Nanotechnology – A path forward for developing nations

S Ismat Shah1,2 and Thomas M. Powers3, 4

1Physics and Astronomy, University of Delaware, Newark, DE 19716, USA.
2Materials Science and Engineering, University of Delaware, Newark, DE 19716, USA.
3Philosophy, University of Delaware, Newark, DE 19716, US
4Public Policy and Administration, University of Delaware, Newark, DE 19716, USA.

E-mail: Ismat@udel.edu

Abstract. One of the major issues with technology in general, and nanotechnology in particular, is that it could exacerbate the divide between developed and developing nations. If the benefits of the research do not flow beyond the national and geographical borders of the traditional major bastions of R&D, these benefits will not be equally and globally available. The consequence is that the technological divide becomes wider at the expense of mutual reliance. As much as developed nations need to rethink the strategy and the policy to bring nanotechnology products to market with the goal of global prosperity, developing nations cannot afford to simply wait for the lead from the developed nations. In the spirit of collaboration and collegiality, we describe issues with the current practices in nanotechnology R&D in the developing world and suggest a path for nanotechnology research in energy, water and the environment that developing nations could follow in order to become contributors rather than simply consumers.

Several decades have passed since nanotechnology was introduced to the world of scientific inquiry. What is now being called a new industrial revolution has changed the paradigm in scientific research and industrial production. Perhaps the transition from science to production was easy for nanotechnology due to the fact that examples of it existed for a long time before being designated by that term. No matter what the reason, we now see over 1,600 nanotechnology-based products in the market [1]. Predictions of a 1 trillion $USD market by 2015 for all nanomaterials-dependent products appear to be on track [2].

This revolution, nevertheless, is yet to make its impact on the majority of the population of the world that lives in the developing nations. The scientific organizations and the governments in these countries, unable to put in the mammoth amount of investment required for industrial-scale nanotechnology research, development and production, are still standing by to benefit from the trickle-down effects of this revolution. There are small efforts, with minimal investment, to get the research started at the least, and there are some success stories. However, there is a reasonable fear that, just as with the IT bubble, most of these developing nations will be unable to get a piece of the pie and the nanotechnology revolution will also pass them by. These nations will eventually become consumers rather than producers of the nanotechnology products and processes, making them even more dependent on technologies developed by the industrialized nations.
The good news is that as much as the nanotechnology revolution seems to be advanced in some regions of the world, there is still “plenty of room at the bottom” for everyone to participate—to engage in collaborative research, aid with user-centric design of products, and make other significant contributions. If there is a serious effort invested in becoming a part of this development, no matter how small their economies are, these countries can still become participants rather than mere consumers of the nanotechnology. This paper describes a path which could allow a healthy participation of these countries as contributors to the developments in nanotechnology. The path prescribed does not merely sketch one of many possible ways to achieve technological relevance, it also takes into account the sociological and ethical challenges that nanotechnology brings with it to help select the best path. As such, this methodology might be more sustainable than what is currently being followed by the industrialized nations with the old “producer-consumer” model. Inclusion of developing nations in the growth of nanotechnology will be necessary to complete a genuine revolution, since a large portion of humanity resides in these countries. In the top 11 most populous countries, 7 countries have GDP per capita of $5000 or less with the only exception being China at $9800. Together, these 7 countries have a combined population of close to 3.5 billion, almost half of the world’s population.

**Table 1:** Richard Smalley’s list of global concerns and the modified list for developing nations.

| Richard Smalley’s List | List for the Developing Nations |
|------------------------|--------------------------------|
| Energy                 | Poverty                        |
| Water                  | Education                      |
| Food                   | Water                          |
| Environment            | Health (Disease)               |
| Poverty                | Energy                         |
| Terrorism and War      | Food                           |
| Disease                | Political Stability            |
| Education              | Environment                    |
| Democracy              | Shelter                        |
| Population             | Population                     |

**Table 2:** List of UN Millennium Development Goals

The big question for developing-world participation is that of the prioritization of the several areas in which work is still to be done. Professor Smalley’s list of top ten global concerns is a good
guideline but it may not completely fit the needs and requirements of developing nations [3]. A slight realignment of the priorities is warranted. Table 1 shows Professor Smalley’s list and the modified list for the developing nations. The modified list aligns well with the UN millennium development goals displayed in Table 2. Since this article is focused on the research and technological development in nanotechnology, we will skip past the poverty and education concerns and selectively concentrate on Water, Energy and the Environment. It is to be noted that many of these issues need to be further aligned at the regional level. A region may have enough potable water but few energy resources and vice-versa, so the area-relevant identification of issues and appropriate solutions should be sought.

**Water:** Perhaps the most important area of interest is the availability of potable water. The earth’s hydrological cycle works with a fixed amount of water that is constantly re-circulated. With the rapid increase in world population comes the consequential decrease in the amount of water per capita. Additionally, there are industrial and agricultural practices that emanate from the ever-increasing demand for materials and food that further reduce the availability of and access to water due to inevitable pollution.

Nanotechnology presents several pathways to address the availability, purification, and treatment of water. Most of these methodologies and materials are relatively cheap to develop and implement and range from materials and devices that adsorb water from the atmosphere, to reverse osmosis, ceramic based nanofilters, and visible light photocatalysis. The research mostly involves materials and processes that are relatively inexpensive and could easily be undertaken by research communities in the developing nations and be applied in those same nations with close attention to resources, needs, and existing infrastructure.

**Energy:** One of the main reasons that a country is counted as a developing nation is that it does not have many internal resources, particularly energy resources. Since all major economic sectors—especially industry, transportation, and agriculture—rely heavily on energy, the energy needs of developing nations often dominate their foreign exchange expenditure, using up capital that could be more fruitful for education and research. There are several possibilities related to nanotechnology-based research and development in energy, but most are dependent on solar energy, including photovoltaics, biomass, and wind. Although there are high returns and many investment options for R&D in this field, the cheaper alternatives are also plentifully available. Polymer based solar cells, for example, are a much cheaper alternative to the currently dominating Si based solar cells but suffer from a lack of durability. This area of research is completely open. Developing nations especially near the equator could take advantage of new solar energy technologies.

**Environment:** Due to their general lack of environmental regulations, most developing nations suffer from water and air pollution that exacerbate public health problems. There are numerous opportunities for R&D in the area of environmental remediation, and nanotechnology could provide cheap and scalable alternatives. An example is photocatalysis in which solar energy is used by nanoparticles of titania to mineralize some of the environmental pollutant.

In all these discussions, we have only considered technological solutions to alleviate some of the concerns relevant to people living in developing countries. This approach has historically been proven inadequate. Here are some of the reasons why.

1. **Complete dependency on technological solutions to the problems:** It has historically been the case that we have sought answers to the energy, water and environmental problems from the stewards of science and technology. In such endeavors only natural scientists and engineers are involved, which limits our capacity to solve the problem. Thinkers such as E.F. Schumacher have drawn attention to the folly of seeking all solutions from technology, when it has also been the source of the problems one is trying to solve [4]. Since the magnitude of many problems has
become immense, it will be shortsighted if we continue to go to the same well of science and technology that provided us with stop-gap solutions in the past. The magnitude of problems calls for a multifaceted cross-disciplinary approach that includes humanities and social sciences in addition to the natural science. Some of the problems have roots in social structures that the natural scientists are incapable of factoring into their formulae. This necessitates involvement of other scholarly fields, practitioners, and policy experts.

2. Inappropriate fixes that do not take into account developmental realities: Purely scientific solutions do not consider geographical and socioeconomic constraints. A good example is solar cells in off-grid applications—often, villages and far-flung communities, typically poor and of low economic standing. Most of these places have limited energy availability and little access to water as well. Solar cell panels in these communities, say in Sub-Saharan and North Africa, and in Central Asia, have to be kept clean for efficient power production. A 10 micron dust coating on the solar cells reduces the efficiency of the cells by 1% [5]. These are the places where rain is scarce. Therefore, a simple solar cell might not be a viable solution for these areas. Also, purely scientific solutions are unrestricted by economic realities. Nanosilver-based materials for antibacterial applications are abundantly available elsewhere but totally economically unfeasible in most developing countries.

3. Diverting resources from bigger problems: Unless the social and economic priorities in development are fully analyzed and recognized, there is a danger of wastefully using limited resources. The socioeconomic structure of a region determines what it needs. Science and technology are generally unencumbered by these realities. Inappropriately large investments are made in areas of scientific research that do not yield solutions to more mundane issues that affect the majority of the population. When widespread problems are neglected, while niche problems are addressed with expensive technology, social divisions can grow.”

4. The excitement of new technology overshadows other issues: This is perhaps the most troublesome aspect of rapid development of technology, particularly nanotechnology, when the science and technology, for reasons of competition, ownership, profits, etc., leave behind other more important concerns. Environmental and ethical issues become secondary, and sometime not even a consideration at all. Safety is intentionally or unintentionally sacrificed. Progress becomes synonymous with taking chances.

Under these considerations and concerns, what path should a developing nation follow so that it is not left behind in the “scientific revolution” but still does not sacrifice the health and safety of its population and its economy? There are pathways that could make the journey successful once a commitment is made to the general betterment of all its people. A nation so committed may find some of the following practices useful for effective and conscientious progress.

1. Shared Resources

There are not enough resources for each developing nation to work in isolation, therefore it is absolutely necessary that these resources are efficiently utilized and shared. One way is to form small consortia and scientific partnerships, perhaps at the small provincial level up to a larger multi-national level. Instead of individual research teams, multi-user regional centers can be formed where interdisciplinary teams can utilize a single facility to view problems from various angles simultaneously. Sharing not only reduces redundancy and increases efficiency, it also provides added opportunities for collaborations and cross-disciplinary approaches to problem solving.

2. Research for the Community

As much as “science for science’s sake” is a valid motto, its applicability under constrained economic capability is restricted. There has to be proportionality between the efforts of science and education and technology and application. Academic institutions that train students with undergraduate and post-graduate degrees have an obligation to both the academy and society in general. While preparing experts for the next generation, institutions ought to focus on technological solutions and the needs of the next generation. A “best fit for the future” is achieved not just by involving technocrats but also through an alliance of the
STEM workforce with those humanists and social scientists who understand and help to shape society. In many developing areas, religious values are of utmost importance to people and that should be a consideration in the design and manufacturing of materials. Nanotechnology particularly brings into sight applications that tread near religious, social and cultural boundaries and at times seem to cross them. A sensitivity of the local customs and traditions, religious or social, might reduce alienation of a group of potential contributors and participants.

3. **Collaboration between Developed and Developing Worlds**

There is an undeniable interdependence between these worlds but the interdependence has to grow away from the old “producer-consumer” model. There have to be shared values for doing science and technology for a better world for all humanity. The developed world enjoys a wonderful academic system that is available for use by the developing world. This starting point for expansion should be utilized by the current academics in developing regions who have appropriate knowledge of local needs.

4. **Academia – Government – Industry Collaboration**

Academia, government, and industry have to collaborate in deciding the path forward and identifying areas of research and development to pursue. This is particularly important for nanotechnology due to its potential to challenge policy and regulatory guidelines. Since new policies will probably be required in dealing with these new materials, pre-emptive measures could reduce or remove tragic outcomes, like asbestosis. Governments and regulatory bodies are vitally important in keeping the consequences of nanotechnology in check as it spreads from industry to household. Industry, in its own way, holds the key for recognition of the potential of the technology and to take action for responsible development of products from new research. Academia is the link between the government and industry that not only provides for scientific discovery and innovation, it also provides proper training for the workforce in terms of ethics, social responsibility, health and safety. Academia also interacts with government to develop policies based on the social, economic and scientific expertise that is uniquely and simultaneously available at the academic institutions.

In as much as all the arguments listed in this essay are equally applicable to any new technology that comes into the picture, there are specific issues related to nanotechnology that make the exercise of going through all of these points very important, particularly for developing economies. The small size of nanoparticles requires visualization tools that are very specific and expensive, including transmission electron microscopes and atomic force microscopes. Therefore, availability of these instruments for researchers in the developing world becomes difficult. A regional facility could solve some of that problem. The small size of applications may eventually bring into question ethical issues related to surveillance and therefore to privacy. Thus, close regulation by governments concerning the appropriate uses of these technologies is imperative. The small size of nanomaterials warrants attention to health and exposure, since general protections, natural and artificial, fail to perform at this size level. Attention requires awareness, education, and research in areas that have so far not been needed for safe development of technologies based on bulk materials. There are some lessons learned already; the developing nations do not have to commit the same mistakes. The risk of failure in these developing nations in much larger due to very limited resources, but the potential for benefit from conscientious participation in appropriate nanotechnology development is almost unlimited.

**References**

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