# Our Universities: Knowledge Foundries for New Global Challenges

## Closing the Gap Between Our Education and Our Future Through Transdisciplinarity Across the Arts, Humanities and Sciences

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***The modern approach to University education and research recognizes the need to cut across traditional subject boundaries. However, in order to obtain maximum benefit from research effort globally, Universities need to adapt their existing approaches to the management and organization of research and teaching for transdisciplinary working. This has become an urgent consideration given that we now face unprecedented global threats, ranging from infectious diseases to global warming, which are no longer amenable to single discipline resolution, and which demand a new kind of skilled individual who is technically literate across multiple fields, an intellectual and practical multi-tasker. In Europe, we have already secured a standardization of our degree awards, and actively promote cross-European student mobility. However, for the next generation of students, this will need to be extended globally and to reach out across both continents and language barriers. Only in this way can there be the advancement of global inclusiveness and an opportunity for all to contribute their talents to the global challenges that affect us all. Universities are well placed to take on such challenges because within their existing departmental structures they already harbor the necessary specialization's spanning across engineering to sciences and the arts. Already the new approaches embodied within nanotechnology manifest an unprecedented convergence of disciplines. Emerging in a practical sense, for example, as nano pharma. This new dimensionality to molecular drug development offers now an indispensable means of widening our drug armory as a powerful alternative to molecular scale development. What is urgently needed is to extend the pharma model approach in other endeavors, and to synthesize new Faculties and Departments founded primarily on transdisciplinary science These would be based on combinations of teaching and research that could never have been envisaged before, but which now come into sharp focus as a means for our gearing of a global effort to tackle awesome global challenges. This paper describes the way individual multi-specialist affiliations can be leveraged for student transdisciplinary science covering, respectively, medicine, biological science, geography, pharmacy and humanities. The need for this is for a future that is becoming the present a rapid pace, and one moreover that will demand the greater emphasis on ethics. In conclusion, two decades after the successful Nano Research Initiative, it is necessary to prepare an all-inclusive Transdisciplinary Research and Teaching Initiative embracing all disciplines, eliminating all borders that prevent cross fertilization, and boosting innovative solutions for a sustainable world.***

## 1. Introduction

This millennium will see revolutionary change across a range of key technologies, from medicine to transport, that will transform the way society operates. With increasing insights at the fundamental level, new technological tools will emerge at rates unprecedented in modern scientific history. With this will come a convergence of the disciplines of physics, chemistry, materials science, biology through to computer science, and with this novel and superior products and systems that have been the stuff of science fiction until the 21st century. Without new models of collaborative working across the disciplines, however, this will not be possible.

Up to now, academia has operated within distinct academic disciplines. Yet, most of the major challenge's society faces, notably concerning the environment, energy, and health, and which research and education are supposed to solve, are no longer definable in terms of cognate disciplines. There is no longer a match between the growth of these problems and the development of our scientific culture, increasingly driven by hyper-specialisation.

New topics will also emerge, such as Cognitive Information Processing and Cognitive Computing, as crucial technologies of the 21st Century [1], but these inherently demand competences that extend across diverse fields ranging from solid state and organic chemistry, biology, medicine, physics and mathematics through to information and computing sciences and engineering. Broadly, the imperative is for a transdisciplinary approach to complex industrial and societal challenges. Universities will need to reconfigure current degree programmes so they are 'fit for purpose', losing neither focus nor the needed intellectual depth in this «broad band» strategy. A plethora of programmes that merely give independent pathways to some unified academic qualification will only confuse students, teachers, and employers alike. Nascent fields such as nanotechnology, smart materials, biomimetics, cognitive informatics and computing, especially, will not prosper without intensive crossover effort across disciplines.

The University now operates in a rapid change environment (social, institutional, financial, regulatory) [2]. Also, many traditional jobs will disappear, certainly by the time pupils currently in primary education have graduated. The transformed job market also means that many new jobs will be created, but now a premium will be placed on candidates showing adaptability, an open mindset and transferable skills.

Governments recognise that new university generated scientific knowledge holds the key to future prosperity. The shift in industrial focus in the USA from, say, traditional steel production in Pittsburgh and car making in Detroit to high-technology companies such as those based around MIT, Silicon Valley, Stanford University and the University of California are a 20th century foretaste of change. If Europe is to compete successfully with the USA, and now with Asia, it must focus on high end technology products driven by ideas from our universities. The advancement of a transdisciplinary agenda for universities as a part of this is thus timely.

We need, for example, to make it easy for an Engineering or Science student to acquire knowledge and expertise across multiple topics including extending out to social sciences, economics in the arts, along with foreign language skills. This must also not lead to a more crowded curriculum. Concerning research, so often the most exciting and useful research occurs at discipline boundaries. Thus, many researchers involved with drug discovery may have been trained as biologists, physicists and computer scientists [3]. Functional materials for next generation mobile devices, computers, cars and planes are now being designed and developed by materials scientists working hand in hand with chemists, physicists, and engineers. The traditional university departmental structure is not geared to secure the necessary dialogue to prepare for this New World, and may, in fact, create barriers to transdisciplinary research.

There are tangible challenges ahead of us. COVID-19 has had a partial response, but we do not have the final chapter on this, let alone the alert and template of response for the next lethal pandemic. Our climate change strategy is excellent at tracking global warming effects, but not the gearing of interlinked responses to mitigate these, some of this moves us into advanced information technologies for prediction and information exchange, rather as is being done for weather forecasting, but now needing to be stretched to cause-effect relations of what we do on this planet; herein lies one major test for future AI.

At the individual level it is new endeavours such as nanotechnology which will allow us to bridge the molecular and macro-structural world to allow new, multifaceted tools for measurement and manipulation.

A background concern is the growing administrative burden being placed on universities by burdensome government regulation and reporting. There is compounded by an internal disconnect between the administrative and front-line academic functions of a university.

## 2. Reformulation of our Education, Research and Innovation Base

University education is integral to the well-being of a global society, and it is recognized that there is a strong link between educational quality and economic prosperity and stability. Our challenge is now to provide a new transdisciplinary education in Europe that can serve as a global model. The impact of any model of teaching and research also has to factor in the ethics of the outcomes, given the increasing potency of our technological advances.

### 2.1. 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 aim to analyse, understand and describe parts of Nature.

***Multidisciplinarity*** is the case where several disciplines come together in parallel to tackle one subject. An early example is the tailoring of isotope-bearing chemicals for imaging and therapies for use in Medical Physics.

***Interdisciplinarity*** is the case where the concepts and methods of one discipline are used in the work of other disciplines. A classic example is biomaterials research which draws on both physical materials science (polymers, ceramics, metals) and the biology of tissue and cellular processes.

***Transdisciplinarity*** is a holistic approach that sees all aspects of the world as interrelated through patterns of interdependent systems. These include natural, social, economic and even 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 as well as a basic understanding of other disciplines and their language. This all takes time and personal commitment. Such transdisciplinary research and teaching must not be constrained by traditional subject boundaries. A typical example is the epidemiology of infectious disease. This requires factoring in of the bio-/physical fundamentals governing organism transmission through to a comprehension of human societal behaviour, psychology and cultural norms, e.g. in relation to health compliance and vaccine uptake. Alternatively, there is a need to understand animal and insect vectors in the context of ecological systems through to the genetics of susceptibility. The requisite disciplines may appear to be too disparate to allow for a single transdisciplinary pathway in teaching, but medical and dental training already provides models for how subject integration can be achieved.

### 2.2. Challenges for Inter- and Transdisciplinarity (I/T) Activity

- ***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 of another discipline.

- ***Methods:*** Disciplines are often devoted to their own methods of investigation. This may lead to misunderstanding and opposition.

- ***Institutional constraints:*** Institutions are mostly discipline organised, creating barriers for I/T-disciplinarity. However, strong, well-defined disciplines are necessary as any interdisciplinary activity starts from 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 research. This raises a question of the impact of these difficulties in education and achievement of the formalisation of interdisciplinary training programs.

- ***Assessment:*** Experts (reviewers) for evaluating the results of multi-disciplinary research and education are lacking. Standardised bibliometric information is scarce and not representative. New ways of quality assessment need to be developed. In this context, it will be necessary to improve the traditional «closed loop system of the classical university» of Fig.2.2, which is usually focused on a specific discipline and in the worst case scenario experts may not be able to see the «wood for the trees».

- 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 or 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.

- New training models and the break with tradition they represent leads to qualifications which may not be obvious to an employer, and this creates a risk to both the student and the employer with respect to both employment and employment success.

- For early and mid-career staff moving to re-designed centres, there is a career risk as their new specialism is not readily recognised.

- Teaching validation and standard setting become more uncertain and quality measures need to be rigorously set.

- For engineering orientated courses, accreditation by a learned institute is indispensable. New training in a new I/T-disciplinary programme makes accreditation more difficult.

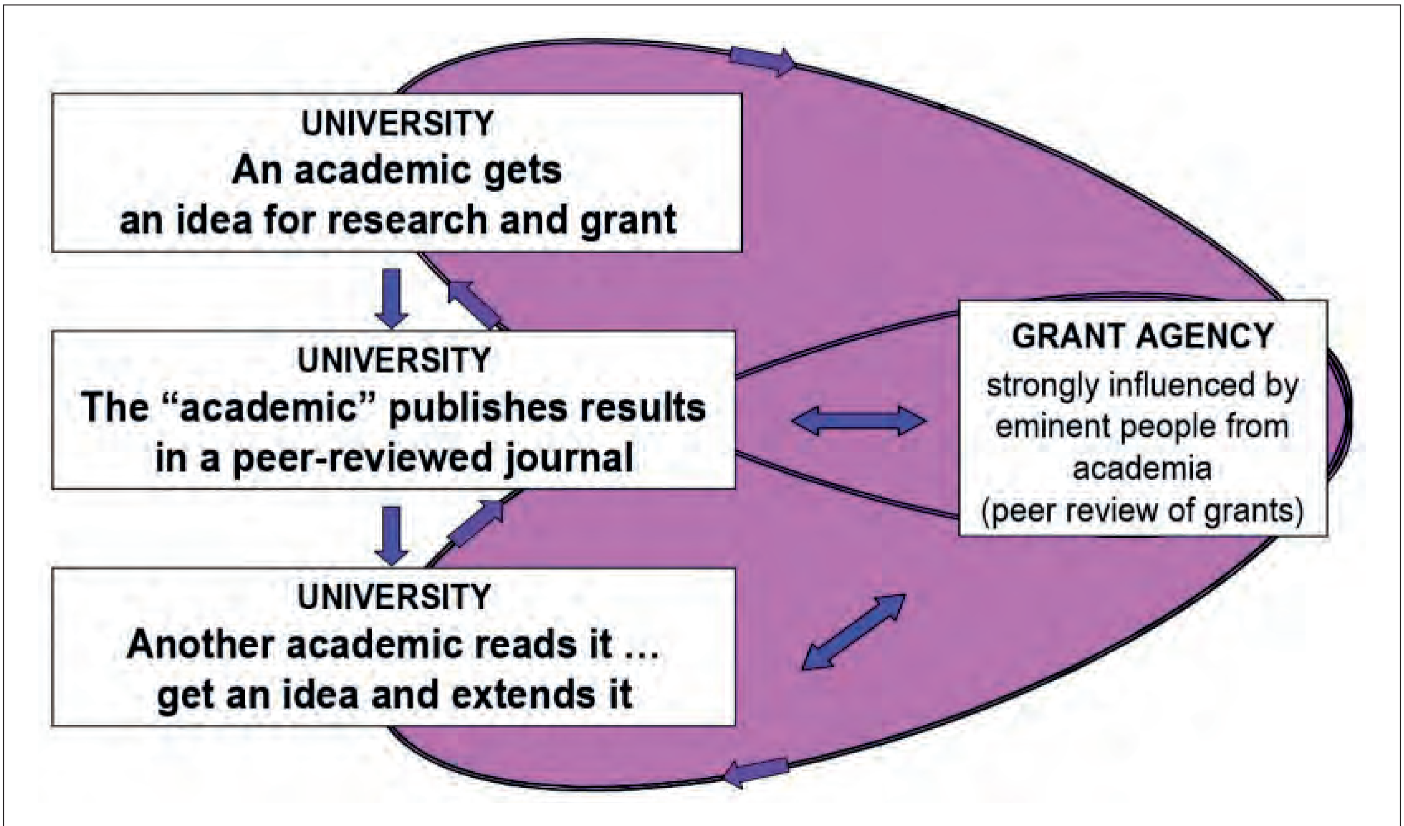


Fig. 2.2: Standard «Closed Loop Model» of an academic institution. (Courtesy: Hans Leuenberger [4])

### 2.3. Concerted efforts

These challenges are the very reason that a concerted effort needs to be made to create the conditions for transdisciplinarity. There is a need to start early – at secondary school – where the balkanization of topics can create undesirable early specialization. A wider choice of learned subjects here will prepare the student to accept transdisciplinaryarity as a valued norm and not as an inferior generalist. The guiding principle should be the alloying of physical, biological and humanities subjects. Excellence can then be equated with versatility and not with narrowness, which often masquerades as depth. The exact discipline mix is not the critical factor, but it might contain say 6 examinable subjects. The drive for this change needs to come from the Universities and industry jointly to demonstrate the added value to future careers of flexibility and the ability to move between careers in a world where the 'job for life' concept is fast disappearing. Without leaders presenting a convincing case, the status quo will remain. The case would need to identify intellectual, economic and prestige benefits. If curriculum change is not inspired through opinion leaders, why should the student take on the adventure of transdisciplinarity?

#### 2.3.1. Identification of Research Translators, Multi vs Mono Cultural experts

Multi-domain education to high level poses learning challenges for the individual, and not all will reach to the demanding agenda [5]. So some student selection is inevitable; this can be based on the 6 core subject performance. Selection will benefit society by identifying research 'translators' vs those who will do better as mono-discipline specialists. Both will be needed in the future. Selecting out the different aptitudes, in a culture of mutual esteem will be as important for selecting excellent candidates. The triad of knowledge, skills and attitudes must also not be diluted, on the contrary, greater attention to the latter will serve as a guiding thread for the individual through more complex career pathways and promote success in the workplace.

With intellectual openness, the student will take the new education in his/her stride, feeling enriched by the added dimensions. To achieve his there cannot simply be a token move to transdisciplinarity, otherwise failure is inevitable. Precious, valued disciplines need to be embedded in new departmental structures: physics into biology, chemistry into medicine, robotics into bioengineering etc. One such desirable mix is the bridging of biomedical and physical/engineering sciences coupled with new numeracy skills. Other disciplines that can be reinvented thus are environmental sciences, manufacturing, energy and human geography. Beyond the taught elements, a selected project would be chosen to be transdisciplinary. The final output would be a graduate able to accommodate other disciplines and a teacher able to transmit concepts from multi-domains as a normal part of their teaching. Such intellectual convergence will bring down traditional barriers and, in short, achieve the requisite re-invention of the Departmental model. This will also open up space to address the ethical implications, both of the technological approach and its impact. Ethics should be formally taught because no advance can be considered entirely risk free, and choices that are decoupled from ethics will also lead to decoupling from moral cultural standards, a price society may eventually not pay.

#### 2.3.2. Postgraduate Studies

At the postgraduate stage, hyphenated MScs of equal prestige to a PhD could be developed where a sequence of 3 years expose students to tailored, contrasting topics. As an example, a sequence of biology, physical and computation science may have a core thread of engineering science. The graduate then has an appreciation of the universality of fundamental concepts. For partial completion of the MSc there are still benefits to the individual as a transdiscipline lead, and this should be rewarded with an alternative MSc award – not a diploma which would not have the same traction. Accommodation would need to be within the current ecosystem, and complementary to the deep but narrow focus of the PhD.

#### 2.3.3. Importance of Inter-/Transdisciplinarity for University Development

Inter/transdisciplinarity matters because, in the real world, most scientific, technological, and social problems span different disciplines. 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. Today someone with inter/transdisciplinary expertise is viewed as a generalist, in the future this capability will be regarded as a specialization in its own right. For example, a graduate with a triple MSc degree in biology, informatics, and engineering, may well, in future, be better off than a PhD specialist in biology. Whilst an ad hoc I/T-disciplinarity might be achieved by a PhD later on, it is preferable that this is properly organized at an earlier stage. Degree structures will need to be carefully organised to avoid simply amplifying the workload. An MSc transdisciplinary degree sequence would involve multiple Faculties. One barrier has been the lack of mutual esteem, but with transparency in the educational process and a clear set standard this can be reversed. Industry, any case, will be keen to hire graduates who have mastered the challenge of studying different fields and are able to work as effective team members.

The further need is for the next generation of scientists to know how to deal with technical problems they have never met before, and on a realistic time-scale with a realistic budget. Future research is going to have to focus on solving unrealised problems that don't fit neat compartments. The US moon-shot program putting a human on the moon was similar in nature to this. Humanity will have to prepare for many more 'moon shots' as the challenges it faces on earth become more complex and more pressing.

The organisational structure of universities has changed little over the past fifty years. Inter-departmental barriers are too high, particularly at «traditional» institutions based around small Departments, e.g. 10–20 academics, and focused on narrow fields. A modern approach, shown to be more effective, flexible, and efficient, is to have teaching activity based within larger Schools, e.g. up to 100 academics, that can be more broadly based and benefiting from a more comprehensive repertoire. Research and teaching can then be either focused within just the School, or be further extended through cross-cutting University Research Centers spanning the Schools with a fluid organization, new skills can be imported into these structures.

A critical opinion former in any University organization is the full professor. They have been the leaders of our scientific advance through the ages, but now beyond being topic specialists we need them to embrace transdisciplinarity; by both renewing their research interests regularly and rejuvenating their teaching portfolio without boundary constraints they would serve as catalysts for the change we need as we dissolve the margins between different topics. A safe intellectual 'space' might need to be evolved to promote such academic entrepreneurship.

A university thus needs to be flexible in its governance, management and culture and to be constantly evolving new interdisciplinary models for the research fields of tomorrow. The immediate financial 'bottom line' cannot be the dominant driver for this; it detracts from an institution reimaging itself to tackle new challenges.

### 2.3.4. A template of Inter-/Transdisciplinarity for the University of the Future

There is a need for a change in approach, and a revisitation of current policies to enable Universities to become incubators of successful inter/transdisciplinary research.

**For University Leaders,** there needs to be:

- Recognition that teaching is primarily for students who may not become future academics, and who also may be pursuing careers that do not exist yet;

- Recognition that research and teaching must be closely allied, so that students will benefit from the percolation of new ideas, knowledge and skills.

- Recognition that research changes very rapidly. It is therefore good practice to develop teaching within larger critical mass Departments with a strong leadership vision for curriculum and continuity, and exploiting central research institutes. This does not require separation of the staff who deliver the teaching from those conducting the research, simply that staff would have a different mix of affiliations.

**For Funding Agencies,** there needs to be:

- Diversity of approach to funding at all organisational levels, since the challenges of inter- and transdisciplinary science are themselves so diverse.

- Effective communication and co-operation between funders and those who conduct the research, so that funding decisions evolve through better understanding of new identified research challenges.

- Successful models that reward both risk taking and encourage success, but yet impose a low administrative burden.

- Active encouragement of interdisciplinary approaches in the solution of research challenges.

## 2.4. Intermediate Conclusions for Universities

### 2.4.1. Globalized Engagement and Responsibility of the Universities

In ensuring that the move towards a globalized strategy in education is meaningful and successful, collaboration between universities needs to have curricula and awarded degrees showing demonstrable consistency. Already, Europe, with its 30 countries and multiple University systems with different curricula succeeded in realising a uniform University education system through 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 [6] demands great efforts from both Universities and governments. A global, uniform education system will result in benefits for educational quality, enrichment through mobility and greater cultural understanding. Lowered barriers to the mobility of students and academic staff

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*Marcel Van De Voorde studied natural and applied sciences in Belgian and European universities which resulted in various academic degrees. He started his academic career as Professor at the Catholic University Leuven and the State University Ghent in Belgium. In the eighties, he was nominated professor at the Technical University Delft (NL) and visiting professor at various known universities in Europe, US, Japan and China, including the reputed Tsinghua University in Beijing in 1992. In his research career, he had direction and senior scientist functions at CERN (European Organization for Nuclear Research), Geneva, European Commission Research in Belgium, Max Planck Institutes in Germany. He also held important research mandates at the ESA (European Space Agency), Paris and NATO R&D&T in Brussels.*

*He was/is chairman/member of Research Councils and Governing Boards, worldwide e.a. CNRS (FR), CSIC (ES), (CNR (IT), NIMS (JP), etc; senator at the European and is trustee at the World academies of sciences and arts; honorary professor and doctor honoris causa of multiple universities.*

*He had/is advisor to Ministers, Directors of research centres, rectors of Universities in Europe and worldwide and at the Science Council of the French Senate and National Assembly in Paris, etc. He received many honors e.g. from the Belgian King, the Luxemburg State, European Commission etc. He is caritative also very engaged: Promotion of the Catholic universities in Bethlehem and Madaba (Jordan), creation of a research institute in the Balkans, a research center in the Middle-East containing eight countries including Israel.*

*Related to this conference: Important achievements are in University Education in Europe with pioneering work in the BOLOGNA Ministers Declaration with BSc, MSc, PhD degrees all over Europe and the popular EC-ERASMUS mobility programme. In the eighties, he was Co-founder of the IMEC's «Inter-University Nano-Micro Electronics Centre»: a spin-off of the Catholic University Leuven which hosts today 4.000 scientists, engineers, etc from 100 different nations worldwide. The research initiatives on Proton-Therapy for Cancer (PTC) treatments at CERN had, during the last decade, an explosive development in PTC-hospital clinics in Europe.*

*P.S. My pharmacy experience relates to the Dr Paul Janssen Laboratories, founder of the successful «Janssen Pharma Belgium» now the Janssen/Johnson & Johnson US. At the European Commission I was in close contacts with the European Pharma.*

demands that they have prior knowledge of a foreign language and culture and so such teaching should form part of the curriculum. An added benefit is the possible setting up of collaborative education programmes.

A global scale ambition can only be truly realised through the patronage and opinion forming of UN Institutions like UNESCO and UNU (United Nations University in Tokyo). These have targets for the alleviation of poverty, gender equality and widening of participation and transdisciplinarity offer new routes to achieving these. Through their assistance a start should be made with Europe, and then the US, Australia, Japan and China with other regions to follow.

### 2.4.2. Mobility of Students and Staff

This could be aided, variously, by standardised recognition of qualifications, world-wide delivery of training courses and a formalisation of exchange programmes. An interdisciplinary culture has to be specifically promoted through educational and funding initiatives.

### 2.4.3. Globalized University Curricula

**Criteria needed** for a high-level education can be formulated as follows:

- Active advancement of multi-disciplinary knowledge, skills and attitudes as a curriculum norm.
- Competence development across multiple fields to facilitate future student self-development in keeping with new inter-disciplinary challenges.
- Exposure to leading edge research to demonstrate the value of novel approaches and how transdiscipline research in its own right can provide this by virtue of its novel topic linkages.
- Literacy in key technological areas, irrespective of subject boundaries, to be able to critically assess transdisciplinary research needs for solving complex application problems. Early exposure to technological challenges in the field can form a part of this.
- Teaching of social science, management and ethics, and protected time for foreign language teaching.
- Teaching of arts disciplines to provide appreciation of the human and cultural context of transdisciplinary research and how global issues have impacted on human quality of life and wellbeing. Study of international business, law, finance and entrepreneurship as enablers would be part of this.
- Teaching of the linkages between education, research, industrial R&D and innovation, complemented by project supervision from industry. The latter would also stimulate transdisciplinary university-industrial research partnerships.
- Joint supervision of post-docs, Masters and PhD students to foster the mobility of permanent researchers and academics between institutions to help create extended, global teams.

## 3. Knowledge Transfer between Academia and Industry being facilitated by the Inter-/Transdisciplinarity Research Approach

Technology transfer is the new buzzword in the academic world. Everywhere, researchers look at their American counterparts with envy and respect. To boost innovation, spin-off start-up companies as a result of research findings at academic institutions, it is important to establish the necessary environmental conditions by promoting interdiscipliantry skills at e.g. the University of Applied Sciences of Northwestern Switzerland (article by G. Imanidis, in this SWISS PHARMA 43 (2021) No. 4 issue), incubators such as the Technopark (ETH Zurich, Technopark | ETH Zurich) or corresponding institutions close to an university campus. In this context, governmental agencies such as the former Swiss CTI, KTI, today Innosuisse (Innosuisse replaces CTI: Funding opportunities for Swiss researchers, SMEs and industry – accelopment) are able to financially support research projects based on innovative ideas such as the spray freeze-drying technology at the university of Basel (PhD thesis of Marco Mumenthaler, see article on «Spray freeze-drying for Formulations of Precision Medicine & Vaccines» in this SWISS PHARMA 43 (2021) No. 4 issue. Another interesting institutional concept is the Israel Innovation Authority IIA (The Israel Innovation Authority | Israel Innovation (innovationisrael.org.il), matching up to 90% of venture capital to be invested in a start – up company for financially supporting research projects for strengthening the economy by boosting innovative products.

Providing financial and legal support related to patent protection of ideas and results of researchers/inventors will be an additional incentive leading to the foundation of start-up companies. The availability of venture capital plays an important role for the first round, but the start-up company needs at a later stage additional money. In this context, it is important that the legal framework will allow inventors to be awarded and not only exploited. Unfortunately, in the event of capital increase, the inventors/researchers often lose the majority of votes being linked to the share of the capital invested. This problem is a result of the current law in Switzerland that a company is only allowed to issue additional shares with the nominal value 10:1. However, the ratio 10:1 may not be sufficient to become a «family owned» business with the opportunity of evolving into a world leading company such as Roche in Basel.

The ultimate goal of academic research is, of course, to explore new frontiers, but it is also to create industrial innovations that can lead to globally-successful outcomes. These need to be ranked alongside the recognition that is apportioned to the outputs of Nobel Prize winning research. This type of outstanding academic entrepreneur is, however, very rare and likely to remain so, given the risks to commercialization. Promotion of early-stage entrepreneurship through research industry transdisciplinary partnerships will help to mitigate risks. Inter/transdisciplinarity effort in tandem with the exchange of ideas and inspiration to innovate are the building blocks of future success. The synergy between university-based and industry-based research teams has proven to be an important factor in the success of some high-profile US research, exemplified by joint laboratories established variously by DuPont, IBM, AT&T, and Corning. These laboratories have generated globally leading products as well as Nobel Prize winners.

The tension between curiosity-driven science and the practical needs of society is more perceived than real. One needs only to recall the famous encounter between Faraday and King William IV, who once asked the celebrated scientist what his «electricity» was actually good for. Faraday answered, «One day you will tax it».

So, University research is not simply a less useful version of industrial R&D. It has a special cultural responsibility for free thinking. Curiosity-driven research free from commercial constraint serves as an engine for innovative output. Over the long term, private industry and the economy can benefit from these new ideas and associated discoveries, augmented further by transdisciplinary research. However, to reorientate research deliberately for practical success will likely offer diminishing returns, exactly the kind of 'tunnelling' approach that transdisciplinarity can counter.

As well as the colocation of research by industry on a university campus, it should be possible to use existing funded mechanisms to second industrial staff to universities, undergraduates to industry secondments and cycling of research projects through university and industry laboratories. All this is already in play, but the unique feature here would be the setting up of projects that were intrinsically transdisciplinary and monitored by an appropriate steering group. Such interactions between universities and industry mitigate the risk that research topics are completely detached from the needs of the society. However, it is mandatory that the research is conducted following ethical rules of scientific integrity and integrity of data, which are described in the article «Business Ethics in the Pharmaceutical Industry and Beyond» in this SWISS PHARMA 43 (2021) No. 4 issue. At the same time it is mandatory to declare existing or potential conflicts of interest of the parties involved. The lifestyle based on scientific integrity and integrity of data must be part of transdisciplinary research and of tools used in the area of «Negotiations Engineering and Conflict Management» (article by Michael Ambühl and Nora Meier in this SWISS PHARMA 43 (2021) No. 4 issue).

Computational science and AI are presently boosting the convergence of all disciplines and ending the schism between natural sciences and the humanities.

Hence, similar to the preparation of the National US Nano Initiative in 1999 (http://www.wtec.org/loyola/nano/IWGN.Research.Directions), the implementation of a corresponding «Transdisciplinary Research and Teaching Initiative» is the logic next step and will lead to a new Megatrend in Science [7], boosting innovation for the benefit of mankind. It is important to notice that Mihail C. Roco (Mihail Roco – Wikipedia) invited not only all US research agencies but also leading representatives of the US industry for the successful preparation of the US Nano Initiative in 1999 (see list of participants in the annexe of http://www.wtec.org/loyola/nano/IWGN.Research.Directions). The CASS (today: Swiss Academies of Arts and Sciences) 2000 Symposium was organized by Margrit Leuthold, Swiss Academy of Medical Sciences, (samw.ch), Hans Leuenberger, Swiss Academy of Engineering Sciences, SATW – it's all about technology, and Ewald C. Weibel, 1929*–2019 †, (samw.ch) who invited Mihail Roco being the first informing the participants.

## 4. Achievements to date and future Ambitions

30 years ago, nationally based education across Europe made cross-European equivalence extremely difficult achieve. Thus, an engineering degree in Italy took 3 years and that in Germany 7 years. Population movement was also constrained across national barriers, translating into reduced exchanges in education and commerce. There were also obvious language difficulties, compounded by cultural difference, between North and South and between Western and the then Eastern Bloc countries.

European Union coordinated University education proved to be the backbone of unified development:

1. The BOLOGNA Ministers' Declaration of 1996 to achieve uniformity in the Education System and in the award of degrees.
2. The EC-ERASMUS Program for student mobility between countries.

The third ambition remains unrealized: Unified ranking of European Universities with respect to quality indicators, teaching quality, delivery to industry, student employment etc.

### Appraisal from Australia

*Whether we consider some of the complex challenges facing the world or consider increasing our knowledge of solving a problem in a limited part of a single discipline, advances are always more likely when the inputs come from a wider rather than a narrower set. This truism suggests that deliberately embracing transdisciplinarity should be our standard way of operating, and not simply a minor option.*

*Embracing transdisciplinary approaches in teaching at all levels and in research as well as in innovations in industry does not come easily. Our discipline based approaches especially in universities and in high schools mitigate against transdisciplinary teaching and research.*

*A key is therefore to promote mobility: of people and of institutions. Examples include forming Institutes in a University that comprise teams from several faculties and industry or cooperative research centres that are virtual and include teams from different institutions (and countries). Such institutions almost by definition need regular review and reforming and disbanding based on performance and the perceived need for the particular approaches. The authors explore comprehensively the need for transdisciplinary approaches and the ways we can increase our efforts. This is a pressing challenge and one that deserves even more attention than what has been achieved to date.*

***Robin Batterham AO***
***Former Chief Scientist of Australia***

### 4.1. Present Status

The BOLOGNA protocol for interoperability together with ERASMUS freeing up individual choice have had the following outcomes:

i) Increased familiarity with different cultures and languages at formative career stages.

ii) Broader horizons for employment through better transnational job prospects and employment choices.

iii) Facilitated international communication to facilitate mutual economic, industrial, and political advance.

iv) Greater business efficiency through ease of working and travelling, outside of the home country.

v) A cadre of scientists more able to perceive supra-national dimensions to their work, particulary in relation to global health, energy conservation and recycling, no longer single nation issues.

vi) Better targetting of European legislation to the needs of people living and working outside their national borders.

vii) Accomodation of culturally different modes of working and operating organsations, coupled with newly acquired linguistic skills.

These outcomes have taken 20 years to come to fruition, but have been well justified given the greater impact of research effort in common interest areas such as the evironment, climate, defence and security. Europe has also become internationally more powerful and globally competitive.

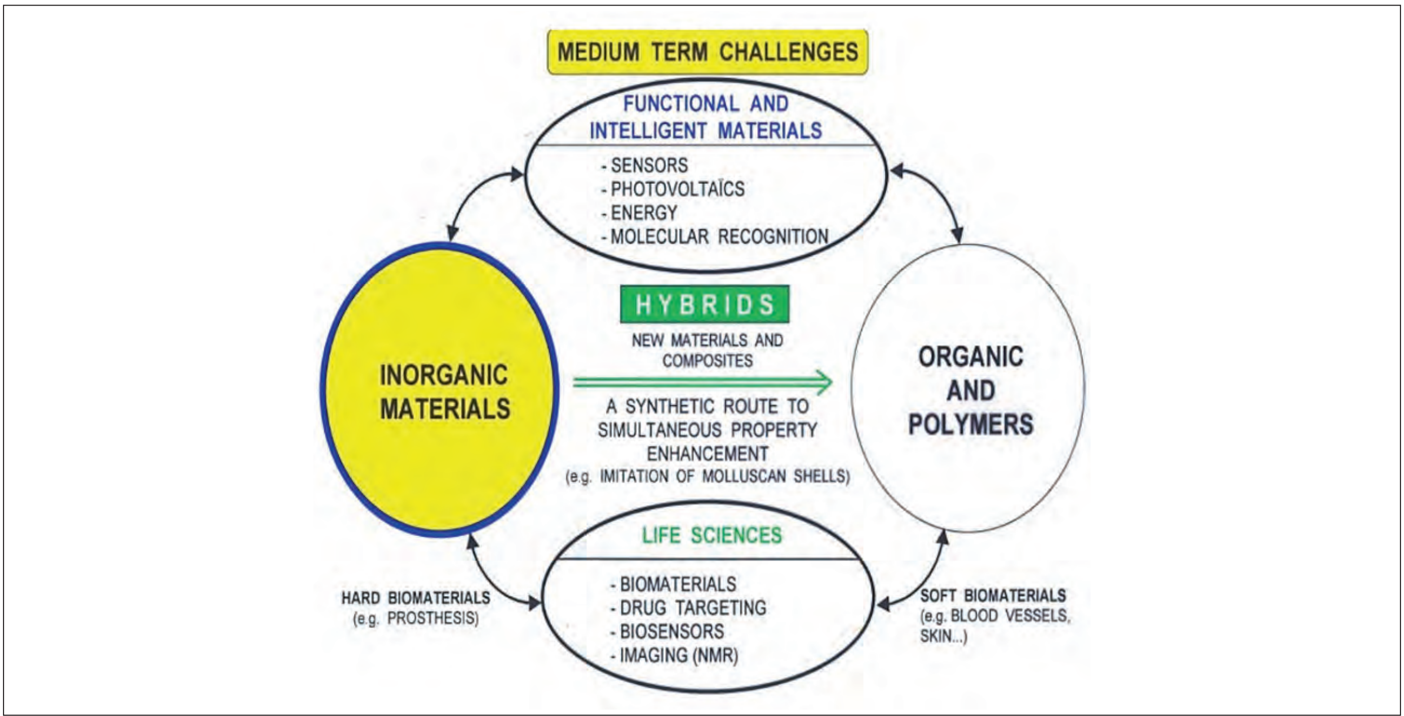


Fig. 4.2.1: Spin-off's of joining departements: Inorganic with Organic Chemistry.

## 4.2. The Developing Needs based on a New Approach

Cross-EU ranking of universities would provide an integrated feedback on key quality metrics. Countrywide ranking already exists, notably in Germany and Spain, but there is natural resistance to go beyond this because of issues of national prestige. Completing this task would help highlight centers of excellence and achieve better dissemination of 'best practice' to assist others for competivenenes on the world stage. Over time, the ranking of performance excellence should extend to ranking of contribution to transdisciplinarity: objective tools for teaching assessment are already used at national level. There would need to be consensus development in what constitutes excellence. For teaching this would incorporate student satisfaction surveys, examination performance, teaching quality audits, clarity of teaching objectves, innovation in how contact hours with students are used, new use of technical aids, class participation levels, how opportunities for two way exchange and mentoring are taken up, the coherence of formal teaching with tutorial, class work problems and practical classes and student feedback reports on taught modules. All these are classic means for assessment but their ranking would need to be worked out anew for transdisciplinary teaching. Excellence in research already has established measures, but also added could be the level of industry involvement, interinstitutional programmes and adventure in transdisciplinary research.

The internationalisation of educational standards beyond Europe can then have wider global benefit in adressing humanity's challenges: climate, migration, social advance, gender equality, clean technology, renewables etc. A more rapid, consistent approach can then be secured with direct benefit to the global citizen, a practical outcome not just a diplomatic nicety.

### 4.2.1. Specialization vs Transdisciplinarity

Specialisation is as fundamental to scientific advance, but a focus on this alone creates long term risk in our handling of global scale problems. Transdisciplinarity offers an alternative that focus the full repertoire of human capabilities towards larger goals.

Advantageous of specialization:
- Deeper understanding of specialist topics.
- Development of leading edge tools for more detailed study.
- High level intellectual challenge to inspire new entrants.
- World class leaders with unique capabilities in specific topics.
- New knowledge and understanding at a deeper level.

Disadvantages of specialization:
- Discipline boundaries constraining scientific cross fertilisation.
- Communicating with other relevant disciplines because of diverging research languages.
- Narrowing skills that is no longer a match to the broad nature of new societal challenges.
- Lack of recognition for the role of the research translator linking disciplines.

Industrial progress has never operated through convenient discipline domains; it relies on a pragmatic approach, constantly redefines itself and converges to a product or service though concerted action. Knowledge has to be sifted and collected between disciplines. Current vaccine development is an example of this, moving rapidly from traditional immune protein design to nucleic acid vaccines, now enabled through nanotechnology. These have answered the threat posed by a global pandemic, and a purely mono-discipline approach does not help here.

Advantageous of transdisciplinarity:
- Barriers between Faculties and Institutes are dissolved.
- Humanity's preparation for global threats such as climate change, which do not respect discipline boundaries, is better organised.
- The talent pool of transdiscipline scientists is better able to adapt to new specialisms and to move on from redundant ones.
- Individual employment prospects improve through greater intellectual adaptibility.
- Topic juxtapositions catalyse novel research combinations and outcomes: 'to think that which has never been contemplated before.

A simple example is given in Fig.4.2.1 when inorganic- and organic chemistry departments are put together, resulting in enormous spin-offs inventions e.a. in life sciences, functional- and intelligent materials, hybrids etc.

Transdisciplinarity need not be considered to be an absolute that does or does not exist. It can be thought of as a spectrum within which degrees of specialism exist. For the best intellectual student, there may be a particular specialist core area that can compete with any specialist, but with sideways integration into other fields. A wider repertoire might not allow for the same level of specialist expertise. A rough guide to an individual might be through an *extensive* knowledge score and and *intensive* knowledge score.

The present stratification of formal degrees should be left as they are, but the components of the BSc should firstly be remodelled to incorporate new topics *(vide infra)*. A commitement to lifelong learning should then allow advancement to a transdiscipline 'hoch' MSc. A subsequent PhD would be for those who have the aim of transdisciplinary university research, while others take the route of research implementation.

## 5. Practical Implementation of the Transdisciplinary Model

Human endeavour is advancing as a global entity with the expansion of international companies and global financial hubs. Education, however, is still a regional or nationally organised endeavour, and accordingly is at a disadvantage. Specialised University studies are pushing us in the opposite direction to global needs. Transdisciplinary approach has the potential to rise to the challenge. Lessons from the past of what achieves breakthroughs have not yet been fully learned; it is through calculated bridging of disciplines that we make our greatest advances. Without this, even the best of our specialists, whether in AI, nanotechnology or informatics, will fail to understand each other or the vital aspects of allied fields; failure to see the bigger picture will lead to failure in solving the bigger problem. In the creation of new disicpline amalgams, there is no single formulaic combination that fits all, more important are the interaction dynamics simply created by the juxtapositions. The following text sets out scenarios for realignments in five sectors by way of example.

### 5.1. Medicine

Medicine as a pragmatic discipline needs to both respond to both advances in basic science and in practical implementation. The advance of new basic science in molecular biology, genetics, robotics and informatics and the realisation of high throughput testing bring with them new challenges of how to equip the modern clinical professional. In this context, it needs to be mentioned that the EPFL Ecole Polytechnique Fédérale in Lausanne, favors inter-/transdisciplinarity with seed fund, see: https://www.epfl.ch/research/services/fund-research/funding-opportunities/research-funding/interdisciplinary-seed-fund/). EPFL is convinced that an interdisciplinary chair in oncology will especially boost positive results at the interface between engineering and cell biology: https://www.epfl.ch/about/working/faculty-position-in-interdisciplinary-cancer-research/. There is greater pressure on the transdisciplinarity that already existed in medicine. The problem-solving nature of medicine, however, has enabled it to accommodate such new fields to supplant the old, and serves as an example of modern transdisciplinary teaching.

At the preclinical stage classical structure and function teaching can be augmented by treating biological processes as management cascades with nucleic acid as governance for trafficking to protein constructs. This then opens up input from engineering and IT. The student gains a wider perspective from allied disciplines never before envisaged. This can extend to pharmacology, specifically, with teaching of nanodrugs and nanomachines. Without grounding in the physical sciences and engineering the practitioner would be relegated to an empirical end user of therapies. It can be argued that a juxtaposition with physical science and engineering (mechanical, process, chemical) is too radical, but medicine is already heavily dependent on such technologies. Artificial organs are another advance operating on engineering principles and feedback which require more detailed understanding.

The new case mix of biology, engineering, nanoscience, informatics and modelling will introduce a level of transdisciplinarity that will prepare the student for the future integral to the art of patient centred medicine that becomes important at the clinical stage of teaching. Distinct teaching areas have already converged to coordinated teaching schedules, but now are set to extend through further transdisciplinarity [8].

What is needed is the setting up of new curriculum committees with multi-faculty input to advance transdisciplinarity in a way that does not burden the individual student, but on the contrary equips them to deal with a field of especially rapid biological, technological and engineering advance. It will be also important that new discipline incorporation does not occur in an incremental way; this will guarantee low impact. Instead, a step change in teaching design and transdisciplinarity is necessary to justify the effort in the first place. The University hospital is a further venue where such new subject interactions can provide teaching benefit at the clinical stage. A key context for all such transdisciplinary teaching needs to be the ethics of healthcare delivery and its priorisation in a global community, brought into sharp focus in the current global vaccination program.

### 5.2. Geography

Geography already has a strong culture of transdisciplinarity. Current teaching covers domains such as human populations, pollution, aquatic physical processes, ecology, climate and agronomy. Greater transdisciplinarity will strengthen the teaching platform. This will usefully include teaching of economics, politics, history, genetics (to understand population movements) and epidemiology (the disease – climate link). With such input, future researchers will be better able to institute predictive models for pandemic spread and climate threats to agriculture and the hydrosphere. This 'new' geography will be a reservoir for dealing with global scale challenges, infection and resource related. Other domains can be readily included, such as of the urban and built environment – of direct relevance to infection transmission. As with medicine, competencies should be imported from other University departments including the Arts (business, politics, history) [9], and there should be teaching of ethical decision making given the wider impact of geography cantered policymaking in society.

### 5.3. Biological Sciences

Biological sciences have seen a revolution through input from chemistry. This has been synthesised into a transdisciplinarity that we refer to as biochemistry, often forgetting this development by last century pioneers. Ultimately biological events converge to being the same as those studied in physics and chemistry. Inclusion of physics, new chemistry and engineering concepts [10] into teaching will create a new type of graduate student able to move readily between biology and the physical sciences. An indication of the transdisciplinary future is shown by the advent of quantum and computational biology and the use of AI to achieve predictive modelling of protein, once thought impossible. Progression to a deeper understanding of biology from the physical science perspective will bring us ever closer to understanding biological phenomena, inclusive of energetics and free radical effects, of fundamental relevance to ageing. Beyond this physics will provide a probe to the elemental atomistic processes that govern life. The context of biology is also important and ethics teaching will enable future practitioners to critically evaluate both biological techniques and the outcomes of biological interventions.

### 5.4. Pharmaceutical Sciences

In 1231 Frederick II (1194*–1250 †), Holy Roman Emperor (Frederick II, Holy Roman Emperor – Wikipedia), king of Sicily, was the first to issue a medicinal decree defining the tasks of a pharmacist and of a physician leading to the separation of the two professions and disciplines. Today, the city of Basel not only hosts the headquarters of the pharmaceutical companies Novartis and Roche but also the «Basel Oath of Pharmacists» in the Red Book of the Basel State Archive, being written around 1300. After a candidate with a master thesis in Pharmacy passed the federal exam at the University of Basel he/she does not only receive the federal diploma as eidg. dipl. Apothekerin (Ausbildung zum Apotheker (pharmasuisse.org)), but as well, as a gift, a copy of the historical «Basel Oath of Pharmacists». The article «Studies of pharmaceutical sciences in Switzerland» in this SWISS PHARMA 43 (2021) No. 4 issue by G. Borchard and Ch. Moll describes its societal impact on the Swiss economy. The University of Basel and the nearby University of Applied Sciences of Northwestern Switzerland (FHNW) are surrounded by world leading research laboratories of the Swiss Pharmaceutical Industry that allow extremely fruitful interactions and collaborations. Thus, it is possible that PhD students do their thesis at an industrial laboratory. In such a case, the science faculty and the industry allow the responsible professor at the University of Basel to supervise the thesis at the respective laboratory, (www.ifiip.ch/annual reports). After the PhD exam, most PhD students are directly hired as industrial pharmacists in Analytical Pharmacy, Clinical Pharmacy & Research, Drug Research, Pharmaceutical R&D, Quality Assurance, Pharmaceutical Production, etc.

This is a unique situation ***promoting transdisciplinary research,*** since the PhD student is collaborating with scientists of different educational background and culture. In addition, the following advantages are evident: a) The responsible professor at the University defines along with the industry the topic of the PhD thesis with the goal of a «win-win» situation; b) The PhD student has an official contact person at the industrial laboratory, serving as a liaison officer, who is in the ideal case, but not necessarily, also a lecturer at the university; c) The responsible professor at the university has access at any time to the industrial laboratory to supervise the work of the PhD student; d) The responsible professor discusses on a regular basis the progress of the PhD work with the student and the industrial liaison officer; e) The PhD student is using the high-tech laboratory equipment available at the industry; f) The salary of the PhD student and cost of materials, insurance, etc are covered by the industry; g) The liaison officer at the laboratory thus knows the performance of the PhD candidate before he or she may be hired by the company; h) The PhD candidate becomes familiar with the daily work of an industrial pharmacist, that may motivate the PhD student to apply for a job in the industry. Due to the evident «win-win» situation, there should be no need to apply tools of the article «Negotiations Engineering and Conflict Management» in this SWISS PHARMA 43(2021) No. 4 issue.

As with medicine, pharmaceutical sciences, is a crossroads discipline grounded in transdisciplinarity that covers chemistry, drug design, disease related knowledge through manufacturing. For future pharmacy practitioners, the traditional headings may well remain in place, notably 'retail', 'industrial' and 'research', but their functions will be radically different. A retail pharmacist will go beyond being a purveyor of medicine to one who is a point of contact for patient care, recommending drug therapies and providing diagnostic consultation based on new analytical tools. The retail pharmacist will also have access to patient metrics for individualised drug therapy. This possibility is indicated by work on the human genome, the establishment of biobanks and advances in pharmacogenomics. The future industrial pharmacist will develop manufacturing processes for biological drugs following up from small scale genetic expression systems. This has been seen for current vaccine production. The skill set of today's biochemical engineer, including modelling and molecular need to be included in teaching. The administrative role will be to compress the time between tailored drug production and its point of care delivery for labile biologics. High level management coordination and IT skills are need for this; there is a parallel to 'just in time' manufacturing in the car industry. Delivery of a drug can be to home, retail or doctor's office locations analogous to consumer goods. The pharmacy, however, is at the hub of decision making of a precise drug dose, type and formulation – a more complex task underpinned by IT support. Whilst they refine the therapy in this way and have a more two-way relation with the doctor, the primary decision to institute a therapy, governed by national bodies and the condition of the patient, must rest on a medical decision in consultation with the patient. So, the balance decision making does not change, but it is the complex formulation decision that the pharmacist finally makes.

New teaching therefore needs to broaden the transdisciplinarity agenda. New staff added to pharmacy schools will have molecular modelling/biology, bioengineering, informatics nanotechnology [11] and IT expertise. Combating resistant infectious disease [12] is a particular responsibility for globally positioned pharmacy, and here the adaptation of nanomedicine tools will allow existing drugs to overcome resistance mechanisms. The efficacy of corona virus vaccines through lipid nano packaging are an example.

Advances in nanotechnology are increasingly being utilized in combination in biotechnology as well as pharmacy. The unique properties of materials at the nanoscale, our ability to synthesize them, to visualize their workings and the ability to manipulate and tailor their physical chemistry at the boundary where biomolecular interactions take place opens up a myriad of opportunities in the pharma arena with extension to medicine and biotechnology [13]. It also gives us the unprecedented possibility to directly manipulate interactions at the biomolecular scale. The motivation to create smart nanostructures will not only be because of their chemical and biological activity, but also because they can be targeted delivery vehicles able to reach regions that traditional methods cannot and thus circumvent barriers that prevent the delivery of traditional pharmaceutical approaches: stealth objects. Ultimately, advanced medicine will not progress on the basis of knowledge alone, there will be a need to exploit hybrid technologies such as nanotechnology coupled with the rapid design, processing and implementation that AI can now offer us, now brought within reach of the healthcare professional at the patient interface. The risk to the continued flow of new drugs in the traditional drugs pipeline remains high, and it is likely that nanotechnological re-design of existing functional chemistries will be necessary for future effective drug agents, particularly with regard to antibiotics. The deployment of advanced technologies will bring ever greater need for ethical scrutiny, and teaching of ethics needs to be integral to transdisciplinary teaching; without transparency on this, societal acceptability may be limited whatever the technological merit of a give approach.

Organizationally, where national policy has produced pharmacy teaching in parallel with life sciences teaching to BSc and MSc level, it is beneficial to create a transdisciplinarity for pharmacy by exploiting the biological expertise directly within their teaching – the advent of biological drugs makes this a timely move. With jointly led reformating, a single merged curriculum can be successfully achieved effecting a reinvention of pharmacy. In view of the above three specialisms for pharmacy practitioners, at later years, students would be able to take up optional modules enabling them to progress along particular pharmacy technological aspects. Within each of these, however, also the principle of transdisciplinarity has to be maintained to avoid a narrow preparation for future careers, and in so called specialism there will be a need for chemical, biological, nanomaterials and other teaching to be included. The nominal specialisms of the retail, research and industrial pharmacist may be kept as such, but their function will develop considerably. Already, the retail pharmacist is providing health guidance to the patient in many countries, and given the complexity of future drugs, they are set to become a specialist who can guide the clinician, already overburdened with managing complex medical treatments and technologies. At research level, the unique combination of physical and biological science the pharmacist will have will result in important leadership roles given that mastery of drug design and biological action will be increasingly needed in combination. For manufacture, biological and bioprocessing knowledge of the pharmacist will be crucial in leading new production processes for biologics; we have seen precisely this kind of skill set requirement for vaccine manufacture. The reality is that the current complexity of healthcare demands the greater input of different professional types, and pharmacy is set to play a crucial role in simplifying the work of the clinical practitioner through contributing detailed drug therapeutic knowledge, from side effects to efficacy, and this may expand to drug diagnostics, monitoring and the individualisation of therapies as we advance our genomic knowledge.

With respect to implementation, such a School would have a leadership represented by physics, engineering, computing, chemistry engineering and biology. They would direct the teaching in partnership with established pharmacy teachers who would also do teaching in these other topics. At each stage, whether BSc or MSc, 30% of the curriculum would be 'non-pharmacy' teaching, and extra space for pharmacy teaching left out at undergraduate level would be provided in the MSc. The first years would have separate modules, but with increasing use of problem-based learning, the student would be tasked with problems that could only be solved by transdisciplinary approaches. Critical to the first years would be the accumulation of fundamental knowledge and principles which would be tested by knowledge and understanding, but in later years this would give way to use of knowledge in multifaceted problems, not in textbook recall.

### 5.5. Humanities

The rate of change in our cultural and social space is as every bit as fast as for the natural sciences. Accordingly, there is a need to bring together the principles by which we understand human cultural domains, whether these are in the artistic, social, anthropological, philosophical or historical domains. All are interrelated to varying degrees, but a light is seldom shed on the nature of the linkages, how one type has influenced the other, and how all are a manifestation of how humanity has tried to rationalise and communicate higher order concepts in a kaleidoscopic natural world. Transdisciplinary teaching here should have its core set in the teaching of linguistics, philosophy and psychology as human engines of thought, and then bring in history/anthropology, social sciences through to aesthetics and the arts (literature, music, theatre) in subsequent years, including at postgraduate level, as the outward expressions of the human internal mind. History and politics, in particular, will be better understood in terms of the human mind reacting to external complexity. The incorporation of different ethical and cultural value systems teaching will also have an influence on how different fields of the arts are understood and valued in different cultures. This will, preferably, be coupled to the teaching of legal systems. Overall, it is the mutual influence of arts topics that needs to be taught and to thereby impart a holistic understanding of what is beneath the outward manifestations of humanities subjects. Whilst this is necessary for the arts simply as a cultural responsibility, it does also have utilitarian value. Policy making and resource allocation are ultimately rooted in a societal value, and unless a broader teaching has been achieved, our policy makers will have a narrow prism from which to make decision that affect all of us.

Through such changes, the overall university role also shifts. As a specialist arm of society, it can provide new policy input for scientific research on global problems as part of a coordinated consortium with other international and national centres of learning. Science policy departments have been established, an effort that is a reflection of the recognition in university teaching of global priorities. Thus, universities are enabled to be part of the wider policy dialogue with other government. The internal organisational structure of the university also needs to change with governance a 'bottom up' activity rather than 'top down'; this returns academics to a different level of academic freedom, conditioned not by institution norms, but by the local level inventiveness and free thinking that resides at departmental levels close to the teaching and research front. An agile local level organisational structure also is able to rise to new challenges with an ability to network more readily with their equivalent globally on a target driven basis for research and teaching with equivalence in degree awards. The formal structure of the university does not change, it is the level of managerial input and resourcing at top level vs that at the local level that changes in its balance. The cascade of management: Central – Faculty – School – Department can be as before but the balance of decision-making shifts down this cascade. Where critical mass for a particular unique activity is needed, then staff in existing structures can come together under a special research 'home' – the Research Institute, one with a specified research goal and achieving a global reach. Such centres may be of finite lifetime, new ones would come forward and should be limited in number. A centre may also be a more suited for joint activity with industry. Here the University Science Park concept overlaps with the academic research centre concept but the mission limited status would help to focus joint research effort. With such teaching and research centres, the talent pool for industry can also be better tailored to need.

The launch of the transdisciplinary initiative needs to be via a European Rectors meeting who have the unique power to agree general principles and to institute change at demonstrator locations. However, there has to be participation, also, of learned societies, the European Commission and Ministries in order to map out specific details with representation of their 'end user' requirements for a future graduate work force.

### 5.6. Studies in Nanosciences

Studies in Nanosciences are by definition transdisciplinary. The Swiss Nanoscience Institute (SNI) at the University of Basel offers a Bachelor and Master Program for students interested in biology, chemistry and physics with enthusiasm to explore the nano cosmos. The Bachelor of Science with Major in Nanosciences is the prerequisite for follow-up studies to obtain a Master of Science with Major in Nanosciences or with Major in Biology, Chemistry or Physics. In this context, Joel de Beer (Study | Swiss Nanoscience Institute), master student, declares «*The advantage of the Nanoscience program lies in the linkage of a very broad selection of contemporary science disciplines and the applications thereof. While providing a unique insight into completely different mindsets, it simultaneously* *allows the exploration of common denominators and mediates a wide fundamental understanding of nature. During my undergraduate and graduate studies, I experienced the University of Basel as a progressive center of research and innovation that encourages international mobility and maintains a close partnership with global industrial players.»*

Since 2001, the Swiss Nano Science Institute (SNI) of the University of Basel is hosting the National Competence Center in Research in Nanoscience (NCCR Nano). Partners in the network of SNI are: University of Applied Sciences of Northwestern Switzerland (www.fhnw.ch), Paul Scherrer Institute (www.psi.ch), Swiss Federal Institute of Technology Zurich (ETH Zurich – Homepage | ETH Zurich), University of Zurich (UZH – University of Zurich), EMPA (www.empa.ch), IBM Research Laboratory (IBM Research | Zurich), Swiss Center for Electronics and Microtechnology CSEM (Industrial Research and Development | Technological Innovation (csem.ch), University of Neuchatel (https://www.unine.ch/), University of Fribourg (https://www.unifr.ch), and the Swiss Federal Institute of Technology in Lausanne EPFL (École polytechnique fédérale de Lausanne – EPFL). Head of the SNI is Christian Schönenberger (Christian Schönenberger – Wikipedia).

## 6. Conclusions

Universities have historically focussed their education and research within specific academic disciplines [14]. Many of today's problems that research and education are needed to help solve are not defined in terms of convenient disciplines, yet these are precisely the problems that humanity needs to solve with urgency, covering especially the environment, energy, and health.

It is not enough to *value* individual experiences, disciplines, creativity and ideas. It is imperative we have practical strategies and practices that transform interdisciplinary links into more effective connections. We have to recognize the importance of discipline interdependence in order to actualise it, and we have to know how to act once we have developed that «recognition» [15] .

In ensuring a broadly-based education, that is both globally recognized and allows for the 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.

This higher-level ambition can only be realized through structural change in the teaching case mix for the new generation of students. It cannot simply be a matter of topic 'add-ons', but a reinvention of curricula is needed with participation of new disciplines from across different sectors. Technical literacy in multiple fields and the ability to synthesize novel ideas and concepts are not always possible from a single discipline standpoint. Trans discipline effort brought to bear on multi-faceted problems is the most efficient way for society to win the race against the threats and to allow us to exist in equilibrium with the natural world. Achieving this transdisciplinarity is not set to be easy, not least because traditional thinking sets barriers. However, as a matter of urgency, what was correct for the quiet past is not appropriate for the turbulent future. For this reason, reputed universities in the United States

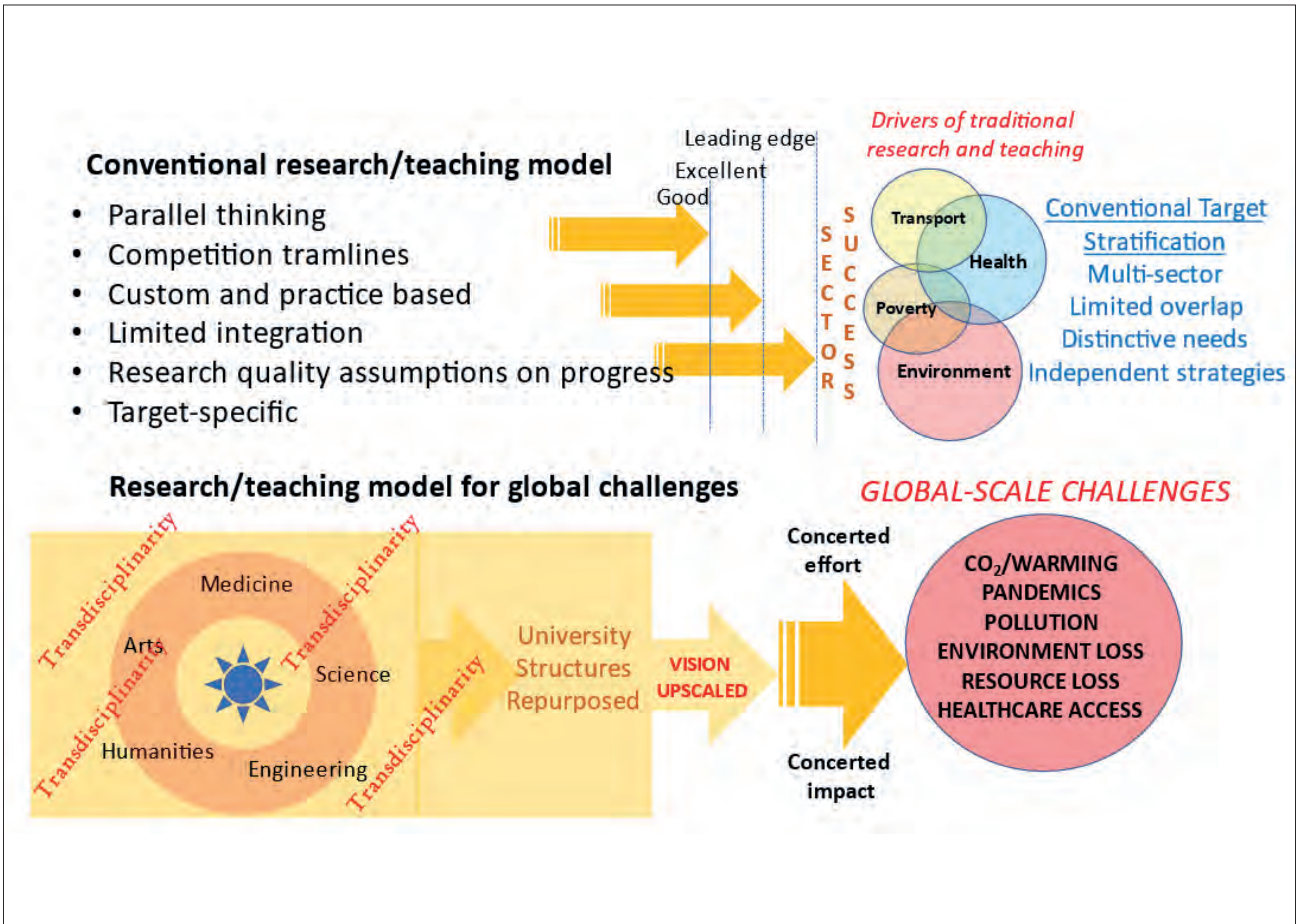


Fig. 6.1: The Model of Transdisciplinarity

started to create inter-/transdisciplinary chairs being followed in Europe. In this context, EPFL – Ecole Polytechnique Fédérale in Lausanne opens an inter-/transdisciplinary faculty position: https://www.epfl.ch/about/working/faculty-position-in-interdisciplinary-cancer-research/. There may be risks to radical educational change, but the bigger risk is educational stasis.

There are also huge intellectual benefits for the transdiscipline empowered individual with proficiency across different fields. Hitherto such a capability came about in exceptional individuals through unorthodox careers. It is no accident that the Chief Scientific Advisor to the US Government is mathematician who moved into molecular biology. However, such innovative combinations cannot be left to chance, but need to be a structural part of our teaching policy. The capacity to do this is already within grasp, since universities already have the requisite skill sets; they simply need to realign them in the service of a human need that transcends just the world of learning.

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 our economies and greater society.

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