Panel 9 - EDUCATION FOR FULL EMPLOYMENT

1. INTRODUCTION

This millennium will see us enter an era of novelties in medicine, transport, society… . With new tools, new insights and understanding, and a developing convergence of the disciplines of physics, chemistry, materials science, biology and computing, we may dare to dream of novel and superior products and systems that were, until the 21st Century, the stuff of science fiction. This will not be possible without collaborative links between disciplines.

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 interdependence in order to actualise it and we have to know how to act once we have developed that recognition. *[R. Burnett "Disciplines in Crisis: Transdisciplinary Approaches in the Arts, Humanities and Sciences", http://www.eciad.bc.ca/~rburnett/]*

Up to now, the academic education has been strongly oriented towards academic disciplines. In this, it is often overlooked that most of the problems that research and education are supposed 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, health

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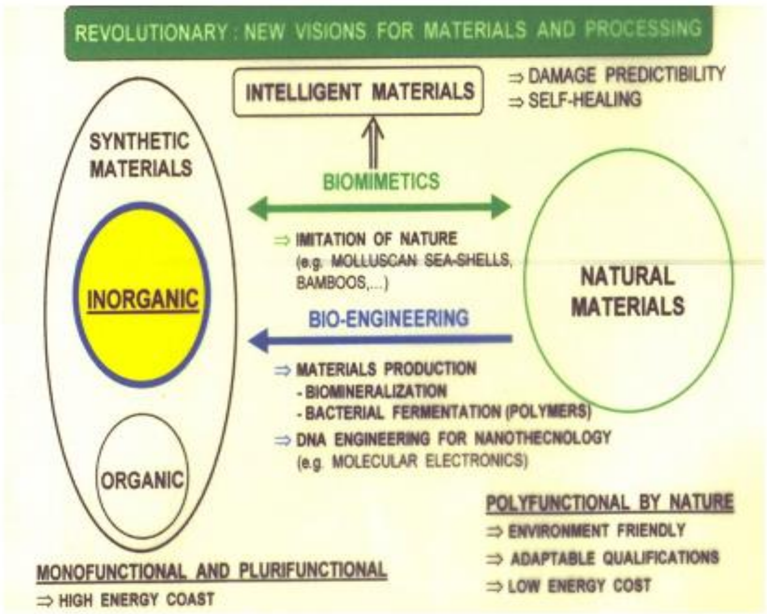

Figure: Example of the potentials of inter-disciplinarity in the chemistry education

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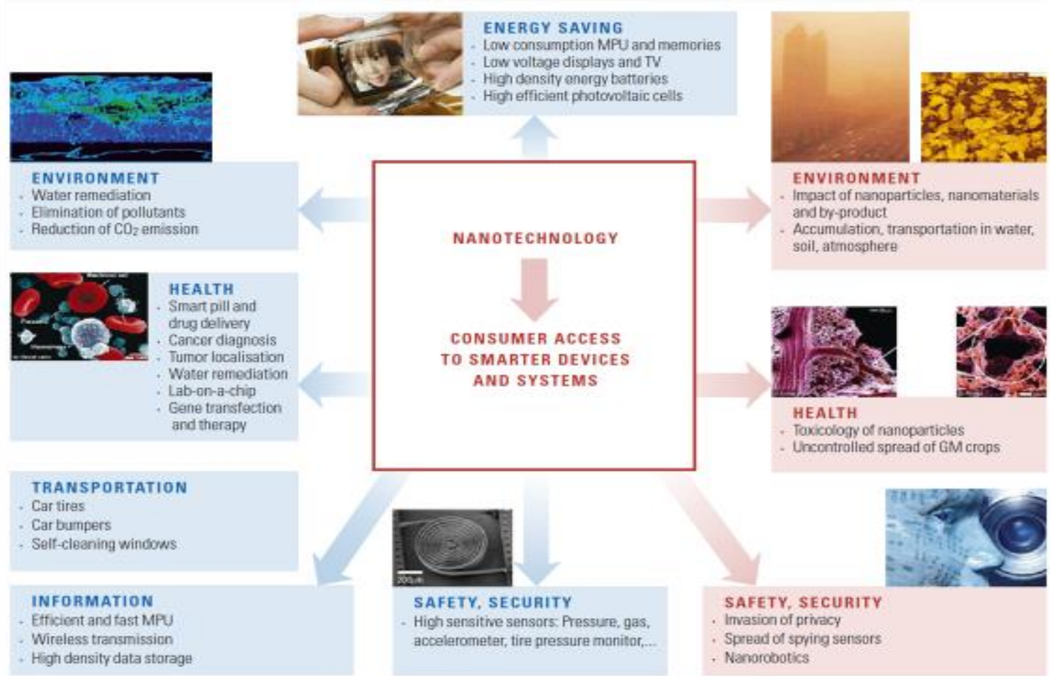
There is an asymmetry between the development of problems and the development of disciplines, and this asymmetry is growing to the extend that disciplinary development is increasingly determined by specialisation. Ecological problems are complex problems, and they can only be solved by the cooperation of many disciplinary competences. The same is true of energy and health.

In this context, the need for inter-disciplinarily is often mentioned. But inter-disciplinarily, i.e. is a cooperation between disciplines with a finite duration, is not enough. The development of the problems tackled by today's Science implies that inter-disciplinarily is more a repair measure than a new instrument of science and research. Figure gives an example of the potential benefits of inter-disciplinarity.

The developments in the world are drastically changing with agriculture as a first revolution, followed by the industrial and information/communication revolutions. Nanoscience and nanotechnology are announced as the fourth revolution in the he 21st century; all industrial developments will be affected as well as the whole society. Figure gives an overview of the potentials of nanotechnology.

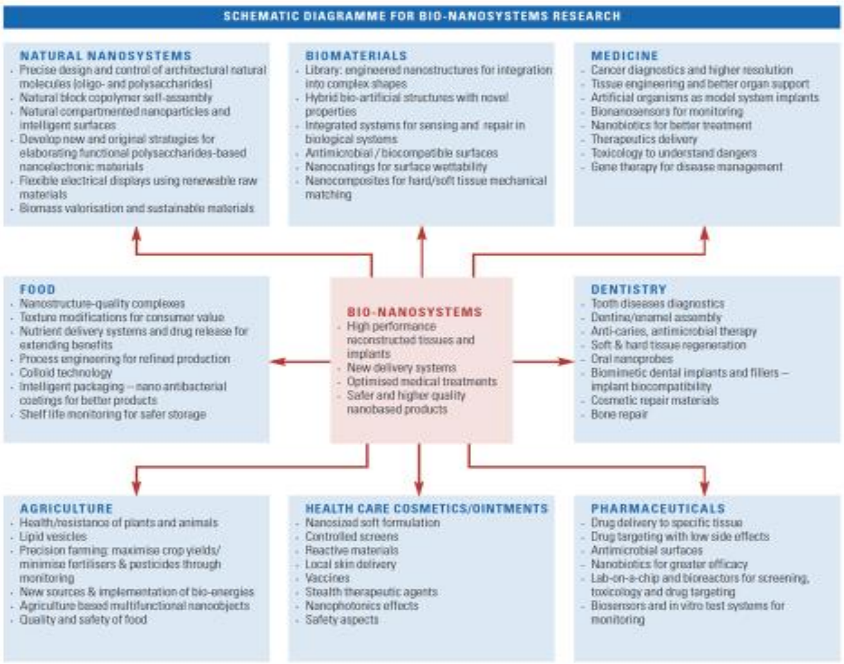


Benefits and risks of nanotechnology; some examples.

Nanotechnology is a typical area where inter-disciplinarity is vital for its developments : discoveries and innovation. Some examples are given in the following figures for the whole health care sector: from nanomedicine to nanoagriculture and foods and health care.

"Bio-medical info-physics engineering" may become in 5 to 10 years an own discipline: the training is to day not available and even not possible due to the inter-faculty rules etc Such inter-trans disciplinary educations within the university need urgently to be issued by decree, in order to make crosswise education in a smooth and prompt way possible. It certainly will demand discipline from the professors and the students to deal properly with the "NEW" freedoms! In order to avoid: i) random course shopping with a loss of the intellectual route by students and ii) the confrontation of professors with a pleads of student's profiles, a structuring mechanism needs to be installed.

The growing fields of nanotechnology, bio-intelligent materials, biomimetics etc etc will not prosper develop without intensive crossover and interaction between disciplines.



Overview of bio-nanosystem technologies.

A specific example is given for dentistry where all interventions in future will be different from treatments of today. Figure ..gives a general picture of nanodentistry in the future.

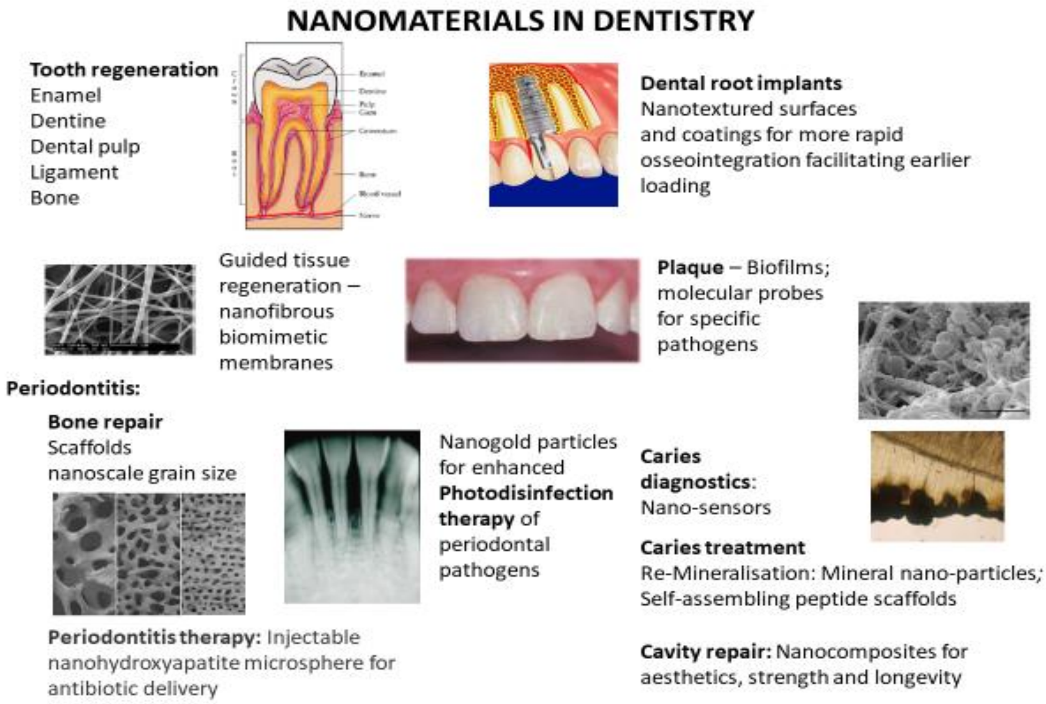


Figure: the potential developments of nanomaterials in dentistry

The university has to change – because its environment (social as well as institutional) is changing, and because science and research, to which it obeys in its internal structure, are changing. The internal structure of the university has to change to satisfy the future success of its students in research, industry, and the welfare of the whole society.

It is clear, that some conventional jobs will disappear in the near future. All others will transform radically and many new jobs will be created. Half of all jobs that exist today will disappear by the time children who are now enrolled in primary graduate.

The industry, the government, the service sector etc. will limit, in the future, <u>recruitment to broad-minded candidates</u>! And <u>young persons without the formation may be victim either in finding a good job or soon become victim of unemployment.</u>

The historical development of the universities is highlighted in the table: fifty years ago there was little interest in universities by the government: see table

Visions on University Structures - 2010/2020 — TU Delft, Delft University of Technology

1. Fifty years ago governments showed little interest in universities, unless they propagated anti-government views. Governments were content that universities should be seats of learning, pure research, and scholarship. Universities around the world had broadly similar structures, with essentially independent departments of history, physics, philosophy, etc. Governments accepted such structures, provided funding, and did not normally interfere.

2. In the last fifty years the world has fundamentally changed. Many 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 upon discoveries made in universities. The industrial hubs in the USA increasingly move away from the steel centre of Pittsburgh and the car centre of Detroit to high-technology companies based around MIT, and Silicon Valley companies based around Stanford University and the University of California. If Europe is to compete successfully with China and the USA then it has to focus on high-technology products and the ideas and materials for many of these will originate in our universities. Hence, governments around the world are now intensely interested in their universities.

3. However, the structure of our universities has changed little in the past fifty years. We still tend to have departments of history, physics and philosophy, with inflexible high walls separating them. A key feature of the university-of -the-future must be FLEXIBILITY. Concerning teaching, we must make it easy for an engineer to learn i.e. Chinese or Japanese or an Indian language, history and culture. This will require a revolution in the way we teach our university students, and an emphasis at the undergraduate level on breadth as well as depth.

4. Concerning research, we must acknowledge that much of the most exciting and useful research is occurring at the boundaries between traditional disciplines. Many of our best structural biologists, who design new medical drugs to attach to specific protein molecules, have been trained as physicists. Many new materials or next generation mobile phones, computers, cars and plans, are designed and developed by materials scientists working with chemists, physicists and engineers. However, current university departmental structures impede rather than facilitate multidisciplinary research. We need to create 'departments without walls' in our universities.

5. A major concern is the increased number of administrators, and the increased level of bureaucracy, in many European universities. We need better, well-paid administrators, but fewer of them. Their role should be to facilitate research and teaching and to provide the flexible structures required in the University-of-the-future.

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2. EDUCATION FOR FULL EMPLOYMENT: "Enhancing the Education, Research and Innovation Base"

The social, scientific and technologic conditions for the development of ideas, of knowledge and of solutions to problems have changed dramatically over the recent decades. The globalisation of information, of work, of ecologic aspects, to mention just a few, has made a tremendous impact on our life. Problems have become more complex and their solutions require a new thinking which has to consider the influences from multiple sources in our world.

University education plays a vital role in the welfare and well being of the society on the globe. Efforts should be made to realize good education systems worldwide. A successful career with full employment during the working span of life demands for

- Trans-disciplinary university education and training
- Uniformity in education systems and the challenges of mobility worldwide

2.1. Multi-/ Inter-/ Transdisciplinary Education

- **Definitions of disciplines, see last figure in the text**

Discipline = sub-field of science, of engineering, of humanities, etc. with its specific perception, concepts, language, methods, tools, aiming to analyse, understand, describe parts of Nature.

Multi- (Pluri-) disciplinarity = several disciplines work together in parallel on one subject. Its goal remains limited to the framework of disciplinary activity.

Interdisciplinarity = the concepts, methods of one discipline are used in the work of another discipline (transfer of methods, etc. from one discipline to another). Combining or involving several academic disciplines or professional specialisation in an approach to a topic or problem. Its goal remains within the framework of disciplinary activity.

Transdisciplinarity = holistic activity contributing to a more general understanding of the world, one of the imperatives being the unity of knowledge - a way of thinking that sees all aspects of the world inter-related through patterns of interdependent systems. These include natural, social, economic and political systems. Transdisciplinary genuinely transcends "disciplinarily by cutting across disciplines, integrating and synthesising content, theory and methodology from any discipline area which will shed light on the research question/s" *[W. Russell "Forging New Paths – Transdisciplinary in Universities", www.wisenet-australia.org/issue53/transdis.htm]*.

Essential requirements for any transdisciplinary work are curiosity and patience; understanding of other disciplines and their languages takes time and commitment. And so, does I/T-disciplinary teaching. Transdisciplinary research and teaching do not respects institutional boundaries.

- **Challenges for I/T-disciplinary activities**

Certain characteristics inherent to I/T-disciplinarity challenge new ways for education and of undertaking research:

- *Language*: Each discipline creates its own jargon. I/T-disciplinarity requires the appropriation and accommodation of different languages. Communication of I/T-disciplinary research results and teaching proves to be difficult since it requires the use of technical terms borrowed from one discipline but that are not well understood by the actors 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. On the other hand, strong disciplines are necessary as any interdisciplinary activity starts with a profound understanding of single disciplines.
- *Cognitive constraints*: It is very difficult 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 missing. Standard bibliometric information is scarce and not representative. It is therefore difficult to evaluate the quality of such activities. New ways of quality assessment are to be developed.
- I/T-disciplinarity requires mastering of more than one discipline in depth. Superficial learning of several disciplines does not lead to I/T-disciplinary research and corresponding solutions of complex problems.
- 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).

***Importance of Inter-Trans disciplinarily for Universities**

Inter/Trans disciplinarily matters because, in the real (as opposed to academic or university) world, most (scientific-technological – social) problems do span different disciplines: in future, post-graduates have to operate in a multi-disciplinary environment, unknown in the past.

Inter/Trans disciplinarity of today is "specialty" of tomorrow! For example; a graduate with three master degrees in biology-informatics and engineering, may – in future – be better off than with one PhD in biology or ….

The real need is for our young 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 real-world time-scale, and a real-world budget.

Somehow, the present generation of students must be convinced that they have good careers if they take a research route in their early years. Most will not stay in academia, or even in academic research, and universities should recognize this in their courses.

In universities, inter-departmental barriers are very high. One useful approach is to have teaching the responsibility of new departments e.g. Natural sciences replacing actual physics – chemistry. biology etc with research also done through various types of University Research Centres..

Interdisciplinariy is absolutely necessary to approach modern research problems with complete coverage of the expertise essential to solve the scientific problems involved and the proper interface with the (industrial) application. In other words, the future research is aimed to solve problems were many traditional disciplines (chemistry, physics, biology, engineering ….) are contemporarily involved. For example; the rapidly emerging field of biomimetic -, intelligent- and nano materials and systems will form most important technologies of the 21st Century. They will require the input of researchers from solid state and organic chemistry, biology and medicine, physics and mathematics, informatics, and engineering if their potential is to be fully realized, see figure "Nanomec research discipline".

The driving force or better the objective of a research project is today determined by a real social need but the activity necessary to give the proper answer has to be performed, looking to the common objective, by researchers having different advanced expertise but speaking a trans understandable scientific language and enter in other ways of thinking. This language/culture can be created only during the training of researchers and must be part of their curriculum. This implies that the University courses must be broader and open to related disciplines thus giving to the students the predisposition to interdisciplinary activity after Graduation.

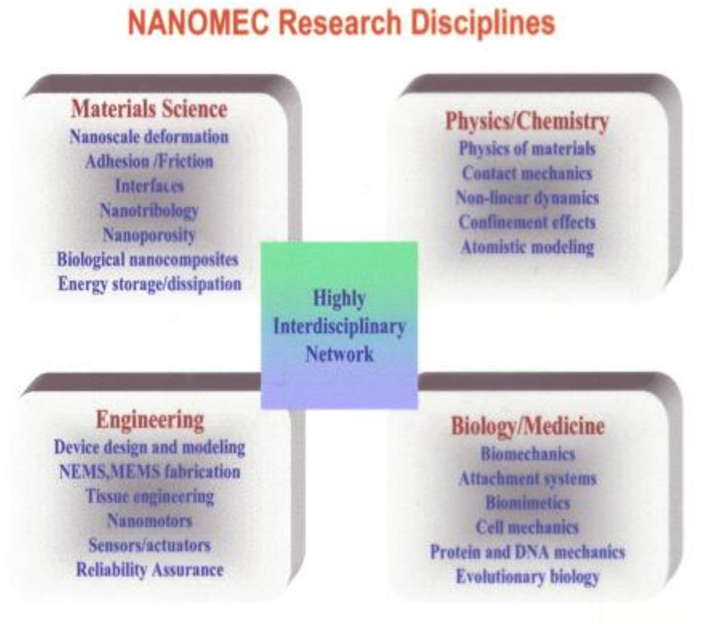

Figure A typical syllabus for a trans-disciplinary Master degree in sciences

The primary function of universities should be to educate students and perform innovative and horizon-broadening research. Universities also need to be flexible enough to establish new interdisciplinary, interdepartmental centres for working on the scientific fields of tomorrow.

It should be made easy to get degrees in interdisciplinary areas without having to fulfill all the degree requirements of the two (or more) disciplines involved. It should be possible to opt for a full MSc inter-disciplinary degree elapsing various faculty disciplines. The industry will be quite keen to hire graduates who have mastered the challenge to study different fields with success and who will also be able to perform trans disciplinary work and research.

***Roadmap(s) for Inter-Trans disciplinary Universities of the Future: "The inter-trans disciplinary Challenge".**

For University Leaders:
- Recognize that teaching (a key-role) is largely for students who will not become future academics, and for careers that don't exist yet,
- Recognize that research and teaching must be linked so that students will be ready for the new ideas of knowledge that research will provide,
- Recognize that research changes very rapidly. It is therefore wise to keep teaching in very-lowly changing departments and have research institutes into which it is easy to bring people from various departments for the span of a project o

For Funding Agencies

First diversity of funding is needed at all levels, since the challenges of interdisciplinary science are so diverse. Those who devise the funding scenarios and detailed methods are too far out of touch with the people who actually do creative science.

Successful models depend on responding to what is available, and especially

- rewarding and encouraging success (success means success, not just visibility)
- management not getting in the way.

Management can get in the way in an infinite variety of manners, including ones that are well-intentioned. Examples are:

- letting scientists believe they are essential without asking the scientists to justify this,
- putting to many irrelevant social extras into funding,
- believe that one project selection approach is "best" for all sorts of projects (diversity is far better).
- Inter/Transdisciplinarity is typically an EU matter as strong argument are necessary to break the tradition at the provinciality of the University in many EU Countries. New Departments should be promoted based on Scientific Problem Solving, where the members come from different traditional areas and are compatibilized by the common interest in a modern interdisciplinary research field. Resources should then be allocated to universities on the basis of the presence in these new situations and not simply on the number of students without regard to quality.
- Universities needs to be restructured: "the life in an ivory tower belongs to the past!" The rigid faculty structures need to be dismantled with the creation of small- and medium sized clusters for education and university centres for research.
- One cannot expect that all students will be – in the next 5 to 10 years - , either for physical or intellectual reasons, not be mobile enough to accommodate to the ideal inter-trans disciplinary modern university model; so, transitional measures and grading systems in the inter-trans disciplinary model need to be developed.
- The creation of the inter/transdisciplinary modern university of the future is a great challenge but demands for great stimuli from governments, the industry and the society. A plea is made for intra-university openness so that a coherent interdisciplinary approach within the university can be realized.
- To reap the rewards of an interdisciplinary approach, universities and research institutes need to encourage more flexible movement between disciplines by
  (a) breaking down rigid administrative structures,
  (b) setting up multidisciplinary groups or research centres/laboratories.
- National governments and funding agencie should also encourage interdisciplinary activities.

References:

- *"A New Vision of the World; Transdisciplinarity", http://nicol.club.fr/ciret/english/visionen.htm*
- *"The Potential of Transdisciplinarity", H. Nowotny, http://www.interdisciplines.org/interdisciplinarity/papers/5/printable/paper*
- *" Rethinking Interdisciplinarity. Emergent Issues", C. Heintz, G. Origgi,* http://www.interdisciplines.org/interdisciplinarity/papers/11

2.2. Worldwide University Uniformity/Degrees - Young People's Mobility

In order to help making the globalisation a successful exercise, the "university "education plays a vital role. To facilitate contacts and collaboration between universities worldwide, it is important that the curriculum and degrees of the various universities is uniform. Europe, with its 30 different countries and multiples universities often of different curricula succeeded in realizing a uniform university education system called "BOLOGNA Minister's declaration". The United States have a system quite similar to Europe and other continents as South America and Asia should bin a next phase to follow with a global unified system in the future.

An intercontinental university education system demands great efforts from universities, and governments. The mobility of young students and scientists demands for knowledge of foreign languages and cultures but this should form part of the curriculum.

It is clear that a global uniform education system which facilitate contacts between students and professors from foreign universities and nations on a global scale. It will result in multiple and great benefits between nations worldwide in the form of peace, economy,..and will finally result in a better globe and welfare..

WAAS as world academy in sciences and arts has here a great responsibility and should take appropriate initiatives in three fields of activities:

*Set-up of a strategy for developing models for Worldwide university systems: "Uniformity of degrees Worldwide"
*Develop ways for "Mobility of Young People worldwide"
*Initiate models for World University Curricula: "College Syllabus".

2.2.1. Uniformity of Degrees Worldwide

To promote the contacts and collaboration between universities, professors and students worldwide it becomes of vital importance to think on a uniform education system between the universities of the various continents. It is vital that the curriculum between the degrees of the many universities should be quite similar and thus comparable.

Two decades ago, Europe was much confronted with the problem that each of the countries had its own university education programme, quite different between the countries. The degrees on similar subjects were often very different in degrees titling, duration of studies as well as the curriculum for similar degrees e.a. an engineering degree in Germany was quite different from an engineering degree in Italy, in study duration as courses contents.

With the creation of the European Union in the ninetieths it became vital from multiple points of view to develop a uniform educational system at university level e.a. for exchanges of students, collaboration between universities of the 30 different countries, but also from economic, industrial, social etc viewpoints. This was a most complex exercise but finally resulted in 1996 on the occasion of the BOLOGNA European Ministers for education declaration. An agreement was reached for BSc, MSc and PhD degrees and which is actually used in all European countries.

A curriculum for a Master degree in natural sciences may look as follows:

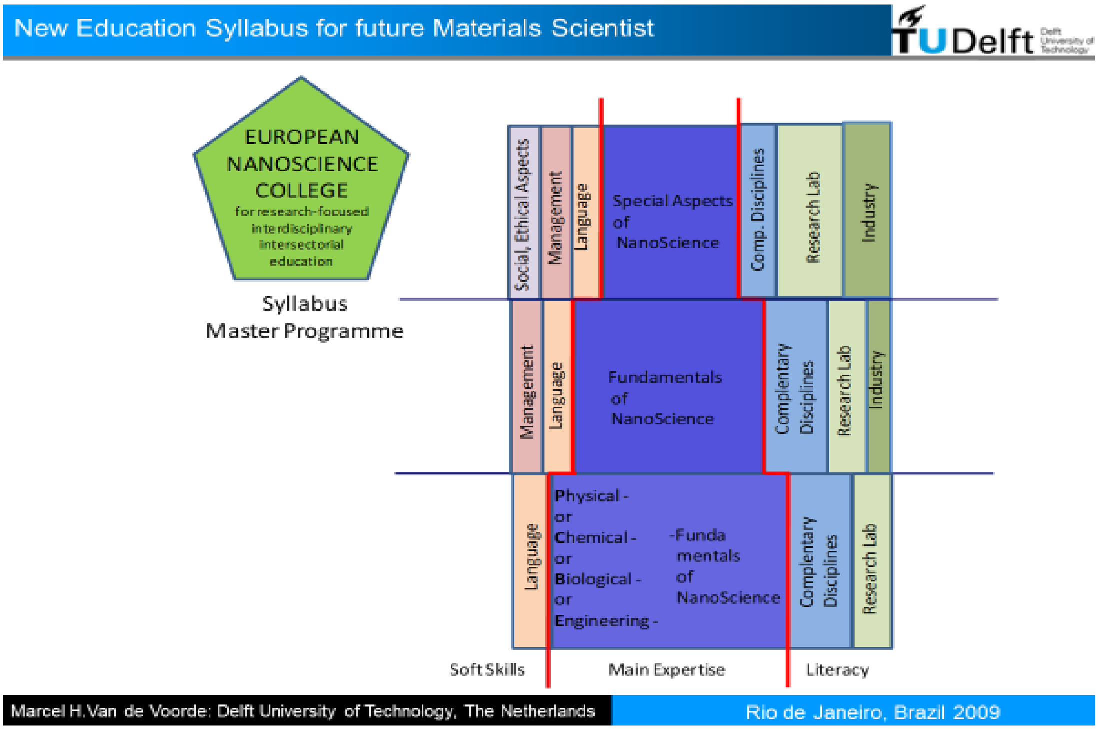

Figure: a typical example for a "Master "Degree in of Natural Science

2.2.2. Mobility of Students and Scientists

It is important to encourage greater exchange of students and scientists between disciplines and countries. One way of achieving this is by ensuring that economic and administrative barriers do not prevent movement of scientists from one discipline or country to another. This would be aided by standardised qualification recognition procedures, World-wide training courses, and official exchange programmes. An interdisciplinary culture must also be implanted through educational (universities, research institutes) and budgetary (funding agencies, national governments, European Commission, United Nations) initiatives. It must also be realised that the heterogeneity of World cultures is an asset with the potential to provide imaginative ideas and diverse skills, and must be more efficiently utilised in the future.
In Europe the BOLOGNA declaration provided these criteria and, on this basis, the European Union ERASMUS programme was launched in which possibilities were offered to students and scientists from all countries throughout Europe to study at the faculties of universities of their wishes with recognition of their obtained degrees all over Europe.

This possibility of movements of young people is extremely profitable with respect to learning different languages, experience multiple cultures, and to become familiar with all European countries. This challenge provides multiple possibilities e.a. to study, to be trained, to work, to live, in the country to its wish.

The industry, the government, the service sector etc. will limit, in the future, recruitment to broad-minded candidates, without giving priority anymore to origine , see table "Search for Talent".! And young persons without the formation may be victim either in finding a good job or soon become victim of unemployment.

The search for talent

TUDelft Delft University of Technology

The world's most valuable commodity is getting harder to find! - ***Explicitly applicable to materials science – physics – chemistry and engineering's***

Company management has a gnawing worry about the supply of talent. It used to mean innate ability, but in modern business it has become a synonym for brainpower (both natural and trained) and especially to think creatively. The modern economy places an enormous premium on brainpower, and there is not enough to go around. The best evidence of a "talent shortage" can be seen in high-tech firms - companies such as Yahoo! and Microsoft are battling for the world's best computer scientists.

Companies in Europe of all sorts are taking longer to fill jobs – and say they have to make do with sub-standard employees. Even more money is being thrown at the problem - last year hundredths of firms adopted some form of talent-management technology. These days Goldman Sachs has a "university", Mc Kinsey has a "people committee" and Singapore's Ministry of Manpower has an international talent division.

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An international partnership and Organisations for Promotion is schematically represented in table:

International Vision

TUDelft Delft University of Technology

International Partnership and Organisations for Promotion :

- Degree system should be made universal: BSc. MSc, PhD
- Develop Unified Study Programmes - Enable cross-disciplinary research
- Optimise the use of infrastructure and facilities
- Coordinate and uniform the multiple exchange programmes
- Develop integration mechanisms: to bridge the gaps between: education, research and industrial innovation; so that research discoveries spin-off into industrial applications
- UNESCO, UNIDO, UMU, IEA, OECD, G-20, DAVOS Conference, Intergovernmental Agencies and Bi-lateral Government Agencies.
- Set-up an International University Agency
- International Industrial Research Management Agency

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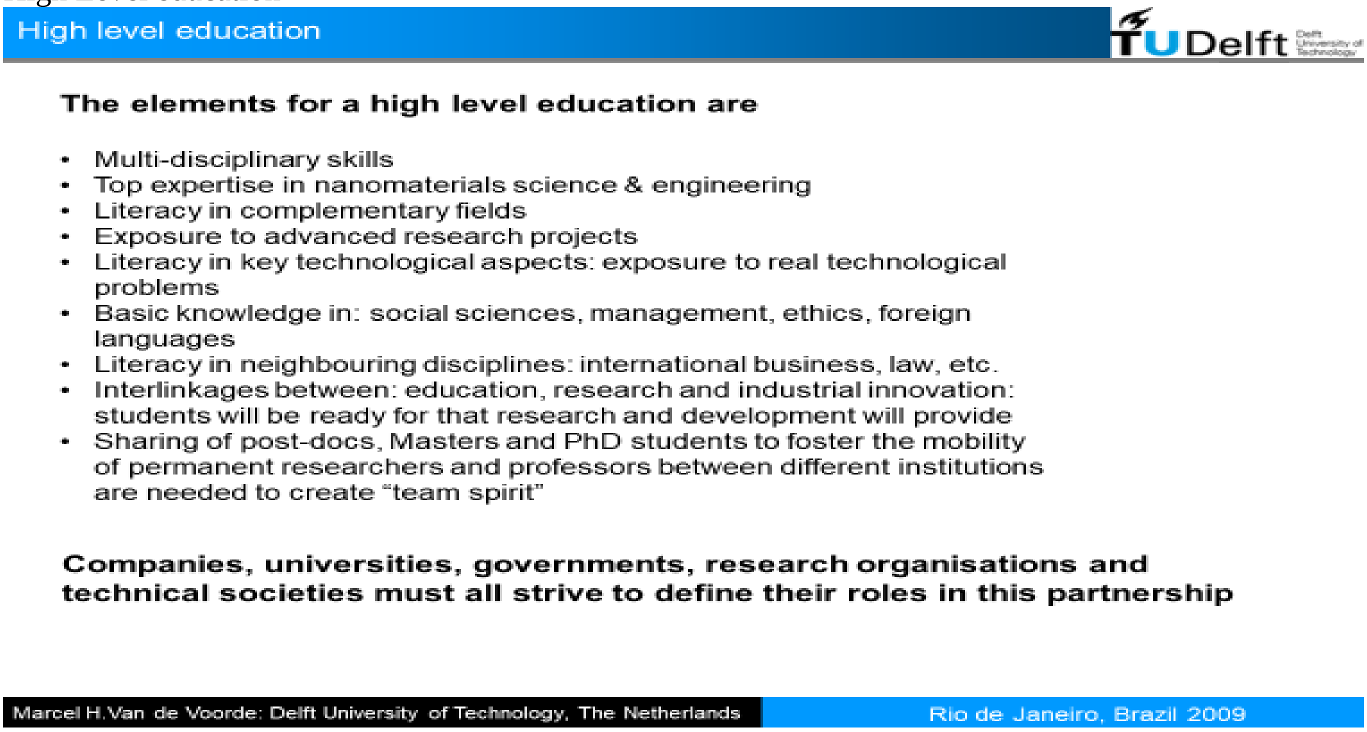
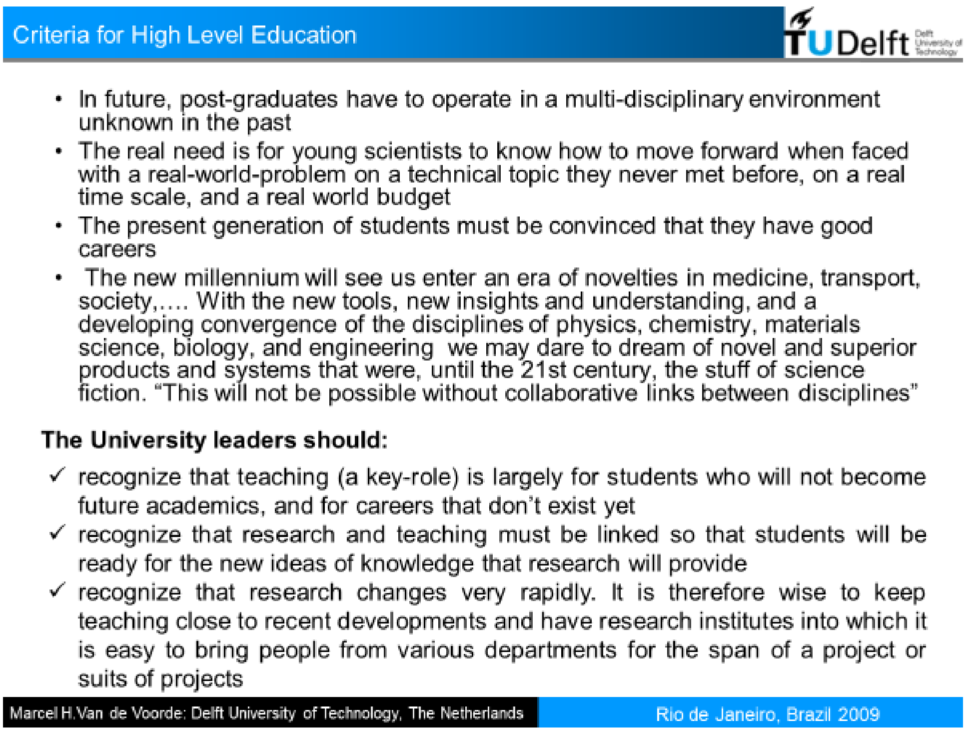
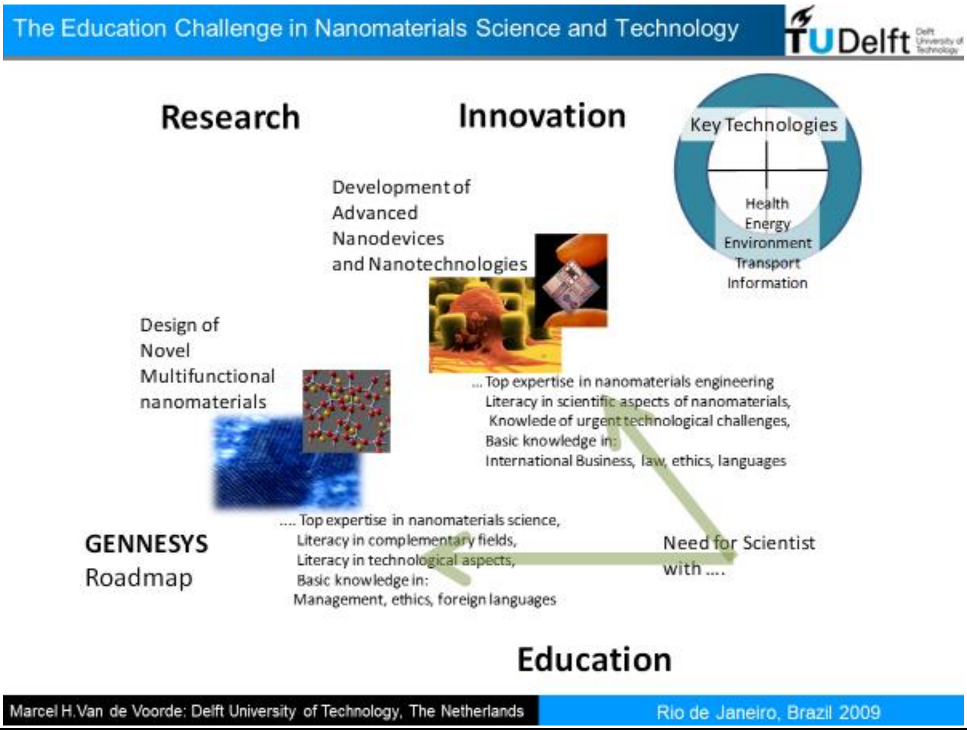
2.2.3. World university Curricula

The criteria for a high-level education could be formulated as follows: see table "Elements for High Level education



The criteria for high level university education are summarized in the table





3. TECHNOLOGY TRANSFER: ACADEMIA TO INDUSTRY BASED ON INTER-TRANSDISCIPLINARITY PRINCIPLES

Technology transfer has become a new “buzz word” in the academic world. Everywhere in the world, research institutions within universities look at their American counterparts with envy or respect.

Which researcher would not be satisfied to see the results of his research used for the well-being of the society? If the goals of research are first to explore new frontiers, it has become clear that its industrial applications have recently contributed as much to the fame of the inventors. And when they become founders of successful start-ups, these inventors are sometimes more famous than Nobel Prize winners in their university.

It does not mean that every person in academia should try to create a company, the academic entrepreneur is a very rare species and it should remain so.

In future business, it will become crucial to always be innovative. It is, therefore, essential to promote collaborative research between universities and industry. It is important to bring together active scientists from academia and technologists from 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 success of US research, exemplified by the excellent “Industry-University” laboratories established by DuPont, IBM, AT&T , EXON and Corning. These laboratories have 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”.

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

Some elements have been brought together together to reflect carefully on the need to develop a World University System which could form a n intern continental network of universities with potentials for active collaborations.

Because of the importance and the complexity of the subject, the WAAS (World Academy for Arts and Sciences) has the duty to have a debate on the subject and the undertake appropriate actions with governments, international organisations and University consortia worldwide.

Revolutionary developments are expected in the “21st nanotechnology fourth revolution “ and may belong at present to the science friction and the world brains will be necessary to dominate the developments.

Up to now, the academic education has been strongly oriented towards academic disciplines. In this, it is often overlooked that most of the problems that research and education are supposed 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, health.

Quite some conventional jobs will disappear and be replaced by more intelligent once. Half of the jobs which exist now will disappear at the time the younger students get their degree.

In future we will need each other worldwide and we should try to help each other to the welfare of all beings.

Marcel VAN DE VOORDE,
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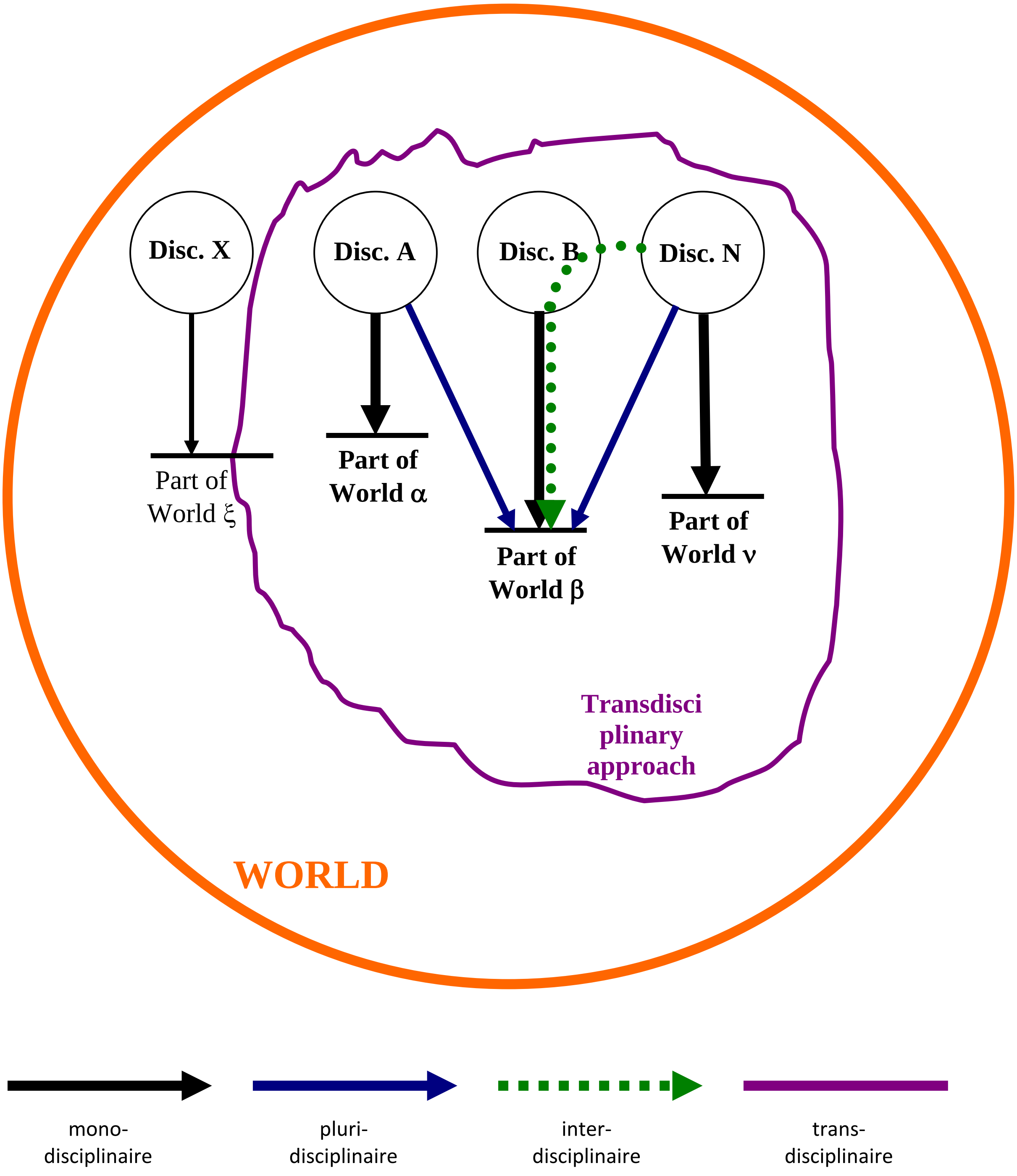
Professor: University of technology DELFT (NL)
Science Council of the French Senate and national Assembly – Paris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