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University Education in Crisis?
Transdisciplinary Approaches in the Arts, Humanities & Sciences

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Abstract

The modern approach to University education and research cuts across traditional boundaries. In order to obtain maximum benefit from research effort globally, universities need to adapt their approaches to the management and organization of research and teaching, to foster transdisciplinary working and promote global mobility for the next generation of students.

1. Introduction

This millennium will see revolutions in a range of technologies, from medicine to transport, that will have transformational effects on society. With new tools, new insights and understanding, and a developing convergence of the disciplines of physics, chemistry, materials science, biology and computing, we will realize novel and superior products and systems that were, until the 21st Century, the stuff of science fiction. This will not be possible without collaborative working between disciplines.

Up to now, academia has been strongly oriented towards specific academic disciplines. However, most of the problems that research and education are supposed to solve are not defined in terms of disciplines, yet these problems are precisely the ones that are urgent: *viz* the environment, energy, and health. There is a disconnect between the development of problems and the development of disciplines, and this disconnect is growing to the extent that discipline development is increasingly determined by hyper-specialisation.

As an example, *Cognitive Information Processing* and *Cognitive Computing* will be important technologies of the 21st Century and will require the input of researchers across solid state and organic chemistry, biology and medicine, physics and mathematics, information and computing sciences, and engineering if their potential is to be fully realized. Such a transdisciplinary approach is indispensable to accommodate complex industrial and societal needs. There is a challenge for Universities in addressing this, in formulating degree programmes without losing intellectual depth in delivering the "broad band" of materials required, and/or do not simply lead to multiple pathways to final qualification confusing for both students and teachers alike. That said, the growing fields such as nanotechnology, bio-intelligent materials, biomimetics, cognitive informatics and cognitive computing etc., will not prosper without intensive crossover and interaction between disciplines.

The University has to change: because its environment (social as well as institutional and regulatory) is changing. Many conventional jobs will disappear in the near future, certainly by the time pupils currently in primary education graduate. The transformed job market also means that many new jobs will be created; premium will be on candidates with flexibility and an open mindset.

Governments now realise that new scientific knowledge holds the key to our future wealth and health: many new medical drugs and industrial products are based on discoveries made in universities. The industrial hub shifts in the USA from the traditional steel in Pittsburgh and car making in Detroit to high-technology companies based around MIT and Silicon Valley companies based around Stanford university and the university of California are a foretaste of change. If Europe is to compete successfully with the USA and now China, it has to focus on high-technology products and the ideas and materials from our universities. Hence governments around the world are now intensively interested in their universities, so the advancement of a trans-disciplinary agenda is timely.

A key feature of the university-of-the-future must be flexibility: we must make it easy for an engineer to learn Chinese or an Indian language, history and culture without this being an additional burden. Concerning research, we must acknowledge that much of the most exciting and useful research is occurring at the boundaries between traditional disciplines. Many biologists who design new medical drugs were trained as physicists. Many new materials for next generation mobile phones, computers, cars and planes are designed and developed by materials scientists working with chemists, physicists and engineers. A university departmental structures is not geared to preparation for this New World, and may be the barrier to, rather than a catalyst for, multidisciplinary research.

A major concern is the increased administrative burden being placed on universities by government regulation and reporting. There is often a disconnect between the administrative functions of a university and the primary activity of research and teaching.

2. Enhancing the Education, Research, and Innovation Base

Societal challenges are becoming more complex and tangled.

University education is integral to the welfare and well-being of global society, and it is recognized that good education systems underpin prosperity and stability. The challenges are to now provide trans-disciplinary education that can be a model for use around the world.

A. Multi- Inter- and Transdisciplinary Education

A *Discipline* is a sub-field of science, engineering, humanities, etc. with a specific approach, fundamental concepts, language, methods and tools, that aims to analyse, understand and describe parts of Nature.

Multi-disciplinarity is where several disciplines come together in parallel to tackle one subject.

Interdisciplinarity is where the concepts and methods of one discipline are used in the work of another discipline.

Transdisciplinarity is a holistic approach that sees all aspects of the world interrelated through patterns of interdependent systems. These include natural, social, economic and political systems. Transdisciplinary integrates knowledge and methods from any source that can be of value in addressing a particular problem or research question. Essential requirements for any transdisciplinary work are an innate curiosity and patience; and understanding of other disciplines and their languages takes time and commitment. Transdisciplinary research and teaching cannot be restricted to traditional boundaries.

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B. Challenges for Inter- and Trans-disciplinary Activities

- *Language*: Each discipline creates its own jargon. I/T-disciplinarity requires the appropriation and accommodation of different languages, meaning communication of I/T-disciplinary research and teaching can be difficult since it requires the use of technical terms borrowed from one discipline but that are not well understood by the specialists from other disciplines.
- *Methods*: Disciplines are often devoted to their own methods of investigation. This may lead to misunderstanding and opposition.
- *Institutional constraints*: Institutions are mostly disciplinarily organised, creating barriers for I/T- disciplinarity; though strong, well-defined disciplines are necessary as any interdisciplinary activity starts with a deep understanding of single disciplines.
- *Cognitive constraints*: It is very difficult for an individual to become expert in two or more disciplines. An in-depth knowledge of different disciplines is however the requirement for genuine I/T-disciplinary research. This raises the question of the impact of these difficulties on education and on the institutionalisation of interdisciplinary training programs.
- *Assessment*: Experts (reviewers) for evaluating the results of M/I-disciplinary research and education are lacking. Standardised bibliometric information is scarce and not representative. New ways of quality assessment need to be developed.
- I/T-disciplinarity requires mastering of more than one discipline in depth. Superficial learning of several disciplines does not lead to meaningful I/T-disciplinary research and corresponding solutions of complex problems.
- Experience has shown that learning the essentials of several disciplines has to be done consecutively, not in parallel: for example, doctoral studies in one discipline and post-doctoral work in another.

These challenges are the very reason that a concerted effort needs to be made to create the very conditions that engineer trans-disciplinarity. There is a need to start early—at secondary school stage—where the balkanisation of topics create an undesirable specialisation. A wider choice of learned subjects will prepare the student to accept trans-discipliarity as a valued norm and not as an inferior generalism. This is the mindset of the 19th century; no longer suited to these times. The guiding principle would be an alloying of physical, biological and arts subjects. Excellence can be equated therefore with versatility and not with narrowness, often masquerading as depth. The formula of a specific discipline mix is not the critical factor but its existence, and it would contain ~6 examinable subjects. Motivation for this needs to come from the Universities and industries jointly to demonstrate the added value for careers of flexibility and a future ability to move careers in a world where the job for life concept is disappearing. Without leaders presenting a convincing case the status quo will remain; such a case would embody intellectual, economic and prestige benefits. If not made at the highest level then a student will not seek the adventure of transdisciplinarity.

Multi-domain education to a high level poses greater learning challenges for the individual and it cannot be that all can grasp the demanding agenda. So a degree of selection is inevitable; this can be based on the 6 subject performance—a key entry requirement. This also benefits society by specifically identifying research 'translators' as well as non-discipline specialists —both will be needed. Selecting out the different aptitudes is surely as important as selecting out an excellent candidate for a single subject degree.

With and intellectual openness a university student can take the new education in their stride, feeling enriched by the added dimensions. To achieve this there cannot be a token move to transdisciplinarity, otherwise failure is inevitable. The optimum way to avoid this is to embed precious, valued disciplines in entirely new environments—physics into biology, chemistry into medicine, robotics into bioengineering, etc. Precise choice is not critical; it is the juxtapositions alone that will fire up the new culture, but a desirable mix would combine biological and physical/engineering sciences with numeracy skills as an integral. Instead of the medicine paradigm, other delivery disciplines may thus be reinvented: environmental science, materials/manufacture, energy, human geography. Operationally beyond the taught elements, a research project would be a transdisciplinary one. The output is both a graduate able to accommodate other disciplines and a teacher able to absorb concepts from another domain. Ultimately such an intellectual convergence will bring down the above barriers, and in short, a re-invention of 'The Department' is envisaged.

At postgraduate stage, hyphenated MScs of equal prestige to PhD could be developed where a sequence of 3 years exposed students to different topics, with a sequence of biology, physical/computation science and core engineering. At the end of this would be an appreciation of the universality of fundamental concepts. Such a graduate direction could have to be accommodated within the current ecosystem that prioritises the PhD focus and its value in the generation of publications.

C. Importance of Inter-Trans disciplinarily for Universities

Inter/Trans-disciplinarity matters because, in the real world, most scientific, technological and social problems do span different disciplines: so in the future, graduates have to operate in a multi-disciplinary environment, very different from what has existed in the past. The present generation of students must be convinced that they will have good careers if they take a research route in their early years, and that University research leads to careers other than in academia. Whilst today, someone with inter/trans-disciplinary expertise might be viewed as a generalist, in the future this could be regarded as a specialism. For example, a graduate with three Master's degrees in biology, informatics, and engineering, may, in the future, be better off than with one PhD in biology, etc. Interdisciplinary degrees need to be defined in a sensible way that does not simply double the workload and content. It should be possible to opt for a full MSc inter-disciplinary degree enveloping various Faculty disciplines. University courses must be broader and open to related disciplines thus giving to the students the predisposition to interdisciplinary work after Graduation. Industry will be keen to hire these graduates who have mastered the challenge of studying different fields with success and who will also be able to perform trans-disciplinary work and research.

The real need is for the next generation of scientists to know how to move forward when faced with a real-world problem on a technical topic they have never met before, on a realistic time-scale, and with a realistic budget. Future research is aimed to solve problems where an interdisciplinary approach is essential.

The structure of our universities has changed little in the past fifty years. Inter-departmental barriers are often very high, particularly in "traditional" institutions based on small Departments of 10-20 academics focused on a single narrow area. A modern approach, that has been shown to be more useful, flexible, and efficient, is to have teaching activity based in larger Schools, of up to 100 academics, that can be broadly based and which allows for a more comprehensive range of discipline specialists. Research can then be focused either within the School around particular themes, to further linked to cross-cutting University Research Centres that can span Schools and even Faculties to further exploit the opportunities that already exist but which remain latent in current structures.

The primary functions of universities are to educate students, perform innovative and horizon-broadening research, and transfer new knowledge for the benefit of society. Universities need to be flexible enough in their structures, management and culture to constantly establish new interdisciplinary models for the scientific fields of tomorrow.

D. The roadmap for the Inter-Trans disciplinary Universities of the Future

There is a need for a change in approach, and a revisitation of recent trends, in fully enabling Universities to become incubators of successful inter/trans-disciplinary research.

For University Leaders, there needs to be:

- Recognition that teaching is primarily for students who will not become future academics, and who will be pursuing careers that do not exist yet;
- Recognition that research and teaching must be closely linked, so that students will benefit from the new ideas of knowledge that research will provide;

- Recognition that research changes very rapidly. It is therefore good practice to develop teaching within large Departments with strong vision for curriculum and continuity, and have research institutes into which it is easy to bring people from various departments for the span of a project. But this does not imply a separation of the people who will be delivering the teaching and conducting the research.

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For Funding Agencies, there needs to be:

- A diversity in approach to funding at all levels, since the challenges of interdisciplinary science are so diverse.
- Better integration between funders and those who conduct the research, so that funding decisions are informed by current challenges.
- Successful models that reward and encourage success, and have a low management burden.
- Active encouragement of interdisciplinary approaches in the solution of research challenges.

E. Global University Mobility

In ensuring the move towards globalisation is meaningful and successful, University education plays a vital role. To facilitate collaboration between universities worldwide, it is important that the curriculum and degrees of the various universities are unified. Europe, with its 30 countries and multiple University systems with different curricula, succeeded in realising a uniform University education system called the "BOLOGNA Ministers' declaration". The United States has a system quite similar to Europe, and other continents as South America and Asia should move towards a global unified system in the future.

An intercontinental University education system demands great efforts from Universities and governments. A global, uniform education system which facilitates contact between students and academics from universities and nations on a global scale will result in multiple benefits in education quality, mobility, and cultural understanding. The mobility of young students and scientists demands knowledge of foreign languages and cultures and this should also form part of the curriculum.

F. Mobility of Students and Scientists

It is important to encourage greater exchange of students and scientists between disciplines and countries. This would be aided by standardised qualification recognition procedures, world-wide training courses, and official exchange programmes. An interdisciplinary culture must be implanted through educational and funding initiatives. As an example, in the European Union the ERASMUS programme was developed in which possibilities were offered to students and scientists from all countries throughout Europe to study at the faculties of universities of their choice with recognition of their obtained degrees all over Europe.

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G. Global University Curricula

The criteria for a high-level education could be formulated as follows:

- Multi-disciplinary skills
- Literacy in complementary fields
- Exposure to advanced research projects
- Literacy in key technological aspects: exposure to real technological problems
- Basic knowledge in social science, management, ethics, foreign languages
- Literacy in neighbouring disciplines: international business, law, etc.
- Interlinkages between education, research and industrial innovation
- Sharing of post-docs, Master's and PhD students to foster the mobility of permanent researchers and academics between different institutions to create extended, global teams.

3. Technology Transfer: Academia to Industry based on Inter-Trans/ Disciplinary Principles

Technology transfer has become a new buzzword in the academic world. Everywhere in the world, research institutions within universities look at their American counterparts with envy and respect. The goals of research are to explore new frontiers, and creators of industrial innovations that lead to globally successful initiatives rank alongside Nobel Prize winners in their universities. The academic entrepreneur is, however, a very rare species and likely to remain so. It is, therefore, essential to promote collaborative research between universities and industry.

The inter/trans-disciplinarity aspects, together with the exchange of ideas and inspiration to innovate, will form the building blocks for the successes of the university-industry research. The synergy between university-based and industry-based research teams has been an important factor in the success of US research, exemplified by the excellent "Industry-University" laboratories established by DuPont, IBM, AT&T, and Corning. These laboratories have in themselves produced several Nobel Prize winners.

The conflict of curiosity-driven science and the current needs of society are as old as science itself. One needs only recall the famous encounter between Faraday and King William IV, who once asked the celebrated scientist what his "electricity" was actual good for. Faraday answered, "One day you will tax it."*

This is not to say that University research should be an extension of industrial development programmes. Allowing scientists at universities to pursue curiosity-driven research free, from commercial constraints is the only way to ensure a truly innovative research environment. In the long term, private industry and the economy will benefit from the new ideas and discoveries that will be made.

4. Conclusions

Universities have historically focussed their education and research towards specific academic disciplines. Most of today's problems that research and education are needed to help us solve are not defined in terms of disciplines, and these problems are precisely the ones that are particularly urgent: examples are the environment, energy and health.

It is not enough to *value* the links between experiences, disciplines, creativity and ideas. One has to develop methods, strategies and practices that will transform those links into real connections. We have to recognize the need for interdependence in order to actualise it, and we have to know how to act once we have developed that recognition.

In ensuring a broad-based education that is globally-recognised and allows for global mobility of students, there is a need to develop a World University System that promotes networks of universities with shared qualifications and close research collaborations.

Governments, Ministries for Education, Research and Innovation together with Presidencies of universities, all over Europe, should take action to reform our university systems for the future welfare of the economy and society.

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* Faraday was right.