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Education for full employment. Closing the gap between education and future. University education in crisis? Transdisciplinary approaches in the arts, humanities and 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.*

Keywoords: *Education, University, crisis, transdisciplinary, technology, jobs disappointment, internationalization.*

Sommario: *L'approccio moderno all'insegnamento universitario e alla ricerca passa ancora per confini tradizionali. Per ottenere il massimo beneficio dallo sforzo globale dalla ricerca, le università hanno bisogno di adattare i loro approcci alla gestione e all'organizzazione della ricerca e dell'insegnamento, di incoraggiare il lavorare transdisciplinare e di promuovere la mobilità globale per le nuove generazioni di studenti.*

Parole chiave: *Insegnamento, università, crisi, approccio transdisciplinare, tecnologia, delusione dei lavori, internazionalizzazione.*

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 practical 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: e.g. 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 who are qualified in fields including 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. A transdisciplinary approach is indispensable for addressing complex industrial and societal needs. Consequently, there is a challenge for Universities to formulate degree programmes without losing intellectual depth in delivering the "broad band " of topics required – programmes that do not simply lead to multiple pathways to final academic qualification, confusing both students and teachers alike. That said, the growing fields such as nanotechnology, bio-intelligent materials, biomimetic, cognitive informatics and cognitive computing etc., will not prosper without intensive crossover and integration among disciplines.

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

Governments now realise that new scientific knowledge holds the key to our future wealth and health For example, many new medical drugs and industrial products are based upon discoveries made in universities. The shifts of industrial focuses in the USA from the traditional steel in Pittsburgh and car making in Detroit to high-technology companies such as those based around MIT, Silicon Valley, Stanford Univer-

sity and the University of California are a foretaste of change. If Europe is to compete successfully with the USA and now Asia, it must focus on high technology products and the ideas and materials from our universities**.** *Hence, governments around the world are now becoming more intensely interested in their universities, so the advancement of a universal trans-disciplinary agenda is timely*.

A key feature of the university-of-the-future must be flexibility: We must make it easy for an Engineering or Science student to develop knowledge and expertise in multiple topics including, if appropriate, social sciences, economics, or foreign languages, 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 devices, computers, cars and planes are designed and developed by materials scientists working with chemists, physicists and engineers. A 'traditional' university departmental structure is not geared to preparation for this New World*, and may be a 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 activities of modern research and teaching.

Enhancing the education, research, and innovation base

Societal challenges are becoming more complex and their solutions require new thinking that has to utilize influences from multiple intellectual sources in our world.

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. Our challenges now are to provide trans-disciplinary education that can be a model for adoption and use around the world.

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.

Multidisciplinarity is the case where several disciplines come together in parallel to tackle one subject.

Interdisciplinarity is the case where the concepts and methods of one discipline are used in the work of other disciplines.

Transdisciplinarity is a holistic approach that sees all aspects of the world inter-related through patterns of interdependent systems. These include natural, social, economic and political systems. Transdisciplinarity 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 basic understanding of other disciplines and their languages. This takes time and commitment. Transdisciplinary research and teaching cannot be constrained by traditional boundaries.

Challenges for Inter- and Trans-disciplinary(I/T) activities

- ***Language***: Each discipline creates its own jargon. (I/T)-disciplinarity requires the appropriation and accommodation of different languages/ This means that communication of I/T-disciplinary research and teaching can be difficult since it requires the use of technical terms borrowed from one discipline, that are not well understood by the specialists from the other discipline.
- ***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. However, strong, well-defined disciplines are necessary as any interdisciplinary activity starts with a deep understanding of single disciplines.
- ***Cognitive constraints***: It is often 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 re-

search. 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 multidisciplinary 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 transdisciplinarity. There is a need to start early – at secondary school stage – where the balkanisation of topics can create an undesirable specialisation. A wider choice of learned subjects will prepare the student to accept transdisciplinarity 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 humanities subjects. Excellence can then be equated with versatility and not with narrowness, which often masquerades as depth. The formula of a specific discipline mix is not the critical factor for its existence, and it might contain ~6 examinable subjects**.** Motivation for this change needs to come from the Universities and industry 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 fast disappearing. Without leaders presenting a convincing case, the status quo will remain; such a case would identify intellectual, economic and prestige benefits. If this curriculum development is 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 mono-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 an intellectual openness, a university student can take the new education in his/her stride, feeling enriched by the added dimensions. To achieve. this there cannot be only 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. *The precise choice is not critical. It is the juxtapositions alone that will fire up the new culture, but one such desirable mix would combine biological and physical/engineering sciences with numeracy skills as an integrating ink. 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 bringing 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.

Importance of Inter-Trans disciplinarity for Universities

Inter/Trans-disciplinarity matters because, in the real world, most scientific, technological, and social problems do span different disciplines. So in 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 an integrated-topic

study route in their early years, and that integrated University programs can lead to careers other than those in 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 specialisation For example, a graduate with three Master's degrees in biology, informatics, and engineering, may, in 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 M.Sc. 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 and teaching can then either be focused within the School around particular themes, or on be 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

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 may 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, knowledge and skills that research can 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 from those conducting the research.

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.
- Effective communication and co-operation between funders and those who conduct research, so that funding decisions are informed by evolving 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.

Global University Mobility

In ensuring that 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 become 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 that of Europe, and other continents such as South America and Asia will hopefully 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 scientist's demands knowledge of foreign languages and cultures and this should also form part of the curriculum. Of special future significance is the likelihood that collaborative education programmes may develop between universities in other countries, facilitated by Internet-enabled communications and formal courses.

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.

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, Masters and Ph.D. students to foster the mobility of permanent researchers and academics between different institutions to create extended, global teams.

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, as exemplified by the strong "Industry-University" laboratories established in recent decades by DuPont, IBM, AT&T, and Corning. These laboratories in themselves produced several Nobel Prize winners.

The conflict of curiosity-driven science and the current needs of society is 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"[1].

1 Faraday was right.

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.

Conclusions

Universities have historically focussed their education and research towards specific academic disciplines. Many of today's problems that research and education are needed to help us to 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-recognized 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 and academic structures for the future welfare of the economy and society.