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BUILDING INTERDISCIPLINARY BRIDGES FOR SCIENCE

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Abstract: Our world increasingly depends on new scientific and technical discoveries and inventions. Often, those with highest potential impact for the human condition (such as DNA editing, nanoscale electronic devices, etc.) intrinsically involve interfaces between classical scientific disciplines. Similarly, there is a need to nurture interfaces between scientists and the general community. This 'opinion' essay suggests some areas where we can take constructive steps to promote healthy, well-integrated progress of enterprising research, with optimal implementation, supported by community awareness. Timely action is needed, not only to develop updated formal academic curricula, but also to create attractive options for up-to-date life-long learning.

Key Words: Inter-disciplinary integration, science education; community outreach, scientific literacy.

Connecting the Disciplines

We are fortunate to live in a world where the bountiful fruits of fast-developing science and technology enrich the lives and accomplishments of most people on the planet – and influence the development of the whole global community. It is increasingly apparent that good research planning and effective application of our new discoveries must rely on responsible and well-informed integration of information and expertise from diverse (yet intrinsically connected or overlapping) fields of science, engineering, and policy.

This situation presents a fine opportunity for our educators to consider innovative and constructive ways to develop both tools and systems that will stimulate and assist interdisciplinary communication among the many fields of science. A key to success will be effective communication between scientists and the institutions of the general community.

It is neither possible nor desirable to contemplate total intermixing of disciplines. Instead, we need to consider building bridges that will facilitate contact and interaction among people who work in diverse fields, and also facilitate their contact with people in the broader community. Such bridge-building is often an unfamiliar art that will demand the best skills of our communities of Education and Policy in order to bring it to full fruition.

The following paragraphs illustrate some types of bridge building that are needed, and some corresponding actions to consider for building those bridges.

Interdisciplinary Bridges among the Sciences

In many school programs and institutions, and in research programs and professional journals, the historical separation still prevails between Physics, Math, Biology, Chemistry, Metallurgy, etc. despite a growing focus on STEM education designed to encourage integrated studies in technical topics. Meanwhile, increasingly it becomes clearer that many of the newest and best research discoveries and technologies depend on expert interaction involving two or more of the separate disciplines. One conspicuous example lies in the ongoing spectacular progress of biomolecular science research, medical sciences, and genomics. In this new era, much progress is clearly driven by integration at the boundaries between the separate disciplines, for research, enterprise, expertise, and collaboration.

New discoveries thrive on cross-fertilization of ideas, and on effective communication, involving a wide spectrum of the sciences, and their applications. Cross-disciplinary collaboration is evident today in research journals and patents, and in consumer products, whose invention and rapid progress to market increasingly stem from linkages forged between hitherto formally disconnected fields, such as physics, chemistry, bio-sciences, geo-sciences, environmental sciences, communications, computer science, and many scientific and engineering technologies.

We may note incidentally that the "new" field titled Materials Science & Engineering emerged during the 1970s, based on the widespread recognition by the research and teaching communities that an impressive scope for future innovation and understanding would be well served by formal integration of curricula under this title. A leading advocate and 'father' of this novel approach was Professor Rustum Roy, of Pennsylvania State University.

Bridges to Community

We need to develop bridges that serve as positive drivers for well-informed decisions, both private and governmental, in areas such as:

- public motivation,
- sound investment,
- effective public health policy,
- societal well-being,
- support of science research,
- setting and execution of government policy – local, national and global

Such bridges will link with areas such as legislation and societal policy, financial planning and management, economic policy, and also urban planning, disaster /risk mitigation, and environmental topics including sustainable food, water, energy and mineral resources. Communication between scientific and civil communities must focus on mutual comprehension and well-founded trust. Good science must be recognized as an integral (and cost-effective) part of policy-setting - at governmental levels, and also in the communities of industry, engineering, commerce and economics.

International Bridges

Sound scientific information and advice are now needed more than ever in fields of universal global impact – where new and locally important research may be wisely supported, with collaboration between well qualified national communities and institutions of advanced technology. In view of the pervasive global links of trade and economics and inter-governmental relations among nations, the landscape of scientific knowledge and its dissemination, recognition, application, and effective implementation must also be global. Research collaborations across international borders can be constructive. Already, much of the community of scientific research functions with strong professional international links (as evidenced by the collaborative publications in research journals and the thriving interactions among participants at international technology conferences.) Additionally, there exists scope for respected international science organizations like the International Council for Science (ICSU), and National Academies to conduct more in-depth, highly responsible scholarly studies whose published reports may indicate paths toward future optimal world-wide strategies for global resource management (such as global energy and water policies), and strategic issues for medical, epidemiological, and public health programs that can only be addressed effectively at the international level. It is of the highest importance that such reports include recommendations that leave no doubt about the meaning and reliability of their key scientific conclusions, so as to provide compelling foundations upon which business decisions can be responsibly based.

Integrated Science Education

Evidently, it is no longer acceptable to plan curricula for primary and secondary schools in which physics, chemistry, biology, and mathematics (and critical thinking) are taught as disconnected subjects. As already recognized in many parts of the world, new curricula have been devised that present science as a logically integrated combination of such topics. This approach makes sense to the students, who then perceive readily the relevance and applicability to their own current and future life experiences. This also can enable the introduction to scientific thinking to be made earlier in school curricula. Such integrated programs of study then prepare students for tertiary education programs that are also designed to reveal, and capitalize upon, the underlying links between previously isolated disciplines. In turn, graduates in science, technology, and engineering will then be realistically prepared for positions of competence, responsibility, interdisciplinary collaboration, and perhaps leadership in the increasingly technological world.

Bridges to the Future. Life-long Learning

A conspicuous feature of the technological and scientific landscape in recent years is its accelerating pace of change. This is apparent in all kinds of diverse scientific fields, including electronics, human health, biomolecular science, materials science, computer science (Big Data), renewable energy, forestry, forensic sciences, geological, oceanographic and climate studies. This applies also for the social sciences, economics, and political science. One of the most important personal assets needed to equip an individual to participate responsibly in his/her community is some level of "Science Literacy". How well can he/she comprehend and responsibly manage life in the surrounding physical and perceptual world, without some basic level of science literacy? Furthermore, in order to remain qualified (and interested) in his/her technical-related job, everyone (including teachers and academics) will need to continuously acquire new knowledge and skills, and be aware of current innovations in advancing science and technology. Hopefully, their early training and education will have endowed each person with skills and motivation for continuous self-education. In that case, they will be prepared not only to follow new or emerging technologies, but also to think laterally, in various different disciplines. By innovating, and inventing their own new techniques, or making their own new scientific discoveries, they will thus contribute to the current and future well-being of mankind. This is one place where a diversified background, and multi-disciplinary competence, can propel us into fruitful and creative careers, over many years. Early mastery of the special art, skills, and tools for life-long learning, and early exposure to multiple inter-related aspects of science (even including esoteric or fundamental topics) can have a major impact on the future – personally for those practitioners, and also for the whole world that benefits from their enterprising discoveries, insights, and outreach.

Challenges for Science Education

The above discussion should not be interpreted as proposing that the ideal future world should be populated by superior beings, each having expertise and in-depth knowledge covering the entire spectrum of science and technology fields and professions. This would indeed be an untenable concept! No, we surely should not expect that every brain surgeon must also be an expert brick-layer, poet, and rocket scientist! Professional and occupational specialization must surely continue to be a basis of our functional fabric! However, it is critical for such specialists to have the skills and tools to support excellent mutual interaction, communication and collaboration. Increasingly, we depend on effective teamwork among specialists in related fields, who can overcome interdisciplinary barriers, comprehend each other's technical (and philosophical) vocabulary, and work together professionally.

How can we best design our education systems and objectives so that they support essential inter-disciplinarily in the modern world, while preserving the important goals of professional excellence and specialist function in the multi-faceted real world?

Within the traditional framework of schooling, a priority for all students and levels must surely be to systematically develop science literacy, while the multi-topic core curriculum is being taught. It is to be hoped that, even when core topics are being studied, the students' interest in interdisciplinary exploration can be sparked.

Promotion of STEM education in traditional school programs is indeed valuable. However, it may not extend into the broadest spectrum of inter-disciplinary topics where bridge-building is most needed – especially those areas linking science with public policy. Future success and function for many people will depend on:

- basic knowledge and skills developed by 'traditional' schooling;
- motivation to sustain awareness of new scientific discoveries and technical achievements;
- life-long use of critical thinking;
- analytical curiosity about the world beyond their immediate environment;
- easy and abundant access to stimulating and constructive resources for learning about new fields.

For whatever purpose - personal satisfaction, career advancement, or even survival - tangible rewards can result from such learning.

Interdisciplinary "bridges" as discussed above need to be devised and built, and made attractive, exciting, and readily available to all. They might take many forms, including on-line tutorials, modular courses, newsletters, conferences, search engines, technical social media, or novel forms of on-line consultation, One often-needed resource would be a well-designed set of lexicons in which the technical terminology that is historically embedded in each of the disciplines is briefly but professionally explained for members of different disciplines, at a level sufficient to constitute a 'language bridge' when needed.

Building 'user-friendly' bridges that actually make interdisciplinary participation compellingly attractive and practically rewarding can surely be one of our biggest educational and organizational accomplishments in the coming years.