J Electroceram (2009) 22:8–12
DOI 10.1007/s10832-008-9417-2

The next generation: Education and broadening participation in science and engineering

Lynnette D. Madsen · Guebre X. Tessema

Received: 4 April 2007 / Accepted: 8 January 2008 / Published online: 29 January 2008

Abstract Attention to the worldwide issues of education and equity would be beneficial for creating the next generation of scientists and engineers. Developing countries, such as Tanzania, have different needs from industrialized countries, such as the USA, however there is considerable overlap as well. A recent National Academy report entitled *Rising Above the Gathering Storm* makes four recommendations for enhancing the science and education enterprise for the USA. The first of these recommendations to "Increase America's talent pool by vastly improving K-12 science and mathematics education" could be applicable to many countries including third-world countries. In general, the issue in the USA circles around how well and how many of American children are receiving quality education educated. In terms of teacher education, incentives are needed to ensure that there are a sufficient number of teachers appropriately trained in their disciplines and in teaching. UTeach, a program at the University of Texas at Austin, is a model program for teacher preparation. The second part of the problem stems from the fact that America is not educating all of its most talented individuals, and the supply of scientists and engineers in the USA is at risk over the long-term due to changing demographics. This report has brought to the forefront the need to educate a broad cross-section of citizens. Women, African Americans, Hispanics, American Indians, Native Alaskans and Pacific Islanders, and persons with disabilities are under-represented in most science and engineering fields. The USA's National Science Foundation (NSF) has a leadership role in addressing these concerns at many levels.

Keywords Broadening participation · Diversity · Inclusiveness · Education · Developing countries · Tanzania · USA

1 Introduction

This topic, education and diversity at the high school level, is an important pipeline for creating the next generation of scientists and engineers, and in the first instance for establishing the pool of university students. This paper was presented at the International Conference on Electroceramics held in Tanzania in 2007. Having the meeting in Africa provided an opportunity to emphasize the importance of pre-university education and the necessity to build more education infrastructure in developing countries, such as, Tanzania. Although it may seem that industrialized nations, such as the USA, have little in common with developing countries, high-school education remains an area of concern in the USA and recently efforts have focused on improving the training of science and math teachers. Gender equity remains a goal for every country and represents a key in achieving a skilled and educated populace. The USA and Tanzania are interesting countries to compare in this regard since they rank 23rd and 24th, respectively, on the Global Gender Gap Report [1].

2 Education as a basis for research

Education serves as the foundation for most research. In the USA, the National Science Foundation (NSF) supports

L. D. Madsen (✉) · G. X. Tessema
National Science Foundation,
Division of Materials Research,
4201 Wilson Blvd.,
Arlington, VA 22230, USA
e-mail: lmadsen@nsf.gov

research and education across a broad range of topics from biology to geosciences to materials (Table 1); other areas, such as agriculture and health, are covered by additional funding agencies.

Similarly, the International Foundation of Science (IFS) supports some of the research efforts in Tanzania (Fig. 1). Most of these topics: e.g., crop science, animal production and food science, have immediate practical impact on Tanzanians everyday life.

However, it is important to keep in mind the broader role that research can play. A vision for research leading to innovation is critical for development and advancement (G. X. Tessema et al. in brainstorming session, University of Texas at Arlington, 2006). It will enable more optimal use of the most critical asset—human capital. The education and training of a future workforce can allow progression through a series of steps from learning the fundamentals and in doing so, mastering the basics of modern science and technology, to developing abilities to deal with greater complexity, advancing scientific knowledge, creating intellectual property, and in turn becoming innovators and competing globally. These comments apply equally well to both the USA and Tanzania. However, Tanzanians may have even better opportunities and advantages in leveraging partnerships, and their gains can be greater as they move from raw material exporters to wealth builders.

3 Education as a financial investment

Economic experts have gone farther and assessed the financial rate of return for education at each level. From a 1999 study by the World Bank, these numbers have been calculated for Tanzania in terms of the benefit for both the country and the families involved (Table 2) [2]. Education is the key producer of cross benefits to family quality, health, nutrition, water quality, etc. More recent studies by the same organization indicate that successful developing countries have much higher rates of return on tertiary education (i.e., completion of a degree at the university or college level or equivalent) than the 1% return previously stated and in comparison to industrialized nations [3]. Among ten of the world's most industrialized countries, relative rewards of tertiary education are greatest in Britain, which gives students a 17% rate of return on their investment [4].

Table 1 NSF-supported areas of research.

Directorates and offices
Mathematical and Physical Sciences
Engineering
Biological Sciences
Computer and Information Science and Engineering
Cyberinfrastructure
Geosciences
Environmental Research & Engineering
Polar Programs
Education and Human Resources
Social, Behavioral and Economic Sciences (SBE)

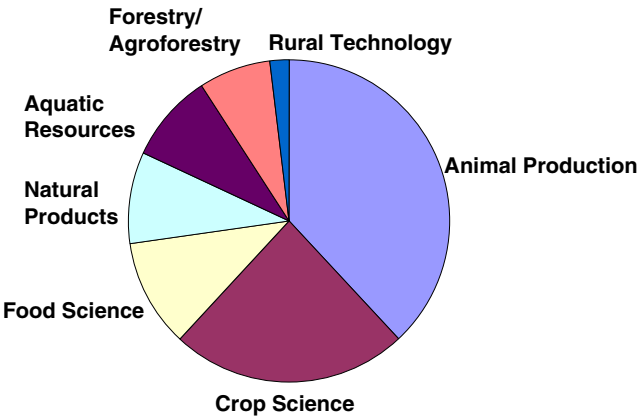

Fig. 1 International Foundation of Science (IFS) Grantees in Tanzania in 2002

4 Rising above a gathering storm

In the USA, 64% of high school graduates go to college; an increase of 17% in the past 30 years [5]. Enrollments are rising for women; however low-income families, Hispanics and Americans of African-descent still lag behind the norms.

Although the USA's overall high school (secondary school) graduation rate is 70%, there are problems in many of the large cities resulting in 14 cities with graduation rates below 50% [6]. During recent years, Tanzania, a country of ~38 million people, has undergone a change in philosophy regarding education that has resulted in dramatic increases in the percentage of children completing both primary and secondary school (Table 3; e.g., World Fact Book [www], The World Bank: International Development Association [IDA; www] and Country Reportson Human Rights Practices,

Table 2 Rates of return on education in Tanzania.

Education	Rate of return for country (%)	Rate of return for family (%)
University level (Tertiary)	1	28
High (secondary) school	18	27
Primary school	24	41

Table 3 Education levels in Tanzania.

Education	1993 (%)	2006 (%)
University level participation	–	1.2
High (secondary) school completion	7	33
Primary school completion	<29	62

http:www//.state.gov/g/drl/rls/hrrpt/2006/78761.htm [2006] and http://www.sussex.ac.uk/education/1-4-25-7-6.html). With this change (to 33%), Tanzania has surpassed the high school graduate rate in Detroit (at only 29%) and is nearly on par with Baltimore and New York City. The combined population of these three cities (Detroit, Baltimore and New York) is approximately ten million people, not insignificant (Wikipedia 2006).

Bill Gates expressed his concern in 2005 in an unambiguous way, "America's high schools are obsolete. By obsolete, I don't just mean that our high schools are broken, flawed, and under-funded—though a case could be made for every one of those points. By obsolete, I mean that our high schools—even when they're working exactly as designed—cannot teach our kids what they need to know today…This isn't an accident or a flaw in the system; it is the system" [7].

The National Academies, a group of four organizations, brings together committees of experts in all areas of scientific and technological endeavor to address critical national issues and give advice to the federal government and the public (http://www.nationalacademies.org/). A committee focused on the USA prospering in the global economy of the twenty-first century produced a report entitled, "Rising Above The Gathering Storm" in 2005 [8]. Recommendations were made in four areas; one area focuses on K-12 science and mathematics education with a strong message to improve the number and quality of high school teachers.

5 UTeach

UTeach, a collaborative program of the Colleges of Natural Sciences and Education that prepares and supports secondary mathematics, science, and computer science teachers at UT Austin (http://www.uteach.utexas.edu/), is explicitly mentioned as a model in the academy report. It has been expanding nationally and with the help of ExxonMobil (to the tune of $125 million), it is anticipated that this rate of expansion will accelerate in the coming years (http://www.exxonmobil.com/Corporate/Citizenship/gcr_education_nmsi.asp).

It would be remiss not to mention the support that NSF provided to UTeach in its early days through to today (NSF grants: 9953187 Teacher Preparation Program, 0334811 Robert Noyce Scholarships and 0630376 Robert Noyce Scholarships [Phase II]). However, it is more than funding according to Michael Marder, co-director of UTeach, "NSF also played a crucial role in putting us in touch with the national community of teacher preparation entities."

UTeach is the largest teacher preparation program in Texas and is now producing ~70 to 75 mathematic and science teachers (in roughly equal numbers) annually [9]. A key factor in their program is to test early-on their participants' interest in actual teaching. As a result of this weeding process, the retention rate for UTeach graduates who are teaching surpasses that of the national average [10]. UTeach has expanded from a pilot project with 28 students in 1997 to a high-profile, well-respected program with an enrollment of more than 400 in just 10 years.

A wealth of information is contained on the UTeach website; herein, the elements of success are briefly described: (1) Create an organization, an academic program with sense of identity, to prepare teachers, (2) get support from university officials and administrators to ensure budget, space and staff that are adequate and continuous, (3) attract and retain top students to become teachers through a variety of means (financial support, recognition, guidance, etc.), (4) create an instructional program (4 years in duration with standards, early field experiences, mentor feedback, flexible program entry, etc.), (5) provide first rate instruction, and (6) make improvements to the program continuously.

6 Broadening participation

In the State of Texas, the numbers of student grades, and in turn college readiness, are directly correlated to economic wealth in the schools (Fig. 2). Hispanics and Americans of African-descent are underrepresented in the wealthy schools and overall in the USA they have less than a 50/50 chance of graduating from high school [11].

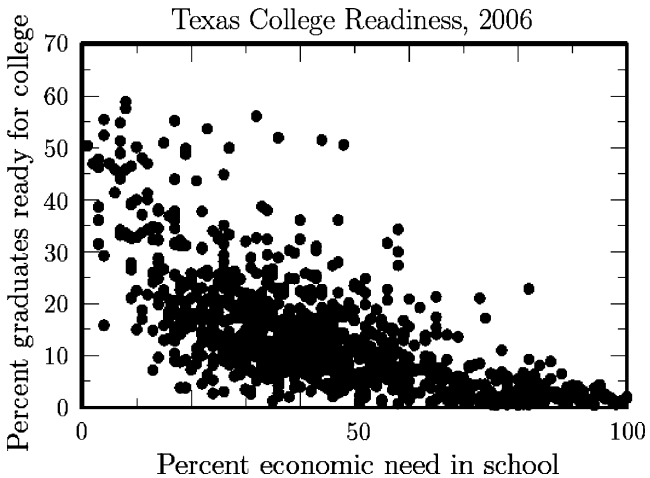

Fig. 2 College readiness in Texas is correlated to economic need in the school. Credit: Michael P. Marder, University of Texas at Austin

The lack of equity in education (and several other areas) does not end there, as the Global Gender Gap Report released in 2006 indicates. This report states, "No country in the world has yet managed to eliminate the gender gap." The report includes data from 115 countries which accounts for 90% of the population (Table 4). A strongly positive correlation between equality and global competitiveness is evident.

The authors measured inequality for four critical categories: (1) economic participation and opportunity (salaries, participation in high-level jobs), (2) educational attainment, (3) political empowerment and (4) health and survival (life expectancy). "The country comparisons are meant to serve a dual purpose: as a benchmark to identify existing strengths and weaknesses; and as a useful guide for policy, based on learning from the experiences of those countries that have had greater success in promoting the equality of women and men" [1].

This report allows for the direct comparison between countries, since differences between gender, rather than overall levels are measured. One can readily see that Tanzania outranks the USA on two sub-indices: Economic Participation and Opportunity, and Political Empowerment, whereas the reverse is true for Educational Attainment, and Health and Survival (Appendix). Both have plenty of room to improve in terms of educational attainment.

7 NSF's role in teacher preparation

NSF supports NSF-wide, directorate and division specific activities aimed at improving teacher preparation, increasing use of high technology, encouraging new teachers, and providing teachers with research experiences (Table 5). NSF sponsors the Presidential Awards for Excellence in Mathematics and Science Teaching (PAEMST) Program established by The White House. This program identifies outstanding mathematics and science teachers, kindergarten through twelfth grade, in each state and the four USA jurisdictions. These teachers serve as models for their colleagues and are leaders in the improvement of science and mathematics education. Since 1983 more than 3,000 teachers have been selected as Presidential Awardees (http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=12802).

Table 4 Selected rankings from the global Gender Gap Report 2006.

Country (total of 115)	Overall ranking
Sweden	1
Norway	2
Finland	3
Iceland	4
Canada	14
South Africa	18
USA	23
Tanzania	24
Jamaica	25
Switzerland	26
Pakistan	112
Chad	113
Saudi Arabia	114
Yemen	115

Table 5 Sampling of NSF programs that support teachers.

NSF programs
Information Technology Experiences for Students and Teachers (ITEST) 07-154
Geoscience Teacher Training (GEO-Teach) 06-526
Math and Science Partnership (MSP) 06-539
Robert Noyce Scholarship 07-529
NSF Graduate Teaching Fellows in K-12 Education (GK-12) 07-555
Research Experience for Teachers (RET)
Presidential Awards for Excellence in Mathematics and Science Teaching (PAEMST) 04-578

8 NSF's role in equity issues

NSF has a multi-faceted approach to equity. Research on gender issues in science and engineering is supported (http://www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf07501). Solicitations seek to increase the number of students successfully completing quality university-level degree programs in science, technology, engineering and mathematics (STEM) [12]. Minority-serving institutions [13, 14] and underrepresented groups [15–18] are provided with additional opportunities for funding. As well, models of excellence have been fostered [19, 20]. One program specifically seeks to enhance diversity by stimulating the development of formal, long-term, collaborative research and education partnerships [21]. NSF also has a website that provides a sampling of information that may help Principal Investigators and others in broadening participation in their activities [22].

Acknowledgements The authors thank Prof. Nava Setter for her invite and encouraging comments, and also for arranging the entire meeting and this session in the lovely setting of Tanzania. Prof. Michael Marder is thanked for his data and many interesting conversations about teacher preparation.

Appendix

Comparison of the USA and Tanzania in terms of Gender Equity

Three basic concepts underlie the Gender Gap Index 2006.1 "First, it focuses on measuring gaps rather than levels" [1].

Second, it captures gaps in outcomes rather than gaps in means or inputs. Third, it ranks countries according to gender equality, not women's empowerment. The USA falls behind many European nations in addition to lagging behind Canada. Twenty-three sub-Saharan African countries were included in this study; they exhibit a range of performances. Tanzania is slightly behind the regional leader, South Africa. Whereas, Mauritania, Benin and Chad are all near the bottom of the rankings.

The ranking for each country included in this study were determined using four categories. For the economic participation and opportunity category, three concepts were captured: the participation gap, the remuneration gap and the advancement gap. Tanzania has the narrowest economic gap between women and men, and thus holds the top spot among the 115 countries on this category. The USA also does well here with third spot.

In the educational attainment category, the gap between women and men's current access to education is captured through ratios of women to men in primary-, secondary- and tertiary-level education. "A longer-term view of the country's ability to educate women and men in equal numbers is captured through the ratio of the female literacy rate to the male literacy rate" [11]. The USA has a slightly lower rate of enrollment at the primary school level for girls than for boys, which causes a dramatic drop in its score on this category (rank of 66). Tanzania on the other hand, has equity at the primary school level, but falls short on the other parameters, putting it near the bottom at 97th.

In the category, health and survival, two factors are taken into account. One, the gap between women's and men's healthy life expectancy, which provides an estimate of the number of years that women and men can expect to live in good health by taking into account the years lost to violence, disease, malnutrition or other relevant factors. The second factor is the sex ratio at birth specifically to capture the phenomenon of "missing women" prevalent in many countries with strong son preference. The USA shares the number 1 spot in this category with 33 other countries. In Tanzania, the life expectancy for women is below the norm, putting it 95th.

Political empowerment mainly measures of the gap between men and women in political decision-making at the highest levels. This concept is captured through the ratio of women to men in minister-level positions and the ratio of women to men in parliamentary positions. In addition, the ratio of women to men in terms of years in executive office (prime minister or president) in the last 50 years was included. The USA has average scores on political empowerment, ranking 66th in this category, since it has only 15% women in parliamentary positions, 14% in minister-level positions and no history of female leadership in the executive office. Tanzania is similar, but with 30% women in parliamentary positions and so it ranks much higher at 26th. "The rate of increase of the numbers of women in parliament has been faster in sub-Saharan Africa in the last 40 years than in any other region of the world" [1].

References

1. R. Hausmann, L.D. Tyson, S. Zahidi, *Global Gender Gap Report*. World Econ Forum (2006)
2. World Bank Tanzania, *Social Sector Review, World Bank Country Study* (World Bank, 1999)
3. World Bank, *Knowledge Societies: New Challenges for Tertiary Education* (World Bank, 2002)
4. Organization for Economic Cooperation and Development, *Education at a Glance* (Organization for Economic Cooperation and Development, 2002)
5. NSF, *Science and Engineering Indicators* (NSF, 2006)
6. G. Toppo, Big-city schools struggle with graduation rates. USA Today (June 20, 2006)
7. NSF, *America's Pressing Challenge—Building a Stronger Foundation, NSF National Science Board Report* (NSF, 2006). http://www.nsf.gov/statistics/nsb0602/
8. National Academies, *Rising Above The Gathering Storm: Energizing and Employing America for a Brighter Economic Future* (National Academies, 2005)
9. M.P. Marder, *UTeach*. Presented to Division of Materials Research at National Science Foundation (Mar. 15, 2007)
10. M.P. Marder, *Testimony before House Committee on Appropriations* (Mar. 9, 2004)
11. G. Orfield, C. Lee, *Brown at 50: King's dream or the Plessy nightmare*, in *Civil Rights Project at Harvard University (2004), Minorities have '50–50' Chance of Graduating High School, Black Issues in Higher Education* (March 25, 2004)
12. *Alliances for Broadening Participation in STEM*: http://www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf07566
13. *Tribal Colleges and Universities Program*. http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5483&org=HRD&from=home
14. *Historically Black Colleges and Universities Undergraduate Program*. http://www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf06606
15. *Minority Postdoctoral Research Fellowships and Supporting Activities*. http://www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf06586
16. *Broadening Participation in Computing*. http://www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf07548
17. *Research Initiation Grants and Career Advancement Awards to Broaden Participation in Biology*. http://www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf07560
18. *Opportunities for Enhancing Diversity in the Geosciences*. http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=12726
19. *Model Institutions for Excellence—Phase III (MIE-III)*. http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5739&org=HRD&from=home
20. *ADVANCE: Increasing the Participation and Advancement of Women in Academic Science and Engineering Careers*. http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5383&org=HRD
21. *Partnerships for Research and Education in Materials (PREM)*: http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5439
22. *Broadening Participation for Greater Diversity*. http://www.nsf.gov/mps/dmr/diversity.jsp