the education sector, including the vocational training institutions and the science popularization initiatives.
2. † Encourage more private sector input on curricula at all educational levels and work with companies to have them host more student internships.

F. Building a Strong National STEM Research Environment

1. Establish a major Shared National Research Laboratory (SNRL) that serves Barbados and the wider Caribbean. SNRL should be owned by the government and administered by a Director who reports to the Director General for science and engineering.

G. Implement Legislation for Business-Friendly Reforms

1. † Introduce policy reforms to promote the rapid use of technology within Government and Government agencies to: (a) provide services more rapidly and more efficiently, and (b) disseminate and share knowledge across and between all sectors of Barbadian society.
2. † Create a more business-friendly environment, including easier access to capital and the removal of unnecessary red tape.

7. CONCLUDING REMARKS

Clearly, sound strategic planning and implementation with strong new leadership will be needed to develop a STEM-based economic pillar for Barbados. The bottom line is that Barbados needs to immediately cultivate a culture of science and engineering across the Island, and substantially expand and diversify its private sector by adding significantly more science and engineering based companies that can be globally competitive. Existing resources (persons and institutions) are not being effectively used to harness science, technology and innovation as a tool for economic development. The country needs to get the people onboard and involved in the HRD Strategic Plan.

Implementation should start with the recommendations in Section 6, not all of which are low cost. The reason is that, in some cases, initial preparatory work is needed immediately on some of the higher budget recommendations. In parallel, Barbados should begin planning for implementation of the remaining recommendations. The many small-business organizations should be brought together to advise the government of their needs and their frustrations and to propose solutions. Government should take their concerns seriously and prepare any legislation necessary to address their concerns. None of these early action items have to be costly, but the government must provide a budget for this 1st phase of implementation planning. The Diaspora can help with establishing the SEAB to the Government, the transformation of NCST, and implementation of the STEM education reform programs, thereby reducing consultancy costs.

Barbados must immediately begin reforming its educational system to address the low number of students pursuing advanced degrees in science and engineering. The focus should be on grooming the next generation of technology entrepreneurs and leaders in science, engineering and business.

Beginning now, Barbados must increase its investment in science and engineering projects within SMEs, and both attract and cultivate more technology-based companies. Barbados should begin

to lay the groundwork for the establishment of the SNRL of the Caribbean. In addition, Barbados must foster a progressive culture and a more supportive small business environment. Simultaneously, the country must find ways to create a vibrant angel and venture capital base both inside and outside of Barbados.

Following through with adoption and aggressive implementation of the full set of recommendations will allow Barbados to harness STEM effectively for economic growth and development.

8. ACKNOWLEDGMENTS

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APPENDIX A - STEM Questionnaire and Responses

This Appendix is a summary of the responses to the 144 questions. The questions on the survey were grouped into 8 categories as follows: General; Teachers, Teaching Methods & Teacher Training; Primary and Secondary Education; Tertiary Education; Private Sector; Entrepreneurship; and Government. Respondents were told to answer any questions they wanted to, and not to worry about responding to all of the questions. In the end, all of the questions evoked responses. In distilling the responses to the questions to extract the most salient points, and to remove redundancy, the questions were regrouped into the 9 categories shown below.

The Caribbean Science Foundation remains grateful to all who took the time and went to the trouble of filling out the questionnaire. Most of the concerns and ideas voiced that were consistent with the overall scope of the assignment, have been incorporated into this Blueprint.

A1. General Strategy and Approach for Developing STEM

a) *The current thinking is that we can create several new high-paying jobs and significantly increase our foreign exchange earnings by developing an economic pillar based on science and engineering. If you disagree, what should be the alternative approach?*
   Overall, there was agreement. However, cautionary comments included finding short-term solutions, encouraging cottage industries, and the need to improve Barbados competitiveness.

b) *What should Barbados be doing in science and technology to earn more foreign exchange in (a) the near term, (b) the long term?*
   In the near-term, attracting foreign investment in STEM from multi-national corporations, and focusing on ICT service exports were highlighted. A general sentiment was that Barbados is not ready in the short term to leverage science and technology (S&T) for significant foreign exchange. For the long-term, developing a culture of S&T, promoting STEM education, and training students and scientists through international exchange were highlighted. Investment from the private sector, and incentives and facilitating the establishment of new businesses were also seen as needed. Further leveraging existing local technology-based businesses such as solar energy through R&D and improved marketing were also mentioned.

c) *How can Barbados build science and engineering competitiveness?*
   Facilitating STEM education at the top universities, and increasing S&T awareness and popularization through science fairs and competitions were seen as critical. A recurring theme was allocation of more resources including more scholarships for STEM education for the youth.

d) *In Barbados, have we established benchmarks and quality standards for research infrastructure (funding, equipment, human resources and time), best-practices in research work and for recognition of science, technology and innovation outputs?*
   The majority of responses was no, and the remaining responders were not aware of such standards. Bureaucracy and lack of implementation were cited as challenges, though it was noted that such standards could be developed by tertiary institutions.

e) *What fraction of the Barbados government budget should be allocated to science, technology, and business stimulation?*
   Responses varied widely from 1% to 20%.

f) *Is the private sector doing enough investment in science and engineering, and in the science, technology and innovation policy/strategy for Barbados?*
   Most believe that the private sector is not doing enough. However, lack of incentive for the private sector and/or lack of appreciation for the benefit to the businesses were cited as challenges. It was suggested to increase internship/apprenticeship programs.

g) *Are existing resources (persons and institutions) being effectively used to improve science, technology and innovation as a tool for development? If not, what should be done to mobilize and deploy these resources?*
   All but 1 responder believe that existing resources are not being effectively used to improve S&T for development. Issues that were cited include a disconnection between public, private, governmental and non-governmental organizations, and the need for better coordination and support of initiatives.

h) *How best can Barbados quickly create science and technology based jobs?*

Several responders highlighted attracting technology-based companies (foreign or local) to establish businesses in Barbados through incentives (which were deemed critical). Identifying areas that are feasible with current resources and expertise, and looking at other nations that have been successful for areas of science to focus on were also mentioned.

i) *It has been suggested that there is no reason why the next "Google" cannot start in Barbados. Do you see this all hype? If not, what do we need to do build the first globally competitive company in Barbados with the muscle of Google?*

Most believe this is possible, with a change in culture and better S&T education as well as improved marketing. Critical and independent thinking, and risk-taking were highlighted as cultural shifts that are needed.

j) *The current thinking is to link science and technology to the post 2015 agenda and the Sustainable Development Goals for Barbados. How should we go about this?*

Education, intellectual property training and investment in research were mentioned.

k) *How should Barbados take the collective wisdom in science, engineering, business, art, finance, social science, and history and combine them to address its economic development problems?*

Cross fertilization of key opinion leaders from these areas at meetings / interest groups was seen as an approach to leveraging the collective wisdom. A specific suggestion to focus on production of crops was made.

l) *What should be the role of the private sector in the Barbados Science, Technology and Innovation development plan?*

The private sector needs to identify economic opportunities in S&T and the skill sets needed of future employees. Specific recommended roles of the private sector centered on funding STEM education initiatives, providing internship opportunities for students, and providing mentors.

m) *Should the private sector be made accountable to contribute to the development of Barbados?*

The consensus is that the private sector must contribute, either voluntarily through encouragement or incentives. This contribution is viewed as critical for the development of Barbados.

n) *What do you see as the role (if any) that the religious sector can play in the economic development of Barbados?*

The religious sector can contribute through dissemination of ideas and information, and through influence, such as being proponents of creativity, and morality.

o) *Some have advocated that the Diaspora should be approached to help Barbados to develop programmes, and to modify and adopt successful programmes from other countries. What do you think of this suggestion?*

Most believe that the Diaspora could bring relevant expertise and resources. However, the Barbados culture was highlighted as a major influence on internal projects.

p) *What role if any would you like the Diaspora to play in the economic development of Barbados?*

Specific roles include expertise, funding, training opportunities, scholarships, and assistance with implementation.

q) *What best practices can we learn from other countries?*

Best practices to learn from other countries include attracting foreign investment with a focus on manufacturing, facilitating innovation, allocating sufficient money and resources to science, attracting highly trained teachers through higher pay, structuring school curricula to focus more centrally on S&T, and including science labs in primary schools.

r) *What should Barbados be doing to protect current intellectual property that will be developed under this new STI thrust?*

Legislation, oversight and education were seen as needed actions to protect intellectual property.

s) *How can we develop and strengthen linkages between the science knowledge networks in Barbados?*

Facilitation via online platforms and regular meetings were suggested.

t) *Do you know if there is an Information and skills network/system in Barbados that facilitates documentation and transfer of scientific information?*

There was no awareness of a broader network/system in Barbados to facilitate communication.

u) *What should Barbados be doing to better utilize S & T in the tourism industry?*

The only respondent suggested creating partnerships.

v) *What should Barbados be doing to better utilize S & T in the financial services industry?*
Specific technology development was suggested.

w) *Is the way forward for Barbados to simply grow the tourism, financial services, and international trade industries and forget about technology, since technology has never been our strength?*
The consensus was that technology needs to be leveraged to diversity the economy, and to strengthen tourism, financial services and international trade. In addition, the application of S&T to the agriculture sector was highlighted as an area of high potential.

x) *What should Barbados be doing now to be able to pay down on the national debt and thereby restore its international credit rating to a healthy level?*
Reduction of government costs, innovation, and self-sufficiency through use and market of Barbados natural resources were cited.

A2. Implementation of Science and Technology Policy and Strategic Plan

a) *Is our colonial past the problem, or is it the after effects of slavery, or is it the government or the people, or our culture. Please elaborate.*
All of the above were seen as contributors. Creativity and thinking outside the box are seen as critical for the future.

b) *How should government reform itself to be able to implement a science and technology policy and strategic plan?*
A holistic approach and broad reform were seen as important for implementation of an S&T policy and strategic plan.

c) *What legislation would you like to see passed to insure implementation of a science and technology strategic plan and policy for Barbados?*
A national policy with emphasis on S&T and a national STEM curriculum that includes primary and secondary education as well as technical/vocational education was recommended. However, legislation was not necessarily viewed as ensuring implementation.

d) *What structure should Barbados put in place to most effectively implement a science and technology strategy plan?*
One responder recommended a single Ministry, the National Council for Science and Technology and a task force (working group). Involving all entities in the process was seen as critical.

e) *Should Barbados establish a separate Ministry of Science and Technology?*
Different views were stated, ranging from agreement (if clearly defined role of S&T, qualified staff and adequate funding) to disagreement (integrate into existing Ministries).

f) *Which Ministries would you eliminate or combine?*
A wide range of responses were provided, including creating a new ministry of S&T, combining S&T with Education, combining Labor and Education, and combining Education, Labor and Human Resource Development.

g) *What should be the role of the National Council for Science and Technology?*
Roles suggested for NCST included coordination of implementing the policy and strategic plan, liaising between private sector and government, promoting innovation, and popularizing science.

h) *How and where can the government find the resources to implement a new science and technology policy when budgets are already stressed?*
Suggestions included sourcing funding through grants, and leveraging existing personnel.

A3. Policies

a) *What should be the key aspects of a science and technology policy for Barbados?*
Key aspects include creating employment opportunities, stimulating R&D, promoting STEM awareness, creating a targeted national curriculum that mandates specific STEM subjects, reforming STEM education (starting early in primary schools), and teacher training. The need for sustainability was highlighted.

b) *What should be the key aspects of an energy policy for Barbados?*
Key aspects include renewable energy (including solar, wind) and energy conservation, R&D, human resource development, employment opportunities, entrepreneurship, and tax credits for sustainable energy use. The need for sustainability was highlighted.

c) *What should we be doing about agriculture in Barbados?*
There were many responders for this question, with overwhelming support for a return of the agriculture sector. Recommendations included developing the sector and encouraging investment with incentives, land development R&D, human resource development, and agriculture education (starting in primary school).

d) *What should be the key aspects of an agricultural policy for Barbados?*
Key aspects should include a focus on food security and health/nutrition, promoting awareness of the use of S&T in agriculture, R&D, protecting agricultural lands, support of locally grown food, and providing incentives to local farmers. The need for sustainability was highlighted.

e) *What should be the key aspects of a food policy for Barbados?*
Key aspects should include food security, reduction of food imports, healthy eating, and increased attractiveness of locally grown food. The need for sustainability was highlighted.

f) *What should be the key aspects of an environmental policy for Barbados?*
Key aspects should include sustainability, recycling, reduced emissions, and wise management of natural resources.

g) *What should be the key aspects of a health wellness, and safety policy for Barbados?*
Key aspects should include disease prevention, health maintenance, reduction of obesity, and emphasis on life-style. The need for sustainability was highlighted.

A4. STEM Awareness/Sensitization

a) *How do we go about mobilizing and motivating the people of Barbados to embrace the new HRD strategic plan for economic development?*
STEM awareness and sensitization was seen as critical. Communication of the plan and subsequent personal benefits as well as long-term economic development will be key. A strong emphasis was placed on continuous outreach to the community including public education via TV, social media, competitions, public seminars, and town hall meetings, with links to practical applications. STEM education in the primary school was also viewed as important.

b) *In Barbados, do we promote public understanding and awareness of science, technology and innovation and its role in society?*
The large majority responded no or only to a limited and insufficient extent. Although there is widespread consumer consumption of technology-based devices, there is little awareness of how such devices work or are produced.

c) *How can we get buy in for the development of a science and engineering-based economic pillar from the general public?*
STEM sensitization and showing the value of S&T are key. Science fairs and exhibitions with applications to local problems were suggested.

d) *What should Barbados be doing to popularize science and technology and promote an STI culture?*
Suggestions included science fairs and exhibitions, science competitions, science museums, radio shows, TV shows, websites, and career showcases. Promoting STEM in the schools at all levels, starting with primary school was a repeated theme.

e) *What are the best ways to harness, cultivate and sustain the science and technology talent in the youth?*
There were numerous responses that converged on stimulating interest in science and technology in the youth through science fairs and competitions, TV shows, and science clubs. Promoting STEM in school starting with primary school, particularly with great science teachers who are passionate about the subject and infectious with their enthusiasm, was seen as key.

f) *How can we increase the number of students interested in pursuing STEM-based careers?*
The numerous responses focused on sensitization and making science fun. A change in attitude was seen as important – science should not be viewed as difficult or boring and only for the gifted, but rather exciting and relevant with real life examples. Science should be incorporated into the curriculum early – at the primary school level, and more emphasis needs to be placed on science and math in the curriculum. Teachers who are passionate about STEM are key. The broad range of STEM-based careers needs to be made known to the students so that they are aware of the diverse range of opportunities available, along with the possibilities of success (financial an otherwise). Students should be provided with role models

whom they can relate to, and who can serve as mentors and advisors. Scholarships and awards for STEM students should be made available.

g) *Is there a need in Barbados to expose more young people to role model scientists to motivate them? If yes, how would you do this?*
In general, the response was yes. Approaches included career day/career show cases, internship/apprenticeship programs, visits to the schools from scientists, profiling scientists locally on the radio and TV with their journey outlined, and connecting the students with successful professionals.

h) *Should we have more math Olympiads, science fairs, robotics competitions for youngsters, and how should they be run and organized so that they are sustainable?*
Overall, the response was positive, though the need for coordination was mentioned. The more opportunity that students have to see science in action, the greater their potential interest. Science fairs and competitions on an annual basis were highlighted.

i) *Should the private sector be co-opted to support science clubs in schools and to participate in national S&T events that are intended to excite and motivate young people through competitive activities? If yes, how should we go about making this happen?*
There was unanimously positive response. Companies with S&T interests should be identified and asked to sponsor these organizations/events and/or students. The businesses could promote their brand to potential future employees.

j) *Do you agree we should be utilizing youth-targeted communications, e.g. websites/twitter/facebook to promote science and technology to the youth in Barbados? If yes, who should be in charge of this initiative?*
The Ministry or Education (possibly in collaboration with the teachers), the youth themselves, the Ministry of Youth Affairs, or the CSF should be in charge of this initiative. The individual schools could be responsible to a certain degree for their students. Youth leaders could be identified to help coordinate their school's communications. Parents were viewed as an important part of the communications.

k) *What is your definition of engineering?*
Engineering was defined by most as the practical application of science or scientific knowledge to designing/building products.

A5. STEM Education

General

a) *What is your vision for STEM education in Barbados?*
The vision for STEM education comprised facilitating the development of the economy towards sustainability, promoting science as a way of thinking, and producing a population who are scientifically literate and have knowledge and skills congruent with existing and projected STEM careers. A shift from a didactic approach of teaching to deep conceptual understanding and application of knowledge especially was advocated. Innovation was highlighted. Applications such as manufacturing efficiency, food production and environmental preservation were mentioned.

b) *What fraction of the Barbados government budget do you think should be allocated to science and technology education?*
Responses comprised a wide range, from 0.25% to 20%.

c) *Is Barbados doing enough to implement policies to monitor expenditures and human resources in the education sector, along with activities, outputs and other areas necessary to provide a comprehensive overview of the situation of science and technology? If no, what should be done?*
The response was no, that implementation has consistently been a problem in Barbados. Cost efficiency and effectiveness were highlighted as areas for improvement.

d) *What should Barbados do with regard to curriculum reform?*
Labor market needs and projections were seen as important for guiding curriculum reform so that changes are relevant. A goal of producing innovators and emphasizing science in the curriculum with conceptual understanding were highlighted. Specific suggestions on curriculum reform included more practical exercises, and incorporation of inquiry- and project-based learning. Internships were also suggested. Several responders stated that the Common Entrance Exam should be revised to include science.

e) *What reforms would you like to see implemented in primary school education?*

Improving the quality of teaching science was emphasized. Teacher training and specialization in specific subject areas in science and math were seen as important and highlighted repeatedly. Ideally, teachers with degrees in science would provide the instruction to students. A common theme was that more practical and relevant exercises should be incorporated to illustrate applications of science that are engaging and fun. Critical thinking, problem solving and creativity were encouraged as key components. A tiered approach to assessment was suggested to evaluate concepts and critical thinking. Including science in the Common Entrance Exam was also suggested.

f) *What reforms would you like to see implemented in secondary school education?*
An emphasis on learning concepts rather than regurgitation of facts was highlighted. Greater diversity in the science curriculum was suggested. A common theme was that a strong practical component should be incorporated, to illustrate applications of science that are relevant and interesting. Career opportunities in agriculture and environmental science should be highlighted. Making integrated science mandatory up to ~3rd form was suggested, as well as providing special classes for gifted science students.

g) *Should science be included in the 11+ exam?*
There were different views on the inclusion of science in the 11+ exam, ranging from no to yes. Continuous assessment was advocated.

h) *Should the 11+ exam be eliminated and replaced with a continuous assessment system that emphasizes a teach-test-correct-teach approach?*
Most responders thought that the 11+ exam should be eliminated and replaced with continuous assessment.

i) *Should Barbados scholarships be limited to students who will major in STEM disciplines?*
Almost all responders thought that Barbados scholarships should cover multiple disciplines. However, greater incentives and scholarship opportunities for students interested in STEM could be provided.

j) *Should Barbados scholars who go abroad be required to return and provide services as part of the condition for accepting the scholarship?*
There was consensus that Barbados scholars absolutely be required to give back whether returning and contributing in person, or from abroad in some form of service to the country.

<u>*Teacher Training*</u>

a) *Are primary and secondary school teachers trained well enough to plan and design STEM activities for their students? And to teach the scientific process to their students? If not, what do you propose we do?*
Most believe that primary and secondary school teachers are not trained sufficiently in STEM. It was noted that all science teachers should have science backgrounds but that currently this is not the case and some are not even familiar with the scientific process. Additional training was seen as needed to address the way in which STEM subjects are taught, increase teacher's knowledge and skills, and increase their experience with projects and practical lab work.

b) *What should we be doing to improve STEM teacher training at the primary and secondary levels? M*ore training was advocated. It was suggested that the Erdiston Teachers' Training College programs be revamped. Specialization of teachers in science was a repeated theme. For primary levels, allowing teachers to specialize in science education (both content and pedagogy) was seen as important. Attracting STEM teachers with a background in science (e.g. gifted STEM graduates) was also mentioned.

c) *Is it your observation that primary school teachers are struggling with simple science and technology concepts, resulting in fear by teachers to teach science subjects? If so, what are your recommendations?*
Training of teachers and specialization of teachers in science were repeated themes.

d) *Should all teacher training institutions in Barbados be reviewed annually to identify areas for improvement followed by a course of deliberate action and correction?*
All agreed to regular review but differed in recommended frequency – annual or less frequently (e.g. every 3-4 years).

e) *Do trained Barbadian scientists trickle back into the school system? Or, instead do they pursue other perceived attractive opportunities?*
In general, Barbadian scientists do not become teachers in the school system. This was widely attributed to teachers receiving low salaries. Other reasons included lack of ability to bring about change, lack of incentives, and more attractive opportunities elsewhere - abroad or in the private sector. Those that do become teachers in the school system do so because of a lack of local job opportunities for scientists.

f) *Are limited resources, incentives and infrastructure acting as disincentives to professionals entering the teaching profession? If not, what is your opinion?*
The main disincentives to becoming a teacher were attributed to low salary and increasing workload. Lack of incentive, lack of resources, and lack of respect for the profession were also cited.

g) *The following were observed as critical contributing factors for the success of education in countries such as Japan, Malaysia and China:*
- *Top graduates from the best universities are selected as teachers*
- *Teachers are offered competitive salaries*
- *Teachers are engaged in continuous training, annually*

Do these approaches make sense for Barbados? If yes, why? And can Barbados afford to follow this model?
The overwhelming majority agreed that these approaches make sense for Barbados. However, a repeated concern was the financial challenge of paying competitive salaries to teachers; this was seen as an impediment to attracting top graduates. Annual training was viewed as critical and perhaps the easiest to implement.

h) *Should Barbados forge alliances for fellowship programmes with institutions in countries such as India and China to train persons (including teachers) at higher levels?*
All but 1 responded yes. However, cautionary notes included cultural relevance and language skills.

i) *In Barbados do we practice continuous training of teachers based on inter-disciplinary integrated inquiry & problem-based approaches?*
Funding and resources were cited as challenges to continuous training. However, programs and workshops for teachers were viewed as important.

j) *Most recommendations focus on teacher training. Should we not have equal emphasis on school Principal training? If no, why?*
Most responded yes, that principals should be trained and sensitized to the importance of STEM education, since they have ultimate leadership responsibility for the school.

<u>*Curriculum and Teaching Methods – Primary and Secondary Education*</u>

a) *Do you think our teachers have sufficient materials to adequately implement activities in their classroom?*
Almost all responded no, that materials are inadequate due to insufficient budgets. The government should do more in this regard.

b) *Is it your opinion that Barbados institutions, including teacher training colleges, continue to use theory based/traditional approaches to education resulting in difficulty for persons to appreciate a more practical approach to STEM education?*
Most responded that STEM teaching was still too theoretical, and that the link to practice needed to be increased, especially with examples that demonstrate the relationship to real-life examples. Breaking with tradition was cited as a needed change.

c) *In Barbados, do we follow a curriculum that integrates scientific skills into the teaching of numeracy and literacy within primary schools?*
A lack of integration was commonly cited. Again, changing old methods was seen as challenging.

d) *In your opinion is there provision of equitable emphasis (time and resources) for science education, literacy and numeracy in primary school classrooms?*
All responded that the emphasis is on literacy and numeracy, and science is de-emphasized.

e) *Is it your opinion that in primary schools, science subjects were taught if and when feasible? If so why?*
The consensus is that science is taught in the primary schools, but is not taken seriously because math and English are the focus of the 11+ exam.

f) *Are Secondary schools participating enough in science and technology? If no, what are your recommendations?*
The majority responded no. Recommendations that were repeatedly made included holding science fairs and competitions, such as those that require STEM to solve local problems.

g) *Is mathematics being approached as part of science, and not being compartmentalized in the education system? If no, what should be done?*
Most responded that math is being compartmentalized, and taught in isolation, rather than in relation to science. Math teaching was viewed as too theoretical, without sufficient application and link to science.

h) *Is it your observation that students are generally not interested in science subjects and often feel discouraged when experiments/activities are not successful?*
Most felt that some students are interested in science when it is taught in a fun and exciting way. The lack of adequate facilities and resources, however, was seen as a challenge. Also, it was noted that science is perceived as difficult.

i) *Do teachers in Barbados focus on how children learn?*
Responses were divided. Different learning styles are often not taken into account, as content is taught in the same way. Class sizes are often a factor. However, some teachers, as a result of training, have become sensitized to different learning styles.

j) *Are teachers in Barbados encouraged to develop an environment that facilitates learning?*
Yes, in theory. However, in practice, resource limitations were cited as a challenge as well as a focus on exam results.

k) *What are your thoughts on problem-based learning and inquiry-based methods of teaching STEM subjects?*
There was overwhelming endorsement for these approaches to teaching STEM subjects. This was seen as important for developing creative and independent thinkers.

l) *Is memorizing and regurgitation the primary form of "learning" that takes place in the STEM disciplines in most classrooms in Barbados?*
Almost all responded yes, that teachers are trained to use this approach and that this practice is exam-driven.

m) *Do teachers know when students are learning, by using proper assessment methods that measure learning?*
Proper assessment methods were seen as lacking in some cases, and overly focused on tests and exams.

n) *How would you feel about a revolutionary new system for Barbados where the focus was first on the student's mastery of the fundamentals? A system in which grades were deemphasized, but in which the tests were used primarily to measure the level of mastery of the material, and the student would have to study, get help, and retake the test until the student reached a sufficient level of proficiency? What do see as the upside and the downside of such a system?*
There was general support for this shift in emphasis. However, resources and time were cited as potential challenges, as well as gaining support and execution of a 'seismic' shift in approach.

o) *To improve the teaching of STEM in our schools, it has been suggested that we need "disruptive innovation". Would you be in favor of providing funding to school Principals to develop and utilize non-traditional teaching and training formats?*
Almost all were in favor. However, implementation questions included support from principals, development of program plans and facilitation of such programs.

p) *At what age should scientific research methods be included in the curriculum as an integral part of the educational process? And why?*
All thought that this should start at an early age – during primary school or even preschool. Tapping into children's natural curiosity was seen as important, as well as integration into students' approaches to problem solving.

q) *Students should start thinking about science and technology from early ages, including how to find and check information and test hypotheses? Is this going on in our schools at the moment? If so, which schools?*
Most responded that this is generally not going on in schools currently.

r) *In your opinion, is science across the education system utilizing scientific methodology and drawing on culturally relevant examples with an aim of generating new scientific knowledge, relevant to the Barbados?*
Most responded no. Teacher training workshops were cited as increasing this approach though.

s) *In your opinion, are we addressing the needs of all students in Barbados (not just those who are considered gifted or who achieve higher grades)? Are there target groups that are being overlooked (e.g., poor, underachieving, etc)?*
Almost all responded that the needs of all students are not being addressed, especially for example those with special education needs, and at-risk youth.

<u>*Curriculum and Teaching Methods – Tertiary Education*</u>

a) *What education reform initiatives would you like to see at the UWI – Cave Hill campus?*
A greater focus on the sciences was advocated. In general, coursework was viewed as too theoretical; more practical applications were recommended, along with opportunities for students to invent.

b) *It has been suggested that the tertiary educational institutions in Barbados re-engineer themselves to play a more critical role in stimulating technology-based innovation and entrepreneurship. What are your thoughts on this idea?*
There was general agreement though how to implement this was seen as a challenge, as well as funding.

c) *It has been suggested that UWI and BCC each set up a Scientific Advisory Board (SAB) consisting of visionary educators and business leaders from Barbados, the wider Caribbean and the Diaspora to help our tertiary institutions re-engineer themselves and to assist with strategic planning and implementation. What do you think of this suggestion? Is outside assistance really needed?*
Generally, this was viewed positively though tapping into local expertise was also suggested. Giving the SAB enough influence was seen as important.

d) *It has been suggested that more collaboration between the universities in the Region and universities and industries in the Diaspora would avoid a re-invention of the wheel and bring much needed expertise into Barbados. If you agree, describe how this would work or give some specific examples.*
This was viewed positively. Specific examples provided included exchange programs for faculty and students, and research collaborations.

e) *How else can we train students today for the jobs of tomorrow, many of which do not exist today?*
Creativity and learning skills were highlighted as key to adapting to the changing needs and opportunities in the work force.

f) *Are tertiary institutions providing enough cutting edge training in STEM? If no, what should be done?*
Responses lacked specifics. One comment was that students were being educated to be employees, not employers.

g) *Should private companies invest in education institutions, be involved in developing curriculum, track students and, later, establish bonds to secure the best students as employees with attractive compensation packages?*
Most agreed that closer ties between education institutions and the private sector were needed to guide curriculum development. Summer internship programs were cited as an example of facilitating interaction between students and companies.

h) *It has been suggested that to accelerate the development of a STEM-based economic pillar, Barbados needs to urgently place more focus on the training of high-technology women and men engineers and scientists to rapidly fill the void. Do you agree, or are we doing OK with the inclusion of women as leaders in the technology sector?*
There was agreement with a focus on source of funds for this training, e.g. from the private sector, and from international grants.

i) *Should Barbados set up a Faculty of Engineering at UWI that offers bachelors, masters and Ph.D. degrees in engineering? If yes, on which disciplines should it focus (electrical, mechanical, civil, optical, chemical, aeronautical, astronautical, environmental, biomedical, software, financial, industrial, etc.)?*
The responses were no, given the Faculty of Engineering at UWI – St. Augustine.

j) *Should Barbados set up a science and technology university (like Trinidad or Jamaica)?*
Most responded no, and instead recommended leveraging existing UWI and community college campuses to accommodate increased curriculum needs.

k) *Some think that a basic entrepreneurial education should complement the STEM education, and should cover basic finance, how to start a business, the various types of capital, intellectual property concepts, how to write proposals and business plans, market place competitiveness, ethics and negotiation skills. Communication skills (listening, written and oral) development are seen as an important part of the basic entrepreneurial curriculum. Most believe that least one foreign language is necessary for today's entrepreneurs. Are we doing anything like this in our schools at the moment? If so, please cite the specifics.*
In general, responders cited inadequate entrepreneurial education in the schools. There was strong support for implementing this at a broad level, starting in the primary schools.

A6. STEM Research

Competitiveness

a) *Do you think the university and the community college are doing sufficient high quality applied research that they can make a significant impact on the economic development of Barbados today or in the near future?*
Responses were negative, and reasons cited included inadequate funding, personnel and infrastructure.

b) *Do you think our university is capable of recruiting and retaining top notch science and engineering talent from anywhere in the world? Please elaborate.*
Responses were negative, and reasons cited included insufficient grant funding, poor research success record, and unstimulating environment.

c) *In Barbados, do we identify and nurture young researchers, and reward science, technology and innovation practitioners? If no, what should be done?*
All responded no. Suggestions included mentorship programs including links with the Diaspora and external institutions, and recognition of excellence and accomplishments.

d) *In developed countries, it seems that there is a correlation between the most highly ranked universities and their contribution to the development of innovative technology products and services. What do you think is the rough numerical ranking of UWI on the world wide university scales? Top 10, top 100 top 300 top 500 top 1000 top 10,000 below 10,000 (circle one)*
Most ranked UWI in the top 1,000.

e) *Should Barbados care or worry about these rankings of its university? If so, why? If not, why?*
The overwhelming majority felt that Barbados should worry about these rankings, since rankings impact ability to attract students, staff and faculty, and since UWI's graduates needs to compete with graduates from top ranked universities.

f) *If you think the rankings are important, what should we do in Barbados to improve the rankings of our university and community college?*
Responders suggested identifying relevant areas and working on improving those areas. Specific areas for improvement included research, teaching, and facilities.

Areas for Focus and Funding

a) *In which research areas should Barbados be investing?*
Renewable energy and agriculture were the most frequently cited areas. Education, tourism, marketing, international business, clinical research, and biomedical research were also mentioned.

b) *As part of its accreditation programme, should the University (faculty and students) be placing greater emphasis on research in response to market demands? From where would such research funds come?*
Challenges in obtaining research funding were cited. Suggested sources of funds included the private sector and international partners.

c) *There was a recent recommendation that Barbados (and other Caribbean countries) set aside about 1 % of GDP (Johannesburg Declaration) for research in science and technology. What do you think of this recommendation?*
Most thought this was a good idea; however, several indicated that this was probably too small of a commitment.

d) *Do the university and community college have a grant coordinator employed to support research funding?*
Yes.

e) *It has also been suggested that the university create technology research centers of excellence in specific thrust areas that are of national interest and that have international recognition. How do we go about attracting world class researchers and equipping these facilities with state-of-the-art equipment, and making them sustainable?*
Funds were seen as critical.

f) *Funding for the R&D centers of excellence and the incubators in the university, and the seed capital needed by the emerging new ventures would have to be supplied jointly by the private sector, the government, NGOs (non-governmental organizations), the international community, and the Diaspora. Are we doing anything like this at the moment? If so, please cite the specifics.*
The issue of overly theoretical programs was raised, in response to this question.

g) *Do you think we have the right technology transfer experts within our universities who can provide business, intellectual property, and commercialization advice and guidance to our students and faculty? Such persons would have the skills to identify potentially interested companies and negotiate deals that would move university research into the private sector.*
Almost all responded no.

A7. Technology-Based Entrepreneurship

General

a) *What is your vision for technology-based entrepreneurship in Barbados?*
There was broad enthusiasm for this as a way forward for the country.

b) *Which technology areas should Barbados focus on and why?*
The most frequently cited areas were renewable energy, agriculture, IT and mobile apps. Biochemistry, marine biology, medical technology, manufacturing, math, physics, robotics, and engineering were also mentioned.

c) *Should the creation of globally competitive technology companies be part of the strategic economic development plan for Barbados or should we focus only on local products and markets?*
Most supported the creation of globally competitive technology companies for foreign exchange, and building international standards.

d) *Are enough technology-based industries being created? If no, what should be done?*
The common response was no and that there is a need for more. Incentives are needed to encourage these industries.

e) *Are there enough technology-based employment opportunities in Barbados? If no, what should be done?*
The consensus response was no.

Regulations – Incentives and Facilitation for New Businesses

a) *In Barbados, is there a need to further promote and grow the entrepreneurial spirit and culture, or are we doing just fine?*
Most responders cited a need to grow and promote the entrepreneurial spirit and culture. Broader support is needed.

b) *In order to create the enabling environment to stimulate technology entrepreneurship, Barbados must develop specific legislation and policies to encourage innovation and new business startups. On a scale of 1 to 10 (10 the highest mark) how is Barbados doing right now?*
All responses indicated that Barbados is not doing well, as reflected by being on the low end of the scale (marks of 1-4).

c) *Do you believe the Barbados Government will be able to create the friendly ecosystem for innovation and entrepreneurship that will be needed to stimulate technology entrepreneurship, or will the civil service sector be forced to continue to read the rule book to entrepreneurs and slow down progress?*
There was general pessimism on this. The suggestion was to implement the right type of performance appraisal with resultant reward/penalty for government staff to act and change the system.

d) *What should the government be doing to reform its agencies to be more efficient, offer faster service and be more responsive to the needs of entrepreneurs?*
Recommendations included changes in attitude, implementation of performance reviews and more e-Government/online transaction systems.

e) *How can we get our legislators to pass new legislation that would remove roadblocks and antiquated laws that are impediments to business formation and put in place legislation that would reward entrepreneurship and start-up business development?*
Lobbying from entrepreneurs and business organizations was suggested, as well as anti-corruption legislation.

Incubators and Mentorship

a) *Do you think government and/or private venture capital institutions should follow Chile and open up business plan competitions to anyone in the world, with the understanding that winners would have to locate their business in Barbados?*
There was strong support for this, for near term benefits such as job creation, as well as long-term benefits,

b) *In Barbados, are university and community college students being encouraged to start their own technology-based business?*
Most responders stated no, that there is not a broad, coordinated approach and more is needed from post-secondary institutions. However, there is an emerging increasing effort to facilitate and encourage students to start their own technology-based business.

c) *It is also thought that we must also provide an avenue for continuing education in business and entrepreneurship principles for those who have already left the school system and need help getting their businesses off the ground, or in making the transition from a prototype to a globally competitive product. Are we doing anything like this at the moment? If so, please cite the specifics.*
Most cited organizations such as BIMAP, UWI Open Campus, Youth Entrepreneurship Scheme, and BYBT for providing continuing education in business and entrepreneurship.

d) *In Barbados, do young entrepreneurs have a place where they can go to learn about intellectual property rights to become aware and appreciative of the significance of ownership of intellectual property (patents, trademarks and copyrights)?*
Most stated no, that lawyers were usually consulted to get advice on IP. This is a key gap.

e) *In Barbados, is there a need for incubation harmonization and mentorship strengthening for entrepreneurs?*
All responded that there is such a need for more mentorship programs.

f) *In Barbados, is the pool of available entrepreneurship mentors large enough? If no, how can we find more mentors?*
All responded that there is an insufficient pool of available mentors in Barbados. The Diaspora and private sector were cited as potential sources of additional mentors.

g) *How would you describe the quality of available entrepreneurship mentors?*
The quality of mentors was generally seen as good; however, there were very few.

h) *There is a lot of talk about science and technology incubators. What should we be doing (more, less, abandon, reorganize, refocus, new management, etc.)?*
The consensus was that more should be done, but that the incubators should be reorganized, and more focused on implementation.

A8. STEM Research

a) *One aspect of promoting an entrepreneurial culture, is to create more access to capital for entrepreneurs. How should we go about doing this in Barbados?*
Recommendations included providing access to early financing options, venture capital, grants and International businesses.

b) *What are some of the innovative ways to build investment capital in Barbados?*
Suggestions included angel investment financing, crowd funding, and special business development funds.

c) *How should Barbados go about helping to significantly expand the venture capital base in Barbados?*
Tax incentives for contributing to venture capital entities and funds, and for angel investors were suggested.

<u>*Sectors for Focus*</u>

a) *Should Barbados forget about high tech and biotech and focus the scarce resources only on skills training? Explain why you agree or disagree.*
Both were seen as needed. Skills training was viewed as essential for supporting high tech and biotech companies. STEM jobs in technology-based companies was viewed as necessary for sustainability.

b) *Do you think it is possible for Barbados to create a strong manufacturing sector that could rival tourism, financial services, and international trade in foreign exchange earnings? If so, how would we get it off the ground?*
Most though this was possible, but would require commitment, foresight and vision. Contract manufacturing partnerships with international firms could facilitate this.

c) *Does creating a biotech industry for Barbados make sense? Please elaborate.*
Most agreed that this would make sense, particularly with a focus on more culturally relevant areas such as fisheries and agriculture. To create such an industry successfully, experienced professionals from the biotech industry would be needed for leadership, and mentorship of local talent.

d) *Do you think it is possible for Barbados to develop a biotechnology industry that could rival tourism, financial services and international trade in earning foreign exchange?*
Most thought this was possible but that it would require major financial investment to build a biotech industry. Low long-term trade costs and location were seen as advantages to be leveraged for Barbados.

A9. Impact of Science and Technology on Government

a) *How are Cabinet members using science and technology to make decisions?*
Most thought that Cabinet members were not currently using S&T to make decisions.

b) *What access do ministers have to science and technology to inform decisions?*
Most responders did not know, but thought that the ministries would have planning/research departments, and employ consultants.

c) *How do cabinet members ensure that they are advised by the best scientists and engineers?*
Responders did not know, but suggested that they establish a high level committee of experts to provide this advice.

d) *Do you think the Government should employ science advisors on a full time basis to be accessible to Cabinet for input on decision making in areas such as international, foreign and national policies?*
Almost all responded yes. It was noted that the Government should be aware of who they could contact for advice. Science advisors were seen as critical if STEM education will be advanced.

e) *How should we go about strengthening the interface between science, technology and innovation and decision making?*
Responses included demonstrating the utility of S&T for decision making, as well as integrating scientists into Government.

APPENDIX B – Town-Hall Style Meetings and Meetings at Offices of Various Stakeholders

Date	In Attendance	Venue
23MAR2015	Director, The Chronic Disease Research Centre (CDRC) Director, The Centre for Resource Management and Environmental Studies, UWI Registrar, Caribbean Examinations Council Principal, Barbados Community College Dr. Samuel Miller, Barbados Community College Principal, Samuel Jackman Prescod Polytechnic Director, Barbados Vocational Training Board Director, TVET Council Dr. Colin Depradine, Dean, Faculty of Science and Technology, UWI Director, National Council of Science and Technology Permanent Secretary, Ministry of Education Principal, Erdiston Teachers Training College Director, The Bellairs Research Institute Principal, Harrison College Principal, St. George Secondary Principal, Caribbean Institute for Meteorology and Hydrology Barbados National Commission for UNESCO Ministry of Education, Science, Technology and Innovation Caribbean Science Foundation	Technical and Vocational Education and Training Council (TVETC)
21MAY2015	Post-Secondary and Tertiary Institutions Key Research Bodies	UWI
22MAY2015	All Primary and Secondary Schools, specifically teachers delivering science education	UWI
28MAY2015	Private Sector Volunteer Members of the Caribbean Science Foundation	Almond Bay Restaurant
29MAY2015	Relevant Government agencies	Ministry of Labour
10AUG2015	Division of Energy and Telecommunications (Prime Minister's Office) Mr. Jehu Wiltshire, Permanent Secretary Mrs. Francine Blackman, Deputy Permanent Secretary Mr. Bryan Haynes, Chief Project Analyst Mr. William Hinds, Chief Energy Conservation Officer.	Trinity Business Centre, Country Road, St. Michael.
12AUG2015	Ministry of Civil Service Mr. Alyson Forte, Permanent Secretary	E. Humphrey Walcott Building, Cnr. Collymore Rock & Culloden Rd, St. Michael
13AUG2015	Ministry of Agriculture, Food, Fisheries and Water Resource Management Mr. Elsworth Reid. Permanent Secretary Ms. Suzette Edey Babb, Chief Research Officer Mr. Farnum, Chief Agricultural Officer	Graeme Hall, Christ Church
13AUG2015	Ministry of Industry, International Business, Commerce and Small Business Development Philmore Best, Permanent Secretary	Reef Road, Fontabelle, St. Michael
18AUG2015	Barbados Coalition of Service Industries	Harbour Industrial Estate, St. Michael

Date	In Attendance	Venue
19AUG2015	Barbados Manufacturers Association	Harbour Industrial Estate
19AUG2015	Barbados Chambers of Commerce and the Barbados Private Sector Trade Team	Deighton Road, St. Michael, Barbados
20AUG2015	Breakfast Meeting with Private Sector Reps	3Ws Pavilion, UWI.
28NOV2015	Hon. Ronald Jones, Minister of Education, Science, Technology and Innovation	Ministry of Education, Science, Technology and Innovation
11FEB2016	Barbados Cabinet	Prime Minister's Office
23MAR2016	STEM Validation Conference	UWI - Cave Hill School of Business

Please note below a list of agencies that were not able to attend the consultations.
Government:

- Ministry of Industry, International Business, Commerce and Small Business Development
- Ministry of Environment and Drainage
- MLSD - representative from MRSU
- Barbados Water Authority

Private Sector:

- Allan Herbert, Chief Information Officer, Massy Group
- Massy Technologies
- Barbados Association Of Energy Professionals
- Barbados Dental Association
- Barbados Institute Of Environmental Professionals
- Barbados Land Surveyors Association
- Barbados Occupational Therapy Association
- Barbados Pharmaceutical Society
- Barbados Veterinary Association
- Barbados Private Sector Association
- Barbados Private Sector Trade Team
- The Banks Holdings Limited
- Mount Gay Distilleries
- Information Society of Barbados
- Sol Petroleum
- Williams Industries
- Lime/Flow Barbados
- Digicel
- Republic Bank
- Insurance Corporation of Barbados
- Scotia Bank

Research agencies:

- Director, The Chronic Disease Research Centre (CDRC), Avalon, Jemmotts Lane, Bridgetown, Barbados
- Director, The Centre for Resource Management and Environmental Studies, The University of the West Indies, Cave Hill Campus, St Michael, Barbados
- Principal, Caribbean Institute for Meteorology and Hydrology, Bridgetown, Barbados

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[7] See the membership of the Governing Council of the Caribbean Science Foundation at http://caribbeanscience.org/governing-council/