Innovative low cost technologies for biomedical research and diagnosis in developing countries

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The relation between science, technology, and economic development is unquestionable. However, in the poorest countries of the world, this relation is tenuous at best, mainly due to the fact that science and technology typically require a large amount of investment in terms of both capital and higher education. In this article, we document the ingenuity and innovative approaches of our colleagues in developing countries who conduct biomedical research and laboratory diagnosis with limited resources. Not only is what they have achieved laudable, but there is much that the rest of the world can and should learn from these examples.

Summary points

Researchers in the developed world can learn much from the ingenuity and passion of colleagues in developing countries

Working in resource poor settings fosters creativity and a mindset for conservation and better management of resources

Understanding the underlying biochemistry of new technologies is essential for sustainable implementation

Research and technological development must be integrated into the fabric of the culture and must cater to local interests and needs

Adapting and innovating

The lack of resources in academic and state laboratories in the developing world produces a creative pressure that forces scientists to invent and reuse as much as possible. The innovations range from substitute equipment, recycling of otherwise disposable materials, and adaptation of cell lines to new temperatures or growth media to simplification of protocols and production of home made kits and reagents.[1–6] For example, plastic pipette tips, consumed in large quantities and usually disposed of after one use, can be reused for certain procedures after disinfection and extensive washing. To make the process more efficient and less expensive, an ingenious Bolivian researcher, Nataniel Mamani, created a tip washer from a plastic jar and inner tubing. The tips fit perfectly into the tubing, allowing water to pass through and effectively wash out the bleach and soap used to clean them (fig 1).[7] This simple contraption can save a laboratory hundreds of dollars a month.

Fig 1 Mamani's pipette tip washer: economic and effective

Simple technological adaptations have a major effect on the everyday operations of a research or diagnostics laboratory in developing countries. Why invest thousands of dollars in a microcentrifuge if you can create one out of a blender and an aluminium bowl?[7] Or buy a fancy lab shaker when a revamped record player will do?[7] Or purchase a transilluminator if you can build your own from a makeshift box and an ultraviolet light bulb?[7] Throughout Latin America, computer scanners have replaced sophisticated photo documentation systems. Simple cocktail party ice crushers substitute for expensive crushed ice machines and solve the constant need for ice.

Since no specialised repair services exist, laboratory staff learn how equipment works and how to fix and calibrate laboratory devices. These are valuable skills not only in developing countries but throughout the scientific world.

Another simple but common adaptation is to use everyday household jars instead of expensive specialised glassware for procedures such as bacterial and cell culture, in vitro plant propagation, and preparation and storage of solutions. Thus, an olive jar or a miniature liquor bottle is transformed into a sterile tissue culture flask. Though far from ideal, the "candle in the bell jar" trick to create carbon dioxide is still used for the culture of certain cell lines.

In-house kits

Reagents as well as consumable supplies can be substituted by simpler variants. Academic and biotechnology

Respondents who contributed to the article through completing a questionnaire are listed on bmj.com laboratories in the United States and Europe are becoming increasingly dependent on kits that call for mysterious reagents from specialised vendors. Although this practice has greatly facilitated experiments, it has also taken away an important element of the scientific method, which is to understand each step of a process in order to comprehend the whole. Breaking down a technique into its component parts also allows more effective troubleshooting when things don't work as expected.

Laboratories in the developing world do, however, use some kits. Often, once a protocol has been established, scientists generate their own reagents from which they produce kits. In Nicaragua, for example, the national reference laboratory of the Ministry of Health adapted an enzyme linked immunosorbent assay (ELISA) kit for diagnosing dengue fever. By shortening incubation periods and generating their own reagents, they reduced the time required for diagnosis from 3 days to 4 hours.[8] Finally, they produced and packaged their own kit, which is distributed and used in laboratories throughout the country. Direct comparisons showed that the kit performed better than others used in the region (A Balmaseda, personal communication). Conversely, commercial kits are often "dissected" and replaced with the individual reagents to make the process less costly.

Challenges

Innovative scientific approaches have become all the more essential recently. Tightening of regulations regarding the transport of certain materials and reagents and the restrictions on travel of collaborators to and from the United States has left many scientists feeling more isolated than ever. Researchers have had to re-invent the way they work. Radioactive materials, for instance, are almost impossible to import into several countries in Latin America; thus, protocols have been adapted for colorimetric or chemiluminescence detection reagents. To keep their work moving forward, scientists rely on friends and collaborators who bring with them small amounts of precious reagents and supplies that can no longer be shipped.

In certain instances, facilities have had to halt their production altogether. A Costa Rican university's oligonucleotide facility could no longer continue its operations because importing some of the essential chemicals is now forbidden. Simple chemicals such as phenol and chloroform, so essential for a molecular biology laboratory, are nearly impossible to obtain through local distributors. This causes an increased dependence on the developed world for reagents and a loss of time and resources, slowing down the advances of many research endeavours.

Despite the increasing difficulties, many groups in less scientifically developed countries still perform high quality research or diagnosis and fulfil the needs of their communities. By using low-cost technologies and adaptations of existing procedures (fig 2), they can produce quality results. One advantage for scientists in developing countries is that they have access to a rich source of primary materials and specimens and great biodiversity, including unique species. Provided that they can continue to spearhead the research in the areas they have mastered and create partnerships with laboratories in developed countries to help them with reagent bottlenecks, they will continue to contribute to the overall body of scientific knowledge and will help solve locally relevant problems.

Fig 2 Loading DNA samples for electrophoresis using Parafilm on a makeshift rack to remove mineral oil after polymerase chain reaction

Eugenia del Pino, a developmental biologist in Quito, Ecuador, manages to publish in internationally renowned journals and is recognised as a leading scientist in her field, despite the resource constraints. She emphasises that from her experience, "in the South, one has to be conservative and efficient in carrying out experiments. One must carefully plan them, thinking through all the options. As supplies and reagents are expensive and extremely difficult to obtain, one only prepares the exact amount needed for the assay." This practice results in less waste and decreased discharge of toxic chemicals into the environment, with the added benefit that experiments often work the first time around due to careful experimental design. Again, there is much to be learnt from this approach the world over.

Role of present and future technologies in a globalised world

Fortunately, many technologies that started off as prohibitively expensive are now affordable and are being implemented in many laboratories throughout the world. Take the polymerase chain reaction. Whereas 15 years ago, it was costly and high tech, most research laboratories in developing countries now have access to this technology.[7] Some laboratories produce their own enzymes and share equipment and resources. However, real-time polymerase chain reaction has now become the standard for many procedures., but the machines and probes required for this technique are still too expensive for most laboratories. Thus, scientists trying to publish results generated with lower cost technologies are at a disadvantage because many peer reviewers will accept only more sophisticated techniques.

Countries in developing areas of the world have vastly different levels of scientific proficiency and technological advancement. For instance, Brazil, Mexico, Argentina, Cuba, India, China, and Singapore are highly developed scientifically and are largely self sufficient in terms of training, reagents, and equipment.

Organisations developing low cost technologies

Program for Appropriate Technology in Health (www.path.org)

Special Programme for Research and Training in Tropical Diseases (www.who.int/tdr/)

Bill and Melinda Gates Foundation (www.gatesfoundation.org)

Foundation for Innovative New Diagnostics (www.finddiagnostics.org)

Sustainable Sciences Institute (www.ssilink.org)

Smaller and poorer countries with little national investment in technology are more dependent on the developed world and are often more scientifically isolated.[9 10]

Yet, scientists everywhere feel the pressure to implement the newest technologies. For example, the current "buzz" about genomics, proteomics, and DNA chips creates an artificial need for their implementation in settings where they might not be appropriate. The technology is changing so fast that a major investment now can be obsolete in a few years. For smaller countries, a more reasonable strategy could be to outsource samples through collaborators until the technology stabilises. Resources can instead be invested in better computers, broadband access, and software to allow for efficient data analysis, bioinformatics, and data mining, as well as in classic technologies and standard equipment.

In some respects, the future looks promising for researchers, physicians, and patients in the developing world. New tools are being created with global applicability in mind—for example, the recent Grand Challenges in Global Health Initiative.[11] Low cost technologies for genetic research are being adapted into generic tools appropriate for healthcare applications, such as diagnosis and monitoring treatment, and these will help shift medical practice from treatment to cost effective screening and intervention. Other applications include cost effective diagnosis of diseases in plants and animals using rapid and cheaper bioassay technologies. For instance, lab-on-a-chip technology promises instant diagnosis of bacterial or viral infections, resulting in more targeted treatments.[12-14] These assays transfer the complexity of large scale laboratories on to minute computer chips and take advantage of volume manufacturing to reduce cost.

Conclusions

The luxuries of high tech research should not be taken for granted. The efficiency and flexibility of our colleagues in developing countries, as well as the conservation and reduced environmental impact demonstrated in their work, provide important lessons for the developed world. We all can be inspired by the ingenuity and passion of many researchers in less privileged settings, as they conduct science to benefit both their discipline and their communities.

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