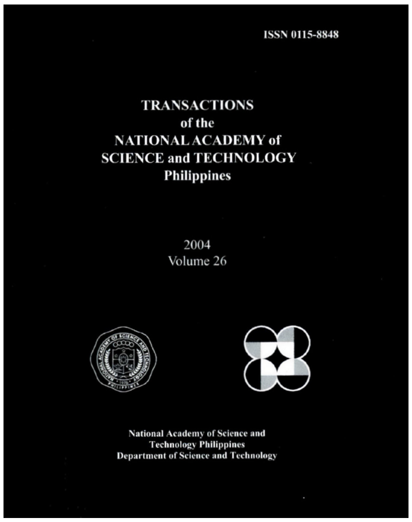
TRANSACTIONSNASTPHL

https://transactions.nast.ph

ISSN 0115-8848 (print)
ISSN 2815-2042 (online)

Vol. 26 Issue No. 2 (2004)
doi.org/10.57043/transnastphl.2004.4708



Talent and Innovativeness to Meet the Challenges of Global Standards in Scientific Productivity

Caesar A. Saloma, Ph.D.

Professor, National Institute of Physics
University of the Philippines Diliman
Quezon City

Citation
Saloma CA. 2004. Talent and innovativeness to meet the challenges of global standards in scientific productivity. Transactions NAST PHL 26(2): 277-288. doi.org/10.57043/transnastphl.2004.4708

Transactions Natl. Acad. Sci. & Tech. Philippines 26 (2): 277 -288 (2004)
ISSN 0115-8848

TALENT AND INNOVATIVENESS TO MEET THE CHALLENGE OF GLOBAL STANDARDS IN SCIENTIFIC PRODUCTIVITY

Caesar A. Saloma, Ph.D.
Professor, National Institute of Physics
University of the Philippines Diliman
Quezon City
e-mail: csaloma@nip.upd.edu.ph

Abstract

Universities particularly their science and engineering graduate programs, are primary producers of precious intellectual capital. We examine the generation of intellectual capital in the Philippines in terms of the number of PhD and MS graduates produced in the natural sciences and the number of scientific papers authored by scientists with Philippine-based affiliations. We utilize the 21 year-graduation data (from school year 1983-84 to 2003-2004) of the College of Science, University of the Philippines and the 11-year publication output (1993 - 2003) of Philippine-based scientists in peer-reviewed journals that are indexed by the Institute of Scientific Information. The Philippine performance is compared with those of other ASEAN countries for the same period of time. The findings are discussed from the perspective of Schumpeter's theory of business cycles. Our analysis reveals that the most serious challenge facing capital generation in the Philippines is the lack of quality graduate programs for producing competent PhD graduates in the sciences and engineering. Local graduate programs are vital in retaining young talented BS graduates who are likely to go to foreign universities for lack of other viable options.

Key words: scientific productivity, innovativeness, intellectual capital

Introduction

Science seeks to make sense of the physical world and the immutable aim of scientific research is to extend our knowledge of the physical, biological, or social world beyond what is already known. The untiring effort towards a better understanding could be due to the innate desire of human beings to overcome ignorance and to rise above helplessness. It could also be motivated by childlike curiosity or driven by personal desire to improve oneself. Regardless of motives, the expansion of scientific knowledge is bound to enrich human society either materially, spiritually or both.

Science is essential for the continued progress of human societies especially those in developing countries like the Philippines. Among the various human endeavors, the scientific enterprise is the most likely to provide the best possible solutions to problems that are caused by increasing human population, dwindling natural resources, and human inefficiency and incompetence. So far, the scientific enterprise has been highly successful due to the uncompromising practice of honesty, openness, collegiality, scepticism, and fairness by scientists themselves [*1*]. It seems logical to extrapolate that significant benefits are gained if those from other occupations in life are also able to practice a similar code of conduct and proper behavior.

A country with an established tradition in science and engineering also tend to be economically robust. In 1939, the Austrian economist Joseph Schumpeter argued that a normal, healthy economy is constantly interrupted by technological innovation and that business cycles are unique and driven by entirely different clusters of industries [*2, 3*]. Over time, the durations of economic waves are shortening, from 50 - 60 years during the first wave (1785 ~ 1845) to less than 30 years in the so-called fifth wave (1990 -) which has been largely fueled by information and communications technology. Innovation which is the application of new knowledge that is gained from scientific research and development, powers the birth of new and better technologies. The cycles of innovation are getting shorter because our knowledge of the physical world has become more accurate and reliable as a result of sustained scientific research and development over the years.

It is difficult to predict the *killer* technologies that will jump-start the next economic wave. However, it is safe to argue that the next killer technology will result from long-term investments in scientific research and development. to To partake in the next economic wave and compete in a global market that is increasingly becoming more capricious in taste and needs, a country (or a company for that matter) must have the wherewithal to generate intellectual capital using resources that are within its control and regulation. Huge amounts of intellectual capital are needed to enable a country to place bets simultaneously on many promising fields in nanoscience, materials science, molecular biology and biotechnology, energy, and information technology – areas where the next technology catalyst is most likely to emerge according to pundits [*4*].

Here, we discuss the generation of intellectual capital in the Philippines in terms of the number of PhD and MS graduates that are produced in the natural sciences and the number of scientific papers authored by scientists with Philippine-based affiliations. We employ the twenty-one year-graduation data (from school year 1983-84 to SY 2003-2004) of the College of Science, University of the Philippines in Diliman, Quezon City. We also examine the eleven year performance (1993 - 2003) of Philippine-based scientists in terms of publications in peer-reviewed journals that are indexed by the Institute of Scientific Information (ISI). The performance is compared with those of other ASEAN countries for the same period of time. We also present the R&D funding profile (1989-2002) of the Philippine Council for Advance Science and Technology Research and Development (PCASTRD) of the Department of Science and Technology.

Universities particularly their science and engineering graduate programs, are primary generators of intellectual capital. The production of PhD and MS graduates is a vital indicator of a country's capability to generate intellectual wealth since graduate degrees are research degrees. A PhD degree is awarded to someone who has contributed to the body of scientific knowledge in his or her particular area of specialization.

The UP College of Science is the most important producer of PhD and MS graduates in the natural sciences in the Philippines today [*5*]. Among its affiliated degree-granting units are national centers in geological sciences (National Institute of Geological Sciences), marine sciences (Marine Science Institute), molecular biology and biotechnology (National Institute of Molecular Biology and Biotechnology) and physics (National Institute of Physics).

Publication of results in a peer-reviewed scientific journal often indicates the successful completion of a research project. The peer-review process is an essential aspect of self-regulation in the science community. It has been largely effective in ensuring that only scientific reports that are original, novel, scientifically valid and important are disseminated not only to scientists but also to the general public. The ISI operates and maintains a database of papers that have been published in scientific journals around the world. To be considered in the ISI database, a scientific journal has to satisfy a number of publication conditions [*6*].

The PCASTRD offers research funding in the areas of biotechnology, electronics, instrumentation and controls, information technology, materials science, photonics, and space technology application [*7*]. It is also a major provider of local graduate degree scholarships in the sciences, mathematics and engineering.

Production of MS and PhD Graduates

The College of Science (CS) was established in 1983. It consists of ten degree-granting academic units which offer the following graduate programs: (1) Institute of Biology (MS Biology, MS Botany, MS Microbiology, MS Zoology, PhD Biology, PhD

Botany, PhD Zoology), Institute of Chemistry (MS Chemistry, PhD Chemistry), (3) National Institute of Geological Sciences (MS Geology, PhD Geology), (4) Marine Science Institute (MS Marine Biology, MS Marine Science, PhD Marine Science), (5) Department of Mathematics (MS Applied Mathematics, MS Mathematics, PhD Mathematics), (6) Department of Meterology and Oceanography (MS Meteorology, MS Oceanography, PhD Meteorology), (7) National Institute of Physics (MS Physics, PhD Physics), (8) National Institute of Molecular Biology and Biotechnology (MS Molecular Biology, PhD Molecular Biology), (9) Environmental Science Program (MS Environmental Science, PhD Environmental Science), and (10) Materials Science and Engineering Program (MS Materials Science, PhD Materials Science).

The National Institute of Molecular Biology and Biotechnology evolved from the Molecular Biology and Biotechnology Program. In 2003, the Institute of Environmental Science and Meteorology was established out of the merger of the Department of Meteorology and Oceanography and the Environmental Science Program. The Materials Science and Engineering Program is a joint effort between the College of Science and the UP College of Engineering.

Figure 1 shows the number of PhD graduates produced by the various CS units from SY 1983-1984 to SY 2003-2004 [8]. In twenty-one academic years from SY 1983-84 to SY 2003-2004, the College of Science graduated a total of 256 PhDs. An annual average of 12.2 PhD graduates is produced by the College. The Institute of Biology produced the largest number at seventy (or 3.3 graduates per year) followed by the Department of Mathematics with forty-five (2.1 graduates per year) and the defunct Department of Meteorology and Oceanography with 41 (2 graduates per year). The National Institute of Physics yielded an average of 1.7 PhD graduates per year. The Materials Science and Engineering Program has not produced any since its inception.

Figure 1 reveals that PhD production is not increasing at a steady rate. Peaks are observed in SY 1989-90 and SY 1997-98 indicating a possible cycle with a 9-year period. The National Institute of Physics produced 58.8% of its PhD graduates in the last seven years of the time series.

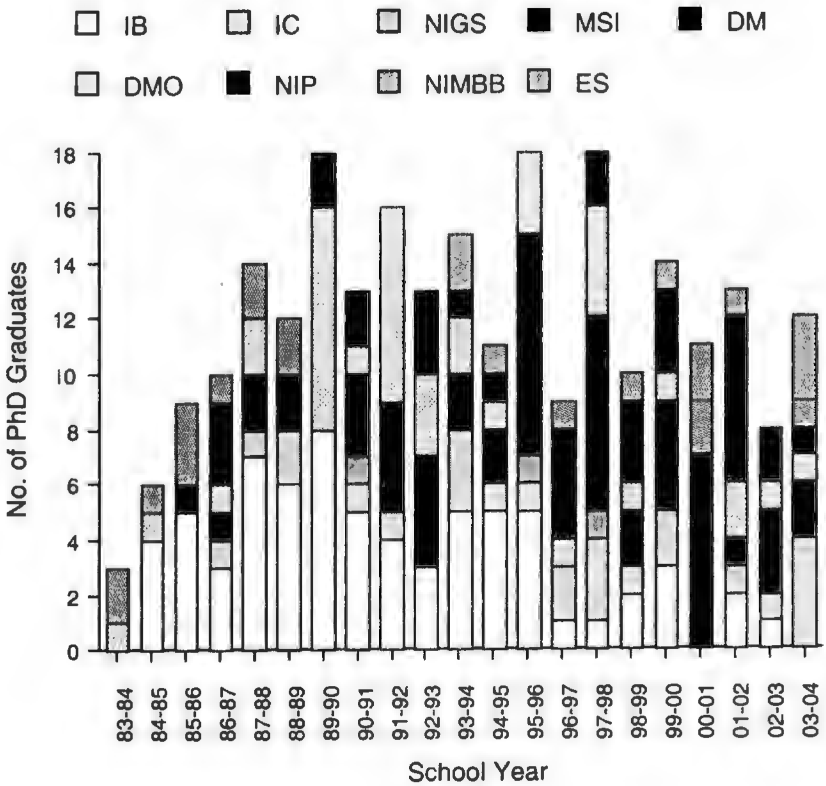


Figure 1. Number of PhD graduates produced by CS units over a 20-year period. Legend: Institute of Biology (IB), Institute of Chemistry (IC), National Institute of Geological Sciences (NIGS), Marine Science Institute (MSI), Dept of Mathematics (DM), Dept of Meterology and Oceanography (DMO), National Institute of Physics (NIP), National Institute of Molecular Biology and Biotechnology (NIMBB), Environmental Science Program (ESP), and Materials Science and Engineering Program (MSEP).

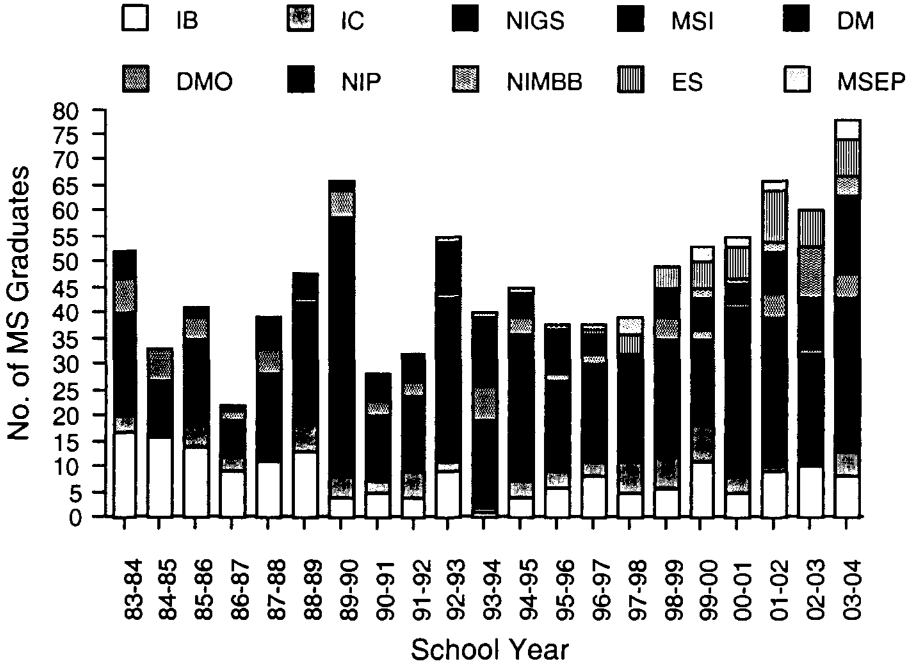


Figure 2. Number of MS graduates produced by CS units over a 20-year period.

Figure 2 plots the number of MS graduates produced by CS within the same 20-year period. A total of 977 students received their MS degrees indicating an annual average of 46.5 graduates per year or 5.2 graduates per year per unit. The Department of Mathematics produced the highest number of MS graduates at 318 (or 15.1 graduates per year) followed by the Institute of Biology with 175 (8.3 graduates per year). The National Institute of Physics yields an average of 5.8 MS graduates per year. The National Institute of Molecular Biology and Biotechnology graduated a total of twenty-one students over the same period.

Unlike the PhD graduation profile, an increasing trend in the number of MS graduates is detected in Fig 2 – about 28% of the MS graduates have been produced in the last four academic years from SY 2000-2001 to SY 2003-2004.

ISI Publications

Figure 3 plots the annual number of ISI publications emanating from Malaysia, Philippines, Singapore and Thailand from 1993 to 2003 [9]. A linear fit reveals a slope value (proportional to increase rate of ISI publications per year) of 373 ppy, 139.33 ppy, 78.436 ppy and 21.11 ppy (publications per year) for Singapore, Thailand, Malaysia and Philippines, respectively . The ISI publication profile of Indonesia (not shown in Fig 3) yields a slope of 31.7 ppy.

The ISI publication rate of our ASEAN neighbors clearly shows an increasing trend unlike the Philippines whose annual output has never exceeded 500 within the 11-year period. In 1993, Thailand with 412, had 2.1 times the number of ISI publications than the Philippines. In 2003, it had 2102 ISI publications representing 4.49 times the number published by Philippine-based researchers.

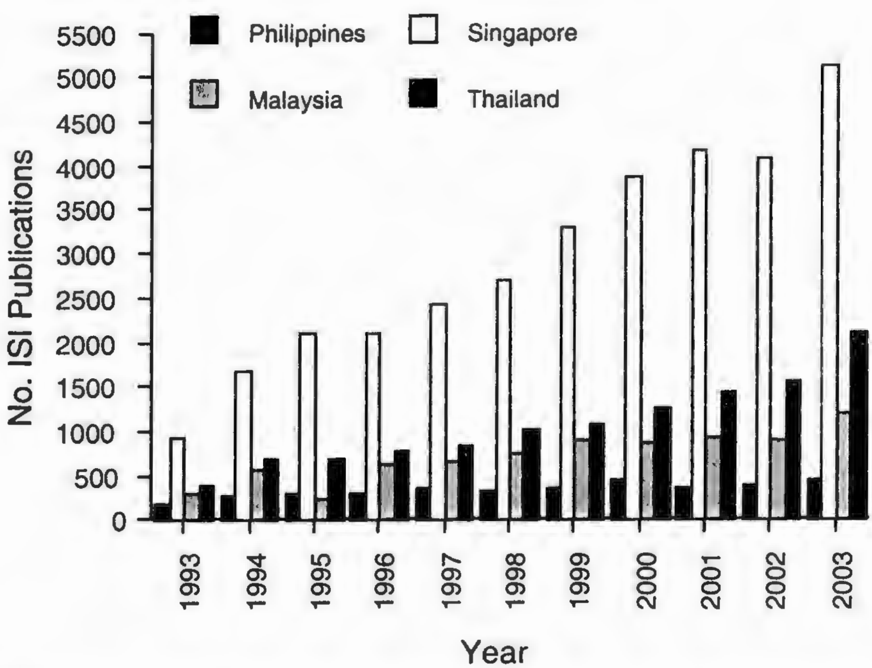


Figure 3. Annual number of ISI publications emanating from Malaysia, Philippines, Singapore and Thailand within an 11-year period.

Funding for Scientific Research

Figure 4 presents the financial support that was given annually by PCASTRD to research projects from 1989 to 2002 [*10*]. Also shown are portions that were awarded to researchers in materials science and photonics sectors. Most of these researchers belong to the Philippine physics community. Within a 14-year period, the PCASTRD released a total amount of PhP164,909,776.42 in research grants of which PhP 67,340,254.11 (40.83%) and PhP 15,524,343.04 (9.41%) went to the materials science and photonics sectors, respectively. The biotechnology sector received 27.45% of the total financial disbursements for research and development.

The amount of money that has been spent for research and development did not increase steadily in nominal terms. The trend becomes even more dismal when we factor in the effects of inflation and the changes in the foreign exchange rate between the Philippine peso and the US dollar. Between January 1990 (USD = PhP24.46) and December 2002 (USD = PhP 53.52), the Philippine peso depreciated by almost 120% against the US dollar. For Filipino researchers the effect is doubly devastating because all precision instruments and devices and research-grade components have to be acquired from abroad.

Discussion

Based on data that have been accumulated over a 21 year-period, the ability of the College of Science to produce well-trained PhD graduates is far from desirable. The annual average production rate of 1.3 PhD graduates per unit is below the performance that can be expected of a college where the average number of full professors per academic unit is 7.8 [*11*]. A PhD student needs a minimum of three years to complete his or her academic requirements (after earning his or her MS degree). Even if we factor that in, still the average production rate remains low because associate professors and assistant professors are allowed by the University of the Philippines to supervise PhD students on their own.

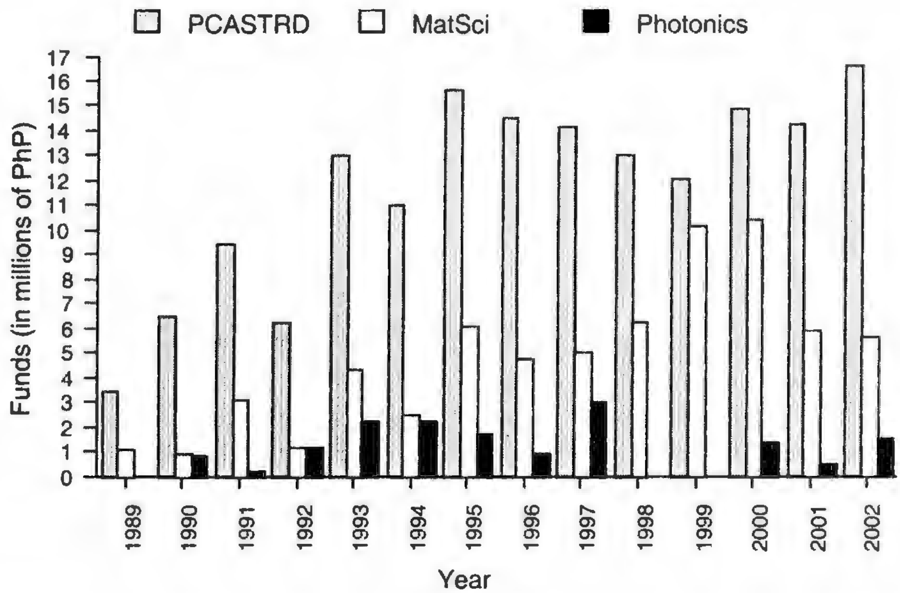


Figure 4. Annual financial support (grants-in-aid) given by PCASTRD. Also shown are portions given to projects in Materials Science and Photonics.

Only the Marine Science Institute and the National Institute of Physics, require a PhD student to publish at least a part of his or her dissertation research in an ISI-indexed journal. To help ensure world-class training for its PhD students, the College of Science needs to adopt the ISI publication requirement in all of its PhD graduate programs. During its initial implementation, the ISI publication requirement is expected to reduce (further) the number of PhD students who will earn their degrees but this is only a temporary setback that is worth paying for to promote genuine scientific excellence in the long term.

Enlarging the pool of competent faculty supervisors who are willing to train PhD students is the most serious challenge facing the College of Science today. To be up to the challenge, a faculty must have the necessary technical competence and the good sense to mentor young scientists and make them achieve their full potential. In a society where scientific tradition is not yet rooted, the scarcity of competent mentors only helps to perpetuate a culture that is incapable of distinguishing and celebrating scientific excellence. A society with such a culture tends to rationalize scientific mediocrity and believes in the mistaken notion that excellence is a matter of patronage or connections.

In 1998, Taiwan produced 907 PhD graduates in the sciences and engineering [*12*]. In the same year, the Philippines with a population that is almost four times larger, graduated an order of magnitude less. Japan and Korea produced 6,575 and 2,484 PhD graduates respectively, in the said given year.

The lack of notable increase in the number of ISI publications from the Philippines can be attributed to a number of factors. It could be due to a lack of an effective (and dynamic) national policy on science and technology or to an ambivalent implementation of an otherwise coherent plan including insufficient and sputtering financial support (from both the public and private sectors) for scientific research and development. It could also be caused by a local science community that is incapable of (and disinterested in) competing with the rest of the world in the generation of new scientific knowledge. The ISI publication performance is a function of the number of researchers engaged in research and development. In 2001, the number of researchers per million of inhabitants in Japan, Korea, US and Singapore were 5321, 2880, 4099, and 4052, respectively [*13*]. In 2001, the density for the Philippines was 157 [*14*].

In 1999, Italy allocated the lowest percentage of gross domestic product (GDP) for research and development at slightly above 1% among the G7 countries. Japan spent the highest at approximately 3%. In the same year, Taiwan spent 2.05% of GDP rising to 2.16% in 2001 [*15*]. In 2002, Taiwan-based researchers produced 10,831 publications in ISI-indexed journal - Taiwan was the 18th most published country in the world in the said year. In 1992, the Philippines only spent 0.22% of its GDP and in 2001, it even spent lower at 0.15%. In 2001, Japan and South Korea devoted 3.09% and 2.96% of their GDP respectively on research and development. In 1992, these countries used 2.86% and 2.1%, respectively [*16*]. Singapore spent 1.13% of its GDP for the same purpose in 1995 rising to 2.11% in 2001.

Whether we like it or not, counting the number of ISI publications is a widely-accepted benchmark for assessing the performance of researchers. Of course, there are finer points of excellence like publishing in an ISI journal with high journal impact factors (e.g. *Nature* or *Science*) or the number of citations (by others) received from previous publications. These details however, are employed to distinguish excellence from the merely good.

Conclusion

We have discussed the capability of the Philippines to generate intellectual capital in the form of the number of PhD and MS graduates produced in the natural sciences and mathematics over a 21-year period. We have also studied the number of ISI papers published by researchers with Philippine-based affiliations from 1993-2003.

Our data indicate a performance that is wanting in both measures. In the competitive index released by the World Economic Forum for 2003-2004, the Philippines occupied the 64th position – a rank that is lower than its Asian neighbors: Singapore

(8), Taiwan (16), Malaysia (26), China (46), Thailand (31), Vietnam (50) and Indonesia (60) [*17*]. Direct investments flow faster towards countries that are perceived to be more competitive.

Our scientific performance is not significant enough because of the low number of Filipinos who are engaged in scientific R & D. The lack of capable PhD supervisors prevents our country from producing enough PhD graduates to make it competitive and attractive to direct investment in the technology sector of the industry. It also makes our domestic graduate programs unappealing to young BS graduates who have no other option but to leave the country.

The key to enhancing the capability of the Philippines to generate intellectual capital is the development of world-class graduate programs in local universities. Sending BS graduates to earn their PhD degrees abroad is not the solution. Supporting locally-trained PhD graduates to do postdoctoral research in top foreign research laboratories, is.

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[*2*] Survey: Innovation in Industry, The Economist (16 May 2002 issue)

[*3*] J. A. Schumpeter. 1939. Business Cycles. Analyses of Schumpeter's works are widely available in the Internet.

[*4*] The Economist (December 6, 2001 issue)

[*5*] College of Science, UP Diliman (www.science.upd.edu.ph)

[*6*] Institute of Scientific Information-Thomson ISI (www.isinet.com). INSPEC (www.iee.org/Publish/INSPEC) is another reliable database of scientific papers in physics, electrical engineering, electronics, communications, control engineering, computers, computing, information technology, manufacturing and production engineering.

[*7*] PCASTRD website (www.dostweb.dost.gov.ph/pcastrd).

[*8*] Data provided by Dean's Office, College of Science.

[9] Data from ISI Web of Science.

[10] Data from the Office of Executive Director, PCASTRD.

[11] Average taken over seven academic units (IB, IC, NIGS, MSI, DM, NIP, NIMBB). DMO and ESEP are excluded because they have been merged. No faculty items are allocated to MSEP.

[12] The National Science Foundation (www.nsf.gov).

[13] UNESCO Institute for Statistics Selected R&D Indicators 1996-2002.

[14] Organisation for Economic Co-operation and Development (www.oecd.org).

[15] National Science Council Taiwan 2003 (www.nsc.gov.tw).

[16] UNESCO (www.unesco.org).

[17] World Economic Forum *Global Competitiveness Report 2003-2004.*