33rd Annual International Conference of the IEEE EMBS
Boston, Massachusetts USA, August 30 - September 3, 2011

The Dilemma of BME Research Projects in Developing Countries: a Case Study

Edmond Zahedi, *Senior Member, IEEE,* Hamid Movahedian Attar

***Abstract*— Researchers are faced with huge challenges when undertaking BME research projects in developing countries. Various administrative, technical, economic and even cultural barriers have to be overcome whereas the quality and quantity of the output has to be comparable with the developed world in order to make results publishable. This paper uses a real project context to highlight the major problems and the necessity of a holistic approach which would take into consideration all stakeholders interests. It is only by tackling problems such as relationship between academia-industry and administration efficiency at their root that significant progress can be achieved.**

I. Introduction

In a short video clip from IEEE EMBS [1], engineer after engineer projects the viewer in a world where one is “thrilled by patients thanking her” for what they have achieved, and “one is doing good when practicing BME”. In another quote, Wilson Greatbatch, the famous inventor of the pacemaker, sends the following transcendental message: “I don't think that the good Lord cares whether you succeed or fail, but I think He does care that you try--and that you try hard” [2].

But all of this is happening in the developed (industrial) world, where not only the scientific establishment, but other inner workings of the society have deep roots – although with various degree - in rationalism. So what is happening in developing countries, with a different context, such as the willingness to immigrate to find a better life? Is the existence of various BME programs that have been established in different parts of the developing world a guarantee of more well-being for their own residents? What are the major impediments that still exist on a large scale that if left unresolved, will probably lead to results far less satisfactory, in countries that usually have already strained resources? The focus of this paper is to address these questions, based on a real case experience of the author, using a rather candid tone. A real example of a still ongoing project is expected to put into context the remarks made, and allow for the presentation of the facts to be pragmatic and better resonate in the developing world.

Manuscript received April 1, 2011. This work was supported by the Iranian National Science Foundation (INSF) Grant 87041735.

E. Zahedi is with the School of Electrical Engineering, Sharif University of Technology, Tehran, Iran (+98 21 66165960; fax: +98 21 6602361; e-mail: zahedi@sharif.edu).

H. Movahedian Attar is with Electronics Research Institute, Sharif University of Technology, Tehran, Iran (+98 21 66164957; fax: +98 21 66030318; email: movahedian@sharif.edu).

II. The Project Case

A. Background

The endothelium (inner lining of the vascular bed) has an important role in homeostasis [3]. Endothelium dysfunction (ED) is a precursor of atherosclerosis, one of the major paths leading to cardiovascular diseases (CVD) [4]. The non-invasive and drug-less characterization of ED is nonetheless traumatic and expensive: a pressure cuff is used to totally occlude blood flow in a limb (usually the arm). Once this cuff is released, shear stresses induce a response by endothelial cells, the expression of which is a relative increase in artery diameter (about 10% to 15% for healthy subjects) which is recorded by an ultrasound scanner [5]. The value of the Flow-Mediated Dilation (FMD) is obtained from:

$$FMD\% = \frac{D_{Peak} - D_{Baseline}}{D_{Baseline}} \times 100 \qquad (1)$$

where $D_{baseline}$ is the brachial artery (BA) diameter (in the case the arm is used as the FMD site) at diastole during baseline (before occlusion). D_{peak} is the BA peak dilation (at diastole) after cuff release.

The *traumatic* aspect of this experiment comes from the fact that the said cuff is pressurized to 50 mm·Hg higher that the systolic blood pressure (BP), and this high pressure (necessary to keep the artery occluded) has to be maintained for 5 minutes. The combination of such a relatively long time occlusion and high pressure results in an uncomfortable sensation of numbness in the subject’s arm and does not exclude the possibility of arterial spasm [12]. On the other hand, the *expensive* characteristic comes from the fact that in order to detect the FMD response, a high-resolution ultrasound scanner (as the typical dilation is only about 500 μm) and an expert sonographer are needed [4]. A high-density linear probe (around 12 MHz in order to achieve high-resolution images) with Doppler flow detection capability are required. The operator time cannot be underestimated, considering the scarcity of such operators and the tendency of physicians to use ultrasound scanning for obstetrics purposes, especially in developing countries. In this short introduction on FMD, details as the normalization to Doppler flow signal [3] have been omitted for the sake of briefness.

Other studies have hinted to the possibility of using the finger photoplethysmogram (PPG) as a potential surrogate to the artery diameter measurement [6]. Indeed the time-course of the PPG amplitude and FMD show typically the same behavior (Fig. 1). The immediate implication is cost-reduction, as recording the PPG requires much less complex equipment and does not really need an expert operator. Another possible advantage would be the reduction in occlusion time, as one of the reasons the occlusion time is so long (5 min) is for the artery to be enough dilated so that it can be accurately measured by the ultrasound scanner.

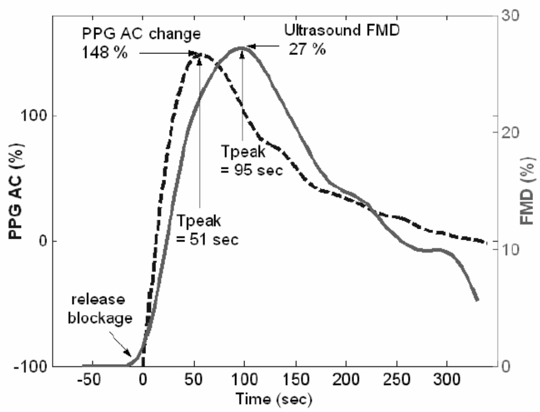

Fig. 1. Sample ultrasound FMD response superposed to variations in the amplitude (AC) of the PPG from the same subject (From [6]).

Given existing DSP algorithms, it was hypothesized that PPG would prove to be more sensitive, therefore this technique would require less occlusion time [6].

Armed with these preliminary results, a new project was defined whereas FMD was to be acquired simultaneously by ultrasound and finger PPG. In order to get funding for this project, a proposal was put forward to the Iranian National Science Foundation (INSF).

III. Challenges

A. The disconnection between academia and industry

One of the most challenging tasks for any investigator working in a developing country is that the existing BME industry is totally disconnected from the academia. Historically, the BME industry in most developing countries is exclusively import-oriented. In Iran, there are few exceptions as some local manufacturers strive with huge difficulties to maintain a presence in the local market. It is encouraging to observe that a few rare exceptions have even been able to export medical devices and goods [9], a really laudable task considering all the current limitations. Considering that transforming laboratory prototypes into commercial products is a risky and long adventure, the local industry prefers to simply avoid any commitment in developing local products. Comparing this process with developed countries where supporting industries are readily available, it is clear that one cannot argue with the industry. Moreover, the local market is quite limited and the high-tech nature of most devices dictates large financial overheads. Even the spot-like intervention of the government by funding the industry on specific cases cannot resolve the issue which needs to be addressed globally. However, the net result of this situation is that students do not feel preoccupied by the impact their work might have on the quality of life of their fellow citizens. This factor is compounded by the trend among students to see their studies as an avenue to immigrate to a developed country, the so old and infamous brain-drain phenomenon [10]. The resulting dismay in which investigators find themselves has often been reflected in the literature [11].

B. Low prevalence of academic research among the medical community

Another obstacle in the developing world is the orientation of medical doctors (MD's) towards clinical practice instead of research. It is difficult to criticize such a position as many arguments seem to justify it, the financial gain being the most important one. Traditionally, the practice of medicine in general and surgery in particular have been lucrative in such regions of the world. The whole picture becomes much clearer if the prevailing inflation rate and rising living costs are taken into account. A consequence of such a situation is the difficulty in communicating ideas, when even scheduling meetings can quickly become a hurdle. Moreover, if co-location is not achieved, collaboration is almost impossible due to geographical constraints and lack of adoption within the medical community, compared to engineers, of email and videoconferencing tools.

Finally, there is the cultural problem: even among those MD's who are willing to do research involving engineers; there is usually some kind of misunderstanding about what a BME researcher can achieve. The MD's expectation from biomedical engineers being very high, they wish for the realization of the same level of quality as imported products and in a short time. Their frame of reference is invariably manufacturers who have over half a century of expertise with proven products and sizeable market share. Often disappointed by inexperienced engineers who prematurely promise extraordinary feats (such as building an MRI scanner!); they are inclined to believe that cooperating with a BME researcher is just a waste of time.

C. Administrative delays in project approval

One of the worst nightmares of a research academician is paperwork. This being said, every seasoned investigator knows that patience is an indispensable (but unfortunately not sufficient) virtue in this context. The problem with administrative delays in approving projects is that the academic calendar is oblivious to such delays, as graduate students need to graduate. One possible way to evade such delays is to use pre-existing data, which was not an option in this case. It is clear that under these circumstances, the investigator has to start the preliminary part of the project, hoping that funding will arrive for purchasing necessary parts & equipments.

Eventually though, this particular project was approved within less than two years of the proposal being filed. It is worth noting that this delay in approval was not far from the average delay experienced by similar projects.

D. The "Running on Empty" Syndrome

The impact of such administrative delays can be formidable: without funds, an investigator may use the fund associated with another project to quick-start the new one. This seems unethical, but is nonetheless a common practice to "bridge the gap" between projects. The problem with such an approach is that it assumes that another funded project, capable of sustaining the new one was already active. As such may not always be the case, it may become difficult to find enough funding to cover the basic expenses incurring even in a relatively low-expense phase such as extension of the state-of-the art literature review.

E. The Need for Details

In any sponsored project, the investigator has the obligation of reporting the minute details of his/her project to the sponsor. Besides this legal requirement, the documentation of these details is a precious source of reference and decision support in later phases. In developing countries, this approach does not resonate well with students. The main reason is that as the rest of the scientific and administrative bodies not being so preoccupied by details, it is unclear to students as why they should spend so much energy in a particular project. Therefore, a clash of mentality with respect to reach excellence actually slows down the research process. Although students do accommodate the wish of their supervisor, the joy and glamour are missing from the scenario, reducing the satisfaction which generally accompanies BME projects.

F. Lack of access to equipment

Assuming that a piece of equipment, available in one academic center, will be made available to a researcher is not always justified. And a particular experience in one developing country (Malaysia), cannot be simply extended to another country (Iran) even if it is of higher academic standing (32 vs. 44, [7] assuming journal ranking as the metric). Unfortunately, the project met some serious difficulties regarding a critical piece of equipment: the high-resolution scanner necessary to perform the artery diameter measurements. Including this equipment in the initial project proposal would have practically meant doubling the requested budget figure, resulting in the proposal being rejected. Needless to mention that imposed sanctions [8] do not facilitate this task.

IV. The Dilemma

Under such conditions, ethical issues do arise: on one hand, the country is in need of better managing its resources to cater for the most urgent health needs of the population. On the other, a certain amount of fund has been granted but with enormous delay, and in any case not enough to cover all the expenses of this BME project, with approved budgets usually 40% less than what was requested. The students are not enthusiastic about achievements, and lots of questions are raised about the need to resolve so many details when answers to bigger questions (i.e. will the principal piece of equipment finally be available to the project?) are still uncertain. The rapid rhythm at which societal changes do occur in developing countries is also unmatched and incomprehensible by the developed world. Although these changes affect indirectly R&D projects, their impact is profound and durable.

V. Lessons Learned

In order to benefit from this experience, some of the solutions to the challenges enumerated in Section IV are listed here:

- Regular coaching

Despite their specific choice of discipline, BME students still need to be coached on a regular basis and reminded about their potential impact towards generating a better quality of life for other human beings. This coaching has to be done against tremendous pressure from external (e.g. society and family) sources which induce negative influences by urging the focus on ill-sighted, self-interest and short gains. An effective way of inducement is to engage in open communication. Unfortunately, this is easier said than done in developing countries, where speaking up is not the usual norm, unless something goes extremely wrong.

- Check assumptions

Great care has to be taken when comparing the prevailing academic culture and inter-varsity collaboration with what is happening in other developed countries. Even if such countries have a rather similar status, it is necessary to double-check all assumptions. Each environment is unique with its own set of limitations and opportunities.

- The least effort path

Human beings are keener on the "least effort" path rather the "most exciting", or "most beneficial to the society" ones and students are no exception. They painstakingly compare the level of efforts they put in a particular project with the effort of their peers, and if obtained outputs are not as spectacular as them, low morale will prevail. To compensate for extra effort, some kind of "bonus" has to be devised.

- Academia/industry links

In developing countries, the BME industry in particular is preoccupied with immediate financial returns rather than long-term research and development (R&D) potential outcomes. Such a view definitely precludes local industries from any involvement and investment in academic R&D. Needless to say that the blame is not totally on the industry's shoulder: problems that are addressed in academia have to be comparable with the developed world in order to ensure comparison on an academic scale. Therefore, the focus in academia seldom corresponds to the interest of local industries. Although this problem is general in all industries, it is more acute in BME due to the specific demands of the end-users of medical technology: MD's are used to the "latest technology", whereas the sophistication of the local industry is generally far behind.

A major issue is the protection of Intellectual Property: as the existing regulations are still not totally enforced, the industry is reticent towards investing in know-how outside its own control.

- Inadequate BME syllabuses

As a consequence of the latter point, BME syllabuses seldom prepare students to the real industry needs. Thus, a vicious circle is established whereas graduates can't possibly fulfill the needs of the local industry, which in turn looses trust in the ability of locally trained BME engineers to resolve their problems. At most, these engineers will be absorbed by the academia, if they can pursue their studies up to the Ph.D. level. Alternatively, they may become sales engineers in local representatives of foreign brands, if "brain-drain" to the developed world does not take them away.

VI. Conclusions

The experience gained in the project detailed in this paper has brought considerable insight as what are some of the hurdles that must be overcome on the way to exciting projects in the field of BME R&D in developing countries.

The most important point is the adoption of a holistic approach and the need to tackle issues at their origin. BME (like any other discipline) can only succeed if all components are functioning in accord. Creating a conducive R&D environment with budgets commensurate with physical achievements (as opposed to pure paper publication) is a must. Approaching the BME industry and concentrating on real needs (which may not be necessarily publishable in academic journals) will encourage students to have a better understanding of the impact their efforts may have. Protection of IP rights has to be definitely enforced. As the academic promotion system is currently almost entirely based on journal publications, new criteria must be made available with similar weight.

Concerted efforts should primarily address the root problems, namely slow administration, lack of communication among peers and paramount to all, hidden corruption. Otherwise, any technology deployment [13] will only constitute another burden on an already weak, mal-functioning economy if more basic problems are not solved first.

Although some worldwide efforts have been deployed to address these issues, it is improbable that an externally funded project [15] without genuine internal support would likely succeed. With this respect, each country presents its unique challenges and opportunities, as the example of China [16] for which a reasonable solution can be more easily implemented thanks to the sheer size of its local market. On the educational side, reviewing the syllabuses of the BME curriculum in order to take into account the stakeholders is also a high priority. Organizing such a review will definitely prove to be challenging, as each institution has accumulated experience to some extent and developed specific customs (and some pride) as to its own curriculum. Finally, in our era of globalization, proper benchmarking by international experts is needed. With this respect, collaboration with teams familiar with similar challenges [18] or keen to undertake such endeavors will set the framework in which efficient BME engineers could be educated. To this end, the involvement of the IEEE EMBS can be a great assistance.

One may argue that the listed problems are more a product of the focus of the university rather than the product of the overall scientific policy of the country. However, as similar patterns are occurring when looking at other universities, the same line of reasoning seems applicable there too.

Unless these obstacles are eliminated by a concerted effort involving academia, relevant governmental institutions and the BME industry, it is extremely difficult to achieve significant progress. The reality is that being number one in terms of publications (where Iran was the fastest growing country in the world in 2008 [19]) is one thing, translating these works into tangible, quality-of-life enhancements is another.

Although the presented remarks in this paper may look like another opinion, they are thought to be an effective motivation in looking towards realistic solutions.

VII. Acknowledgments

The authors would like to express their sincere gratitude to the anonymous reviewers for their valuable comments which resulted in a great improvement of this paper.

References

[1] BME Career Video, http://www.embs.org/docs/embsvideo.mpg, as of March 30, 2011.

[2] W. Greatbatch, "What is the secret of happiness in a career?", Threshold of the new millennium, IEEE Spectrum, October 1999, Volume 36, Number 10, pp 1-30.

[3] R.A. Harris, S.K. Nishiyama, D.W. Wray, R.S. Richardson, “Ultrasound assessment of flow-mediated dilation,” Hypertension, Vol. 55, pp.1075-85, 2010.
[4] M.A. Black et al., “Importance of Measuring the Time Course of Flow-Mediated Dilatation in Humans”, Hypertension, Vol. 51, pp. 203-210, 2008.
[5] D.S. Celermajer et al,” Non-invasive detection of endothelial dysfunction in children and adults at risk of atherosclerosis,” Lancet, Vol. 340, pp. 1111–1115, 1992.
[6] E. Zahedi, R. Jaafar, A. Mohd Alauddin Mohd, A. L. Mohamed and Oteh Maskon, Finger photoplethysmogram pulse amplitude changes induced by flow mediated dilation; Physiological Measurement, 29 (2008) 625-637.
[7] http://www.scimagojr.com/countryrank.php, as of March 30, 2011.
[8] http://www.bis.doc.gov/policiesandregulations/tradesanctionsreformexportenhancementact.html, as of March 30, 2011.
[9] http://www.medicalsupplies123.com/medical-health/iran, as of March 30, 2011.
[10] W.H. Abul-Shohoud, The Brain Drain, A Third World View; Proceedings of the Frontiers in Education Conference, 1982, pp 282 - 287.
[11] R.R. Ernst, Science, engineering, and humanity, Engineering in Medicine and Biology Magazine, IEEE, May-June 2006, Volume 25, Issue 3, pp 1-2.
[12] J.K. Morton, Predicting patients prone to radial artery spasm: Use of flow-mediated dilation testing, Catheterization and Cardiovascular Interventions, Volume 77, Issue 5, pages 655–656, 2011.
[13] P. Meso et al; An Overview of Potential Factors for Effective Telemedicine Transfer to Sub-Saharan Africa, IEEE Transactions on Information Technology in Biomedicine; Sept. 2009, Volume : 13, Issue: 5, pp 734 - 739.
[14] M.J. Kern, Predicting patients prone to radial artery spasm: Use of flow-mediated dilation testing, Catheterization and Cardiovascular Interventions, Volume 77, Issue 5, pp 655–656, 1, April 2011.
[15] G. Kaunonen; Engineering World Health, IEEE Pulse, Sept.-Oct. 2010, Volume 1, Issue 2, pp 28-33.
[16] C.C.Y. Poon et al; Perspectives on High Technologies for Low-Cost Healthcare; IEEE Engineering in Medicine and Biology Magazine, September-October 2008, Volume 27, Issue 5, pp. 42 – 47.
[17] F.R. Beyette et al; Point-of-Care Technologies for Health Care; IEEE Transactions on Biomedical Engineering, March 2011, Volume 58, Issue 3, pp. 732-735.
[18] M. Taylor; Power and Responsibility; Women in Engineering; IEEE Magazine, Dec. 2010, Volume 4, Issue 2, pp. 22-23.
[19] Knowledge, Networks and Nations: Global scientific collaboration in the 21st century, Royal Society Policy Document 03/11, March 2011, Elsevier.