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RESEARCH ARTICLE

Improvisation of Science Education in Indian Universities: A Call for the Inclusion of Elements of National Importance in the Curriculum

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ABSTRACT

India is steadily losing its early dominance in scientific research and development- that attained apogee during classic through middle-ages, and since independence it produced not a single Nobel Laureate in Science. This article examines some of the root causes of the problems that Indian science is facing, including extrinsic factors of bureaucracy and skewed funding. Correlation of research and development expenditures and H-index as revealed in the present study, combined with India's poor 'average citations per paper' benchmark, suggests that a vast majority of scholarly literature that the country produces have little significant research impact. At the same time, the country also delivers a small number of high-quality papers. Almost entire gamut of intrinsic issues can be attributed to the state of science education in the Indian universities, especially much overlooked component, the syllabus. Two new core courses for graduate science curricula across disciplines are proposed: (i) History of Science and (ii) Scientific Ethics. Areas of science syllabi of Indian university curriculum that require urgent revision with respect to the inclusion of elements of national importance are identified and augmentation of curricular resources to subsume modern and effective didactic strategies including podcasts and Massive Open Online Courses (MOOC) are suggested, before concluding with related pedagogical recommendations that include well-developed lesson plans, implementation of Information and Communication Technologies through personal websites, summer/winter internships, and collaborative and interdisciplinary research.

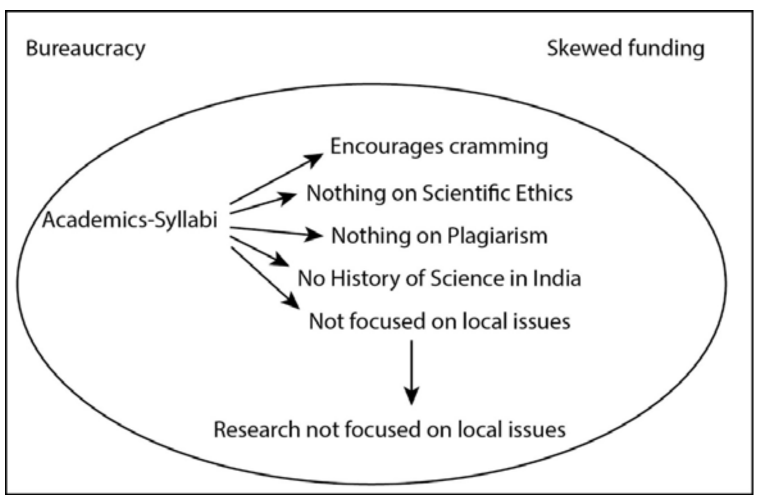
KEYWORDS: Animal Sciences; Collaboration; Pedagogy; Plagiarism; Plant Sciences; Podcast; Scientific Ethics.

Introduction

India is widely believed to be a pioneer in Science and Technology innovations in pre-historical through medieval times. However, this ancient supremacy got stagnated since late middle ages. Colonial India produced some of the greatest scientists and mathematicians the country still proud of, including C. V. Raman who won Nobel Prize in 1930. However, since Independence, scientific research in the country remained largely obscure, with not a single Nobel Laureate in science. Three scientists of Indian-origin have won Nobel Prize; geneticist Har Gobind Khorana, astrophysicist Subrahmanyan Chandrasekhar and molecular biologist Venkataraman Ramakrishnan, and one mathematician won Field's medal, Manjula Bhargava, but all of their winning works were carried out entirely outside India.

A number of factors can be attributed for this decline, which can broadly be classified as either extrinsic or intrinsic (Fig. 1).

Figure 1 — Logical Venn representation of problems faced by science discipline in India. The "Universe" denotes extrinsic problems, while the inside of ellipse denotes intrinsic problems.



Extrinsic problems- factors that are by virtue of the very system beyond the control of the scientific fraternity. They include bureaucracy that values administrative power over scientific advancement, orthodoxy, hierarchy, fear of asking bold questions and sycophancy, and skewed funding. Bureaucratic problems can be effectively dealt with managerial decisions such as rotation of institutional roles and responsibilities, and delegation of more decision-making powers to the young scientists. For example, in a number of research institutions and universities across the country, prior permission from head of the institution is required before submitting a research paper- each forwarding official typically seeking co-authorship with little contribution. Although the practice might have begun to counter deliberate practice of some of the authors to refuse authorship to others involved in the institution-wide collaborative study, this has now become a bureaucratic trap. Applications for submitting abstracts for conferences, grant proposals, or duty leave for conducting research expeditions, also require recommendations from institutional committees comprised of senior scientists. These committees hold meetings only once in a month - postponement of which is commonplace, dragging such applications beyond the comprehension of common sense and the committees typically exercise nepotism while deciding which applications are to be approved.

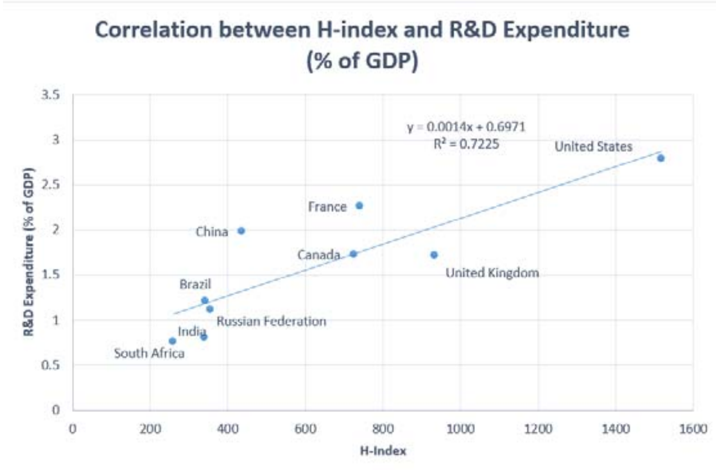
60% of funds allocated in annual Indian Science & Technology budget are set aside for three largest organizations; CSIR, DRDO and Scientific Departments of the government, leading to grossly inadequate resources available for universities (merely 10%) that produces a vast majority of PhDs (Joseph and Robinson, 2014). Funds are also subjected to excessive restrictions applicable for the entire bureaucratic machinery of the government; for example, insufficient funds for travel that renders international travel almost impossible, and restrictions on online purchases, including that of the scientific books. Probably these restrictions have arisen because of the misuse of funds by some scientists. These restrictions make execution of such newly established and prestigious schemes-that are introduced to reduce bureaucracy, such as DST INSPIRE Faculty Award, extremely difficult and inefficient. Fund allocation for scientific research in GDP of India (0.8%) might seem slightly deficient, which is second lowest among BRICS countries (Brazil, Russia, India, China and South Africa)-the lowest being South Africa among BRICS but that alone cannot explain India’s poor scientific output. For example, India ranks 9th in the world for the number of scientific papers produced, 23rd in terms of H-index, but disturbingly 166th in terms of average citations per paper (Table 1). This disparity could be because majority of the papers published from India are relevant only to the national level, and not international level. Unfortunately, partitioned data is not available to test this hypothesis. Another, more obvious reason is that Indian scientists do not exercise prudence while publishing the papers. That is, they don't care the future citations while publishing their papers, and this results in low average citations per paper. While absolute average monthly salaries of academicians in India may be low, in comparison with the rest of BRICS or G8 countries, as per the PPP (Purchasing Power Parity) - adjusted figures, India's figure ($7433) is higher than that of US ($7358) and is only next to that of South Africa ($9330) among the BRICS countries (Altbach, 2012).

Table 1 — Ranks (smaller, the better) of nine selected countries (BRICS + UK, USA, France and Canada) in terms of three measures of scientific productivity (H-index, Documents and Citations per Document) and R&D expenditures. Total countries included in the list was 239. Raw data (year 2013) retrieved from SCImago (2014) and WorldBank (2014).

	H index	Documents	Citations per Document	R&D Expenditure
India	23	9	166	52
Brazil	22	15	127	44
Russia	21	13	212	45
China	16	2	206	28
South Africa	35	12	108	55
UK	2	3	20	31
USA	1	1	2	11
France	4	6	43	20
Canada	5	7	17	30

To know whether the R&D expenditure allocated in national budget has any relationship with H-index, documents, or citations per document (i.e., does the money spent translate to scientific output), raw data for the year 2013 were retrieved from SCImago (2014) and WorldBank (2014) and multiple regression analysis was carried out for 9 countries (BRICS + UK, USA, France and Canada). R&D expenditure against H-index yielded a slight positive correlation (R2=0.7225, Fig. 2), while that with documents had a lesser correlation (R2=0.6605), and that with citations per document did not have any significant correlation (R2=0.3821).

Figure 2 — Correlation between H-index and R&D expenditure expressed as percent of GDP. Data for the year 2013.



A plausible conclusion is that R&D expenditure contributes to H-index and documents, but does not result in an increase of citations per document. H-index (a scholar or institute or country with an index of h has published h papers, each of which has been cited in other papers at least h times, (McDonald, 2005) is dependent only upon number of high-quality publications, and is not affected by low-quality publications, unlike 'citations per document.' H-index of India was 341, and that of the US was 1518 in 2013. It is imperative from the findings of the present study that the vast majority of papers that India produces have little significant research impact globally, while the country also brings forth a small number of high-quality publications. Causes for this asymmetric distribution of scientific output remains unknown, but might be related to the underlying issues of science education in the country, as explained in the following.

The extrinsic problems of bureaucracy and biased funding are merely the tip of the 'intrinsic' iceberg, which almost entirely can be attributed to the poorly drafted science syllabi of Indian universities. Science syllabi, by virtue of their design, encourage the students for cramming, as no resources other than textbooks are recommended therein. Indian universities in general have a course on 'Research Methodology' that is taught to graduate students; however, neither this course, nor other courses (e.g., Bioethics) elaborate scientific ethics to the students. This might be one reason for widespread cases of scientific misconduct, as well as, plagiarism that is plaguing the Indian Science arena. Instead of concentrating to improve the quality, keeping in mind future citations, and to improve individual H-index and i10 index, trend in India is to publish as soon as written (this might be associated with 'hyperbolic discounting' -a cognitive bias that prefers instant over delayed gratification) in journals with no impact factor or no rigorous peer-review mechanism, which is partly owing to the inadequate understanding of scientific ethics. A probable reason could be 'publish or perish' mentality; investigators are indeed pressurized by their institutions and funding agencies to publish their findings, no matter its potential impact. As a result, scientists tend to publish their papers at the nascent stage and ultimately result in lower citations per paper. Concentrating on the overall quality of individual papers would definitely bring down total number of publications (documents), but would improve citations per document as well as the H-index.

An equally serious contention is that science syllabi in Indian universities lack critical elements for inculcating national pride, viz., history of science in India, and do not address scientific issues of national importance. For fundamental sciences such as mathematics, physics or chemistry, this might not be an issue of primary concern. However, a number of allied scientific disciplines including microbiology, evolutionary biology, geosciences, ecology, environmental sciences, animal sciences and plant sciences, have elements of national importance, which are usually omitted in syllabi of almost all universities across the country. This has led to another grave concern, that when the students take up research, the topics tend to deviate from local issues pertaining to India (Fig.1). Argument is not that global issues should be taken out of syllabi; of course they should be taught and should be the main focus. Along with globe-centric perspective, syllabi should be enriched with locally relevant examples and issues. An apparent reason for this state of university science syllabi in India is the scarcity of textbooks expounding Indian issues and examples. Vast majority of textbooks authored by authors from India are indeed based on textbooks written in the West, and therefore focus West-relevant examples and issues. On the other hand, syllabi are prepared keeping in mind of available textbooks, and therefore same issues are recurring there as well. The root problem in my opinion is the unavailability of good textbooks.

In the ensuing discussion two new core courses for graduate science curricula across disciplines are proposed: (i) History of Science and (ii) Scientific Ethics. Areas of science syllabi of Indian university curriculum that require urgent revision with respect to the inclusion of elements of national importance (i.e., 'indianization') are identified and importance of inclusion of resources for catching up with the latest scientific developments are emphasized, before concluding with related pedagogical recommendations.

Proposed *de-novo* Core Courses

History of Science

In a survey conducted as part of this study, it has been found that not a single university in India features a course on the history of science as part of the graduate program in science. This is partly owing to the general consideration in India that history of science is a subject matter of history and humanities, rather than science, which in fact is a fallacious representation. Role of history and philosophy in science teaching is well known, and these are essential components of science graduate curriculum in the West and Japan (Matthews, 1994). Discussed here is not at all about much debated priority of scientific concepts. There are a number of elements of history of science in Indian subcontinent which surely will elicit national pride and boost self-confidence of Indian science students, so that they may genuinely be interested to pursue a career in scientific research.

History of science in India can arbitrarily be divided into pre-history (before 1750BE), Vedic and Puranic period (1750 BCE-1300 CE), Middle-Late Medieval period (1300-1800 CE) and late colonial period (1850-1947). Indus Valley Civilization (ca 4500 BCE) was the first pre-historical civilization with planned drainage and sewerage systems, water reservoirs, and canal irrigation in the world. Charaka (ca1000 BCE) –who introduced system of Ayurveda through 'Charaka Samhita', is widely considered to be father of medicine.

Vedic period (ca 1500-500BCE) witnessed some of the fundamental discoveries in mathematics, including large numbers; Pythagorean Theorem and Pi by Baudhayana (Shulba Sutras); Binomial series, Pascal's triangle, and mātrāmeru series (Fibonacci series) by Pingala; and publication of first Astronomical text Vedanga Jyotisa. During Puranic period (500BCE-1300CE), India had been the most prominent region fostering scientific research. Surgical medicine was introduced by Sushruta (6th Century CE). Three of the famous ancient higher-learning institutions in India, Takshashila (established 5th Century, BCE), Pushpagiri (3rd Century CE) and Nalanda (5th Century CE), attracted scholars from around the world. Puranic period also witnessed a number of scientific discoveries, including atomism, discovery of zero as a number by Brahmagupta, trigonometric functions by Aryabhatta, and Rolle's Theorem in calculus by Bhaskara II.

However, since middle-medieval period (1300CE), the classical stronghold on scientific research had been steadily eroding, except Kerala school of mathematics and astronomy (especially Madhava and Nilakanta), which contributed in a number of discoveries including series expansions of trigonometric functions, infinite series and calculus. This decline might have been partly owing to the occupation of India by a number of invaders.

Colonial India produced a number of successful scientists, including the mathematical genius, Srinivasa Ramanujan, Chandrasekhara Venkata Raman — who won Nobel-prize for work on light scattering, Meghnad Saha — who developed ionization formula for hot gases used in stellar astrophysics, Jagadish Chandra Bose — who made innovations in wireless signaling, Prasanta Chandra Mahalanobis — who is best known for Mahalanobis distance in multivariate inferential statistics, and Satyendra Nath Bose-whose pioneer works in quantum statistics led to Bose-Einstein statistics.

Other internationally renowned and successful Indian scientists of 20th Century include Biologists Salim Ali — who did pioneer work in Ornithology of Indian Subcontinent, Birbal Sahni — who worked on paleo-botany of India, Janaki Ammal-a renowned plant taxonomist, M.S. Swaminathan — agricultural scientist widely credited for bringing green revolution in India, Obaid Siddiqi-whose work exposed many crucial facets of genetics and neurobiology of Drosophila — the model fruit-fly, Ganapathi Thanikaimoni — a famous Indian botanist, K Vijay Raghavan — who did internationally acclaimed works on developmental biology, and Madhav Gadgil and R. K. Kohli — two of the internationally renowned Indian ecologists.

Other famous Indian Chemists include Shanti Swarup Bhatnagar — a well-known colloidal chemist and under whose name the most prestigious prize for Indian Scientists was instituted (Bhatnagar Award), C.N.R. Rao — who did pioneering works on solid state and structural chemistry, Goverdhan Mehta — who is an internationally acclaimed organic chemist, G.N. Ramachandran — who did pioneering works on protein chemistry, and P. Balaram — a well-known molecular biophysicist.

Other important Indian Physicists include Homi Jahangir Bhaba-a well-known nuclear physicist, Daulat Singh Kothari-a famous astrophysicist and Vikram Sarabhai-a renowned space scientist. It is recommended that works and relevance of these and other successful Indian scientists be featured, in addition to other international scientists and scientific breakthroughs of yore, in the course History of Science to be taught for science graduate students.

There are indeed many more living as well as non-living legends of Indian science and a complete survey of them is beyond the scope of this paper. INSA have published a number of reports on History of Science in India, and is publishing a journal (Indian Journal of History of Science), so as IASc (for example, Lilavati's Daughters (Godbole and Ramaswamy, 2008)). Recent columns on living legends of Indian science appearing in Current Science also serve as an excellent starting point for developing a structured and well-crafted syllabi.

Scientific Ethics

There had been a recent surge in cases pertaining to the academic scandal and scientific misconduct in India, including fraud, fabrication of data and plagiarism (Sabir *et al.*, 2014). A number of reasons can be attributed to the issues of academic scandal; probably most important amongst them are ignorance on what actually construes these very issues, and easy access to information via web. While a core course on scientific ethics is compulsory for graduate programmes in US or UK, this subject, including the very definitions of scientific misconduct and plagiarism are lacking in university curricula across India, and this might be one reason behind the trend of increase in cases pertaining to scientific misconduct in the country. A section on bioethics can be found in either research methodology syllabi or combined with Intellectual Property Rights/Bioethics syllabi across some Indian universities. However, this section usually elaborates governmental regulations on research ethics for medical/veterinary/transgenesis experimentation. It is when the students begin writing their research dissertations that most Indian students come across guidelines that advise against plagiarism for the first time, albeit the very term, has not yet been defined unambiguously. Popularity of Wilson Mizner's dangerous quote 'stealing ideas from one is plagiarism, stealing from many is research' comes as an excuse for many, but the students are unaware that research is not at all about 'stealing ideas', but systematic and diligent investigations through falsification of established scientific theories (Popper, 1963) and paradigm shift (Kuhn, 1974) with proper source citation. It is, therefore, suggested that a core course on 'Scientific Ethics' thoroughly explaining various forms of scientific misconduct (Table 2) and plagiarisms (Table 3) be taught at the university level.

Table 2 — Various forms of scientific misconduct (Fanelli, 2009; Montgomerie and Birkhead, 2005)

S. No	Subsection	Scientific Misconduct
1	Data sampling	Fabrication of data: Outright synthesis of raw data with no experiments being conducted, sometimes known as "drylabbing." Manipulation of photographs using software such as Photoshop to distort the meaning. Such results are neither replicable by independent researchers nor tested over a broad range of conditions.
2		No control data: In experimental research, randomized test samples should be compared with the control group, in which all random variables are controlled

3		Deliberate non-random sampling and small sample size: Non-random sampling will lead to skewed representation of the population. Small sample size will reduce confidence in the conclusions.
4		No blind-testing: In many forms of case-control studies, blind testing, in which subject do not know whether they belong to case or control group, is needed to remove unintended bias.
5		Cherry-picking: Deliberately selecting those samples that confirms pre-conceived conclusions, while ignoring other samples.
6	Data interpretation/ Falsification	Confounding: Correlation does not mean causation and conclusion drawn should acknowledge this limitation. Unknown variable might have caused observed correlation, a fallacy known as "confounding". For example, conclusion that higher ice-cream sales cause higher drowning, apparently suffers from confounding; unrelated variable here is "summer season" (ice cream sales are higher in summer months, so as water-related activities such as swimming).
7		Conflict of interests: Research conducted with support from companies (especially drug manufacturers) with vested commercial interests are skewed and while referring these, limitations must be acknowledged.
8	Publication	No-peer review or self-peer review: Publication in, and citation of, non-peer-reviewed and self-peer reviewed publications. A number of bogus journals with no rigorous peer review are being proliferated in the world, and researchers should be careful not to publish in these journals and not to draw conclusions from papers published in those journals. Having an ISSN number do not indicate quality by any means; almost all bogus journals, in fact, have ISSN numbers. The general rule of thumb is that journals with no ISI Impact Factors are low quality.
9		Speculative language: News articles and substandard publications have a tendency to misinterpret the results for the sake of attention-grabbing story, and these should not be referred. Publications that are written in a speculative language with words such as 'might', 'possibly' / 'probably', 'could', etc. should also not to be referred. Also, a large number of citations may not

		necessarily mean that the publication is of high scholarly standard.
10		Sensationalization of headlines: For grabbing attention and increasing citations, some authors have a tendency to sensationalize headlines of research papers, which indeed is a scientific misconduct.
11		Ghostwriting: Person, who contribute the research and write the manuscript is deliberately masked from authorship, to suppress conflict of interests otherwise known from the original author's affiliation.

Table 3 — Various forms of plagiarism (Landau et al. 2002; Marshall and Garry, 2006)

S. No.	Forms of Plagiarism	Severity
1	Identity theft: Steal/Copy/Purchase someone else's entire publication and take full credit.	Staggeringly
2	Copy-cat: Copy chunks of texts/entire paragraph without giving any credit. Or, copying chunks of texts/entire paragraphs NOT inside quotation marks, even if properly sourced.	Staggeringly
3	Cherry-picking: Copy chunks of texts/entire paragraph with a bit of change in terms/phrases, but without giving any credit.	Staggeringly
4	Self-plagiarism/Mitosis: Copy entire publication of your own without citing the original publication.	Staggeringly
5	Self-plagiarism/Recycle: Copy chunks of texts from publication of your own without citing the original publication.	Staggeringly
6	Remixing: Paraphrasing multiple sources and stitching them together to deceive the text as your own.	Enormously
7	Ghost citation: Citing a non-existent publication for sourcing a made-up text.	Enormously
8	Omitted citations: Some sources deliberately omitted from the citation.	Enormously
9	Misinterpreted citations: Some sources are cited out of context/misinterpreted.	Profoundly
10	No original synthesis: Cited all sources correctly, but without any original thoughts/synthesis.	Profoundly
11	Reflection: Cited all sources correctly, but the work closely reflect another's.	Profoundly
12	Mistake in citation: Wrong author/title/year in the citation to cover-up plagiarism.	Profoundly

Indianisation of Syllabi

'Indianisation' primarily refers improvisation of existing science syllabi keeping in mind of Indian students and scientific issues relevant to India. Indianisation of the following areas is discussed herein: Infectious Diseases, Evolutionary Biology/Geology/ Geography, Environmental Sciences/Ecology, Animal Sciences/ Zoology and Plant Sciences/Botany.

Infectious Diseases

Existing syllabi of microbiology or infectious/communicable diseases in Indian universities suffer a serious, but often overlooked, flaw. Diseases that are endemic to the Indian subcontinent are not included, while that of US and Europe are included-which is of little practical significance to Indian students. What is the point of teaching diseases like Rocky Mountain spotted fever, Chagas disease or 'human African sleeping sickness', which are not reported from India? While Malaria, Rabies and Dengue can be occasionally spotted in syllabi of some universities, most of the common endemic diseases prevalent in Indian subcontinent, including Ascariasis, Trichuriasis, Strongyloidiasis, Toxocariasis, Lymphatic filariasis, Trachoma, Visceral Leishmaniasis, Leprosy, Japanese encephalitis, Chikungunya, Leptospirosis, Amoebiasis and Hookworm infection are altogether missing in syllabi of most universities. This would mean students passing out of those courses utterly are ignorant of the local problems pertinent to them- an issue of great significance in the country's didactic policy. These exact diseases are globally known as neglected tropical diseases (there is even an international journal dedicated to study these diseases; 'PLoS Neglected Tropical Diseases'), neglected by the West for obvious reason that these diseases are not found there. But is it not ironical that these are neglected even at home? A number of such diseases still have neither effective treatments nor vaccines, suggesting a lack of research progress in those lines. Medical councils and grant agencies such as Indian Council for Medical Research (ICMR) should urgently prioritize funding research projects on these diseases… As explained earlier, the argument is not that globally relevant pandemics and epidemics of great significance (John, 2013) should be taken out of microbiology syllabi; of course they should be taught and should be the main focus in this era of global travel. Along with globe-centric perspective, syllabi should be enriched with locally significant endemic infectious diseases. Given the limited coverage of infectious disease curricula, endemic diseases of India should be prioritized in Indian syllabi over endemic diseases of other countries worldwide. Greatest harm in my opinion is complete avoidance of important endemic diseases of India while explaining in detail that of Americas, Europe and East Asia, as is the case in most of the Indian universities.

Evolutionary Biology/Geology/Geography

In India, evolution is typically taught beginning with the creation myth, history of evolutionary thoughts in the West, origin of the earth and life, paleontology, to Darwin's theory of evolution and modern synthesis. However, this strategy is tailor made for Western students; Indians never had a problem accepting Darwin's theory of evolution, as similar concepts exist in ancient Indian philosophy. Ancient Indians considered earth is way much older than 6000 years- as thought in the West till 18th Century. According to Vedas age of the earth is 1.97 billion years (precisely 197,29,49,116 years, in year 2015), which is much closer to the current consensus of 4.6 billion years rather than 5943 years, as calculated by 17th Century Vice Chancellor of Cambridge University, John Lightfoot (Livio, 2014) (that the earth was created in 3928 BCE). Vedas regarded that cosmos is eternal, recurring and cyclic, which is strikingly close to the current scientific understanding that the earth underwent cycles of warming and ice ages. In contrast, the Christian world considered the earth is constant as in non-repeating straight-line as it were created by the god. Concepts of intermittent pralayas (dissolution) and mahapralayas (great dissolution) as mentioned in Vedas suggest that ancient Indians were very well aware of modern geological concepts of extinction and great extinction events, respectively. Concepts of human evolution too can surprisingly be found in ancient Indian literature, with 'dashawatara'-ten incarnations of Lord Vishnu, passing through stages strikingly close to the current understanding of vertebrate evolution; Matsya (Fish)-Kurma (Tortoise)-Varaha (Boar)-Narasimha (man-lion)-

Vamana (dwarf man)-Parashurama (man with axe). Famous British evolutionary biologist, J.B.S. Haldane had been awestruck by the 'striking' similarity of dashavatara with the vertebrate evolution (Dronamraju, 2010). The causes and processes behind the evolution were not deliberated in Indic philosophy, as far as I know. My argument is not to adopt these speculative and vague concepts as it is in the syllabi; but to make the students feel wonderful in our ancient sage's ingenuous and scientifically sound fantasy, and it will aid in appreciating Darwinism having seen through our cultural perspective. None of these can be found in syllabi of evolutionary biology across Indian universities. Paleontology part of the syllabi as well is very much skewed to the West, with in-depth coverage of lagerstätten of Canada, USA, China etc., but that of the Indian subcontinent (e.g., Kota, Lameta, Maleri, Mandla Formations), being mostly omitted. Works of Birbal Sahni and Pramatha Nath Bose-famous Indian paleontologists, and M.S. Krishnan, Waman Bapuji Metre and Bangalore Puttaiya Radhakrishna-famous Indian geologists, should be included in the syllabi, so as the fossil parks of India and geological history of Indian subcontinent. Some of these sections can be found occasionally in the geology syllabi of a few universities though, but these are by and large not universally adapted across Indian universities.

Environmental Sciences/Ecology

Environmental Sciences is yet another discipline that is expected to benefit greatly by the addition of topics of national significance. These include Ecological and Biogeographic zones of India, Ecology of Himalayas, Western Ghats, Thar Desert, Mangroves and Gangetic Delta. Protected ecosystems in India should be covered in depth, including National Parks, Wildlife sanctuaries, Biosphere reserves and wetlands. Indian coastal ecosystem is altogether missing across the present syllabi, including island biogeography of Andaman and Nicobar Islands and Laccadives Archipelago. For a majority of students, the biome 'Savanna' is either in the United States or in Mediterranean and they do not know a Savanna (Terai Duar) exists in India, an issue that clearly portrays problems with ecology syllabi across the country. Environmental sciences syllabi across the nation also omit Bhopal disaster, Uranium poisoning in Punjab or endosulfan contamination in Kerala altogether while describing issues like Chernobyl, Minamata or 'The Silent Spring' in-depth. Environmental pollution is covered in depth but does not focus on Indian issues; for example water pollution from Najafgarh Drain, Delhi or Cooum River, Chennai. Practical solid waste management and sewage treatment scenarios keeping in mind issues pertaining to India are also lacking in the syllabi. Most contemporary environmental researches on problems of pollution stop at the monitoring level and verification of pollutants. These hardly ever go to an extent of remediation or recommendation of policy changes, and therefore researches are oftentimes incomplete. While locally pertinent examples of pollution should be taught to our students, methods of its remediation and treatment are universal. A number of localities in India face extreme water scarcity or water contamination including Runn of Cutch, Gujarat and Thar Desert, and topics concerned with efficient and practical water management should be included in the syllabi. India, by virtue of its deep-rooted religious practices, had been conserving bio-resources since time immemorial in the form of sacred-groves (Khumbongmayum et al., 2005; Bhagwat and Rutte, 2006; Gadgil and Vartak, 1976), and an in-depth understanding of sacred-groves in biodiversity conservation should be included in the environmental sciences syllabi. Other topics of national importance include effects and the mitigation of climate change in the subcontinent, factors affecting formation of cyclones in Bay of Bengal and its prediction, renewable energy resources pertaining to India- especially much neglected tidal power and wave power, Indian ocean warming and its effect on monsoon and sustainable utilization of petroleum and mining resources of India, pesticide contamination of vegetables and grains across the entire subcontinent -almost all of which are neglected in the current science syllabi in Indian university curriculum. A large number of new textbooks on these neglected subjects need to be prepared in order to effectively teach them.

Animal Sciences

For decades, zoology students of our nation were studying about animals commonly found in Americas or Africa. While there are books on a few animal orders (for e.g. that on mammals (Menon, 2009)), surprisingly there had never been a book on Indian animals, prior to the book that I have recently published- that detail systematics, conservation status and phylogenetics of commonly found Indian animals (including both invertebrates and vertebrates, both aquatic and terrestrial (Bast, 2014)). When I asked my M.Sc. students to prepare a database of animal taxa found in India from a systematic point of view as an assignment, they have come up with long lists of animals, but most of the animals were endemic to Americas or Africa! Students were surprised to learn common animals included in their lists like giraffe, chimpanzee, hippopotamus, ostrich, zebra, etc. not found in India except in captivation. Zoology/Animal Sciences syllabi in Indian universities should prioritize on dedicating a section on endemic animals of India, including that of the much-neglected aquatic habitats.

Plant Sciences

Plant sciences/Botany syllabi are mostly well-crafted and cover economically important plants of Indian subcontinent. However, a number of elements of national importance are lacking. This includes systematics of Indian mangroves, common seaweeds and seagrasses of Indian coastal region, common terrestrial and freshwater algae of India, and common bryophytes and pteridophytes of India. A section on endemic plants (including algae) of Indian subcontinent is highly recommended (Bast et al., 2014).

Improvisation of Course Resources

Science syllabi in Indian universities typically list textbooks as resources/suggested reading. Dedicated textbooks are available for most of the established courses owing to the fact that either such textbooks are prepared to cover the syllabi, or, as usually is the case, syllabi are prepared from sections of available textbooks. However, this is grossly insufficient and encourages the students to cram for examinations. Given the rate at which existing scientific theories are getting falsified and paradigm shifts are happening on a daily basis (Kuhn, 1974; Popper, 1963), keeping up to date with the latest research developments is of paramount importance for the science students. It is, therefore, suggested that other resources for enhancing and supplementing students' knowledge-sphere with contemporary scientific research should be enlisted, and questions from this section are periodically included for learning assessment. Some of the suggested immersive interface resource types include:

Podcasts: Podcasts are recorded radio shows/talk shows freely available online. The audio file can typically be downloaded automatically (using software such as iTunes or MusicBee) as and when a new episode is released, and be synced with portable mp3 player or phone for listening offline. There are a number of informative science podcasts that discusses the latest development in a non-technical language. Some of the popular science podcasts include NakedScientists, NPR Science Friday, BBC Discovery, Nature Podcast, Science Mag podcast, Scientific American and National Geographic Weekend. There are a number of specialized podcasts available as well, catering to such subjects as astronomy, biotechnology, chemistry, genetics, geology, marine biology, mathematics, physics, and so on. For listening to podcasts a computer or portable media player (media player functionality is available in vast majority of today's feature phones) is required, and therefore might not be feasible for students who cannot afford to have them.

MOOCs: Massive Open Online Courses (MOOCs) are comparatively a new e-resource offered by a number of firms in partnership with universities in which enrollees can take the course online free of charge. MOOCs typically include recorded video lectures, lecture handouts, discussion forums and periodic assessment of progress by way of online quizzes. Upon successful completion, a number of MOOCs offer valid certification. At the time of this writing, notable MOOCs are Coursera, Udacity, edX and Khan Academy. For subscribing to RSS/Atom feeds a computer with internet connectivity is needed and admittedly not feasible for those living in remote areas and for those who cannot afford them.

Popular science magazines: There are a number of popular science magazines which students can make use of. Surprisingly, majority of the university science students are unaware of the very genre and existence of popular science magazines. Notable international popular science magazines include Scientific

American, New Scientist and Popular Science. Famous English popular science magazines published in India include Science Reporter and Resonance. Apart from these, a number of popular science magazines are available in regional languages in India.

RSS/Atom feeds of relevant research Journals: Real Simple Syndicate (RSS)/Atom feeds make it very easy to track new articles published in peer-reviewed research journals in the relevant subject field. Feeds of journals can be subscribed using web-based feed aggregator like feedly.com. Instead of checking at each journal's website for new articles, aggregator consolidates articles from each journal, making it extremely convenient to get updated. For subscribing to RSS/Atom feeds a computer with internet connectivity is needed and admittedly not feasible for those living in remote areas and for those who cannot afford them.

Newspapers: Every major newspaper in India has a dedicated Science and Technology weekly supplement. For example, Science and Technology supplements of the Hindu, Times of India and Hindustan Times. These supplements carry news on significant scientific developments with a national focus. It is suggested that all science students be regular readers of these supplements.

Online multimedia resources: A number of free online resources are available to supplement university science curricula. Examples include a number of hypertext books like that offered by MIT and Nature magazine, educational videos available in YouTube and presentations on science available in TED/TEDx. Admittedly, a number of publically funded educational institutions in the country, especially those from remote villages, are facing extreme scarcity of funds for them to have required infrastructure.

Other Creative Pedagogical Suggestions

Apart from the aforementioned propositions on improvisation of science syllabi, it is expected that the university science curricula will greatly be benefitted by engaging some of the widely adopted practices of creative pedagogy. Detailed lesson plans are almost non-existent in universities and are required to be developed for effective implementation of the course. A well-developed lesson plan should correlate with the teacher's philosophy of education and contain objectives, instructional component, independent practice, summary, analysis, continuity and so on. Other suggestions include implementation of ICT, summer/winter research internship, and training in collaborative and interdisciplinary research.

Implementation of ICT

Information and Communication Technologies (ICT) significantly foster dissemination of course contents to a much wider audience, not merely limited to the students taking the course (Tondeur *et al.*, 2007). Apart from a few institutes including some of the established IITs, not many institutes or science faculty from India have implemented ICT in university education. Faculties have a perception that ICT need to be implemented by their institute via official websites, not by the faculty themselves, which is not true. Faculty can very well implement ICT by means of their personal website, or via online repositories, such as that offered by Greenstone. An example for ICT implemented through website can be found at http://sg.sg/bastfelix (Fig. 3).

The website is hosted freely by Google sites and most of the contents are hosted by Dropbox-a free cloud-based back-up. Contents disseminated via this site include recorded video lectures of the class hosted at YouTube, audio-stream of lectures, PowerPoint presentations, lecture hand-outs, course materials including free e-books, pdf files of scholarly literature referred to in the class, solved quizzes and question papers, consolidated student assignments and term papers, and pertinent hyperlinks to news items, podcasts, and MOOCs. Implementation of ICT also enable this website to foster anonymous submission of the student feedback questionnaire. This was done using embedding of Google Forms- which is linked to a spreadsheet (Google Sheet) database. In addition, the website enables the faculty to share updates of research projects and research expeditions with locations embedded within Google Maps, pertinent multimedia including microphotographs and videos, students' dissertations, and faculty publications. Besides, this site made use of Google Analytics for detailed analysis of usage statistics, including

Figure 3 — An example of ICT-enabled faculty website for course content dissemination. 1. Course pages. 2. Research page. 3. Course overview. 4. Downloadable presentation. 5. Recorded video lecture, embedded from YouTube. 6. Pertinent external links, reprints of references discussed etc.

temporal data of number of persons accessed, their geographical location information (countries), accessed dates, and user's Operating System and Browser information. All these require only basic computer knowledge and infrastructural support; even then, admittedly, might not be practical for those from remote villages due to scarcity of funds and limited computer savviness.

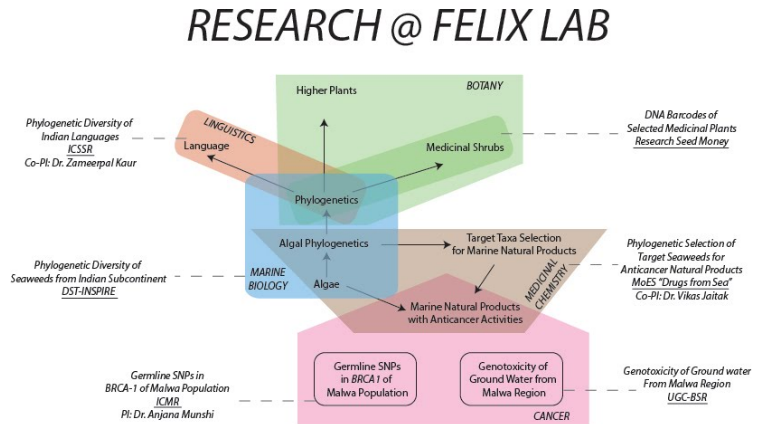
Summer/Winter Research Internship and Studying Abroad

Established and public-funded research internship programs for university science students are available in India. This includes Science Academies' Summer Research Fellowship Program instituted by the Indian Academy of Sciences and Indian National Science Academy; and independent Summer Training Programs of a number of premier research institutes including TIFR, NCBS, IISc and JNCASR. Unfortunately, majority of the students are either unaware of these programs, or their academic calendar or educational institutions do not let them take up an internship. It is expected that the internships will greatly help the students to get accustomed with the primary research and might inspire them to pursue research degrees upon graduation. Students should be encouraged to apply for these programs, or should be offered internship in-house by letting them work with a PhD student during the holidays. Students should be encouraged to avail internship at a place with different linguistic environment (another state with different language) for them to improve communication skills, as well as 'conditioning' for adaptation to various cultural landscapes. There is also a wide consensus on the advantages of studying abroad that include global engagement, cross-cultural experience, strategic international understanding, flexibility, broadening perspectives and broadening post-college career goals (Dwyer and Peters, 2004; Paige et al., 2009; McKeown, 2009). Students should be informed of various overseas scholarship programs mediated by the Ministry of Human Resources and Development, Government of India, including Monbukagakusho-MEXT Japanese Government program, Commonwealth Program for commonwealth countries and so on, as well as procedures for getting admission into graduate programs of US (GRE and TOEFL).

Collaborative and Interdisciplinary Research

One of the major issues that science in India is facing is the scarcity of collaborative and interdisciplinary research. Students should be informed of the importance of collaborative and interdisciplinary research with some class assignments or projects exemplifying each of these. In addition to inter-science research, importance of research involving science and humanities, or science and liberal arts, should be thoroughly explained. For example, research in my group involves disciplines including Sciences and Liberal arts (Fig. 4). Equally important collaborations are those requiring basic research and applied/industrial research and public-private partnerships — both of which are relative rarities in India.

Figure 4 — An example of interdisciplinary research flow-chart spanning disciplines including Sciences (Marine Biology, Chemistry, Cancer Biology and Botany) and Liberal Arts (Linguistics). As seen in the figure, at least three research projects are collaborative.



Conclusion

Science syllabi in university curricula in Indian universities need a serious overhaul keeping in mind issues of national importance. This paper made a cause for the inclusion of two new core courses: History of Science and Scientific Ethics- dearth of which have been gravely affecting the science education in Indian universities, as well as 'indianization' of some of the existing courses. One reason for the problem of syllabi not covering the local issues is that a majority of science textbooks published from India are, in fact, based on textbooks published from elsewhere, notably England and USA, and the syllabi adapted by universities here are in turn based on those textbooks. Other science courses that I have less knowledge also need to be thoroughly revised keeping in mind the issues relevant to India. Other propositions of the current undertaking include expansion of resources for enhancing and supplementing students' knowledge-sphere with contemporary scientific research, including Podcasts and MOOCs, and implementation of creative pedagogical methods, including a well-developed lesson plan, ICT through personal websites, summer/winter internships, studying abroad, and collaborative and interdisciplinary research. A nation-wide effort to 'Indianize' our syllabi and textbooks, along with its timely (preferably annual) revision, is the need of the hour.

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