THE UNIVERSITY AND THE DIGITAL TRANSFORMATION OF SOCIETY

WHAT CHEMICAL ENGINEERING EDUCATION IN 2030?

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V CONGRESO DE INNOVACION DOCENTE EN INGENIERÍA QUÍMICA

UNIVERSIDADE DE SANTIAGO DE COMPOSTELA, 22 JANUARY, 2020

TO SAY WHAT I AM GOING TO SAY....

- Life Today - the need to adapt to the times
  - A note about the evolution - from the 'fifties' to the 'thirties', From 1950 to 2030...
  - The ongoing 4th Global (R)Evolution
- Academic issues - The Substance and the Learning Process
  - The substance of Chemical Engineering Education - the heart of the educational process
  - The learning process, the great challenge of and for the near future, requiring a determined pedagogical innovation attitude

Life Today

The need to adapt to the times

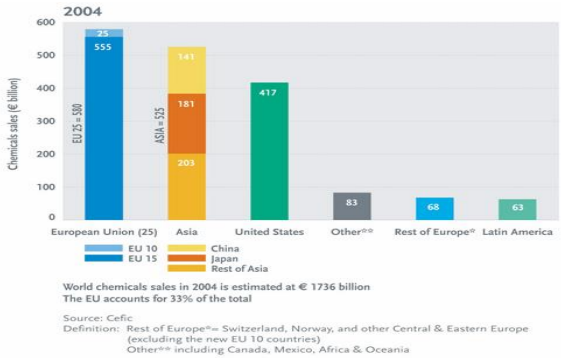
Life Today
I – Driving forces for changes in Europe… and in the World

- Last quarter of the 20th Century - Intense search of new routes for Europe and for the role of Europe in the World, driven by
- Progress observed in Science and Technology, namely
  - in digital systems and communications
  - in health and life sciences
- Political changes that took place in Europe, since the late eighties…
- Expectations and demands of Society
  - Education for All - mass education policies
  - Quality requirements of a Society of "Comfort"

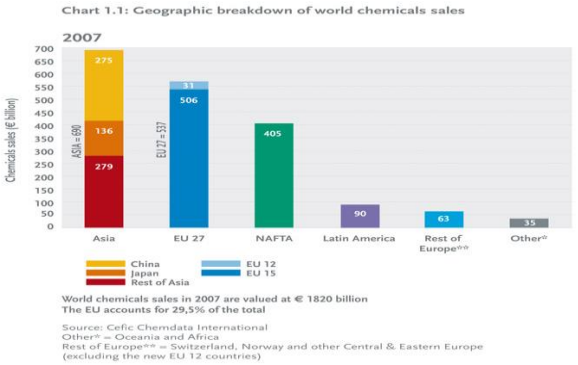
LIFE TODAY
II – A MIX OF CHALLENGES, THREATS AND OPPORTUNITIES

- The computer and communications era - dramatic changes of the concepts of time and space - globalisation
- The global market economy - driving today's Societies
  - The increase of Expectation of Life
  - Sharp increase in standards an competition Worldwide
  - Volatility of jobs
  - Job market and opportunities - wider than ever
- Social sustainability - work longer years
- The decrease of knowledge half-time - back to School
- Significant change in the concepts of individual career management, mainly for Young People

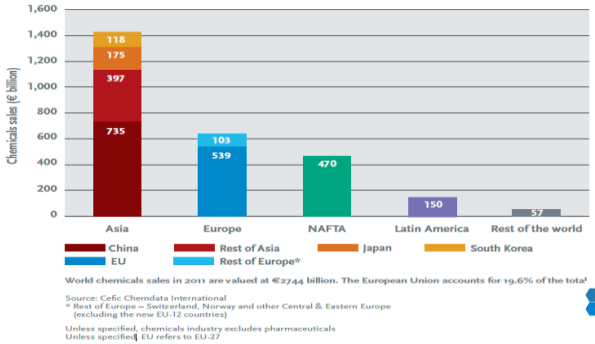
LIFE TODAY – THE RISE OF THE DRAGON AND OF THE ASIAN TIGERS
GEOGRAPHIC BREAKDOWN OF WORLD CHEMICALS SALES – 2004



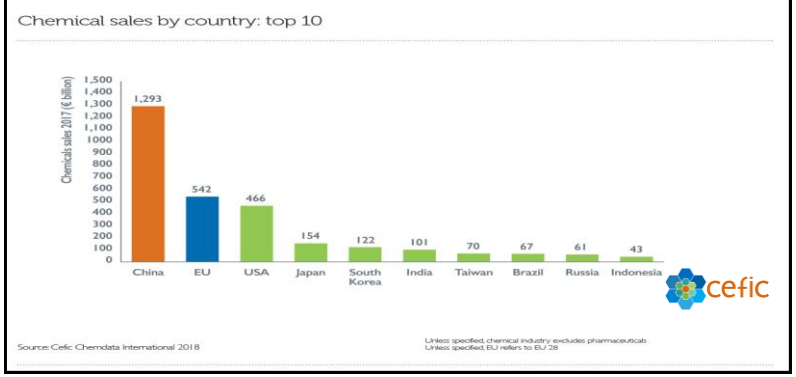
LIFE TODAY - THE RISE OF THE DRAGON AND OF THE ASIAN TIGERS
GEOGRAPHIC BREAKDOWN OF WORLD CHEMICALS SALES - 2007



LIFE TODAY - THE RISE OF THE DRAGON AND OF THE ASIAN TIGERS
GEOGRAPHIC BREAKDOWN OF WORLD CHEMICALS SALES - 2011



LIFE TODAY - THE RISE OF THE DRAGON AND OF THE ASIAN TIGERS
GEOGRAPHIC BREAKDOWN OF WORLD CHEMICALS SALES - 2017



NEW PARADIGMS

- With the evolution of the digital technology, of computer science and of transports - FOR ALL PRACTICAL PURPOSES THE WORLD IS SHRINKING
- A Global World that lives with and in a new paradigma of coexistence
  - ✓ COOPETITION = COOPERATION + COMPETITION
- The need to understand other cultures and ways of life
- The need to THINK GLOBAL, particularly in large companies- think 24/7 - When Asia goes to sleep we start work; when we go to sleep, America starts work
- So, the need to promote Mobility and Cooperation - only achievable by promoting TRUST
  - ➢ Through recognized Quality Assurance Systems, accepted by all Stakeholders

EUROPE - HOW TO FACE THE CHALLENGES WITHIN OUR DIVERSITY?

POLITICAL CHALLENGES THAT EUROPE FACES IN HIGHER EDUCATION

- The need to strengthen the European Higher Education Area (Bologna…)
  - ✓ University Alliances, a good initiative
- Work to face the challenges of Global Competition - a market without borders in the offer of Higher Education
- Promote the attractiveness of the European Educational Model in a lifelong learning and a global context
  - ✓ Face the challenge of the demographic evolution - for all reasons, reach new publics
- Understand the new responsibilities of institutions in this rapidly changing World - provide responsible AUTONOMY
  - ✓ The need to monitor quality within diversity
  - ✓ The need to diversify financing sources

The ongoing Digital (R)evolution

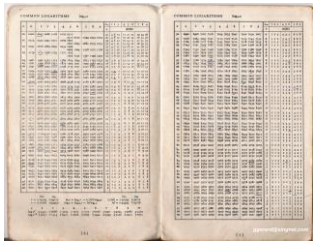
An extraordinary trajectory of development, globally and specifically in the Academia

Instruments from the days of the 'Palaeolithic'
(I) Reference Mathematicians

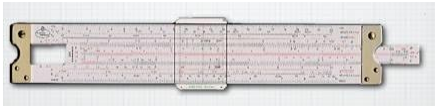
- John Napier (1550 – 1617) – proposed the concept of Logarithm
- Henry Briggs (1561 – 1630) – with Napier, further developed this concept – developed the 'common logarithms' (base 10) and published the Logarithm Tables (?)
- Edmund Gunter (1581 – 10 December 1626) – created the Logarithmic Scales
- William Oughtred (1574 – 1660) – based on Logarithmic Theories and on the Logarithmic Scales, developed the famous and all relevant SLIDE RULE

Instruments from the days of the 'Palaeolithic'
(II) Logarithm Tables and Slide Rules

- These are Logarithm Tables



- E these are 'Slide Rules'



Fundamental instruments for Engineering Design

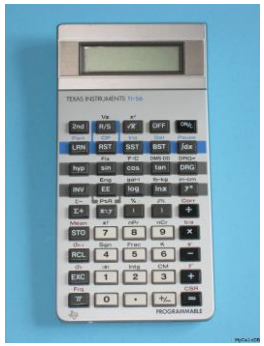
… till the decade of 1970!!! 1970!!!

Instruments form the days of the 'Palaeolithic'
(III) The 'revolutionary' mechanical calculators FACIT (~1960 -)

- What is (was) a FACIT? … that I used widely in the University in 1969, 1970…,

Instruments from the days of the 'Palaeolithic'
(IV) The first scientific calculators

- The first scientific calculators, in 1972 - the HP - Hewlett Packard, far too expensive
- Followed by the more affordable TEXAS INSTRUMENT
- Widespread use, only in the late seventies, they finally took the place of the SLIDE RULE



Instruments from the days of the 'Palaeolithic'
(V) Computer programmes in punched cards (!) (~1977 -)

- Late in the day, used to take them to the Computer Center…
- Early morning, the next day, back to the Computer Center to pick the results up…

INSTRUMENTS FROM THE DAYS OF THE 'PALAEOLÍTHIC' (VI) COMMODORE PET CONTROLLING A PILOT PLANT(~1979

- 'Very sophisticated' system at the time, programmed in BASIC,
- Today, completely archaic… in the face of sensors that communicate with wireless systems… and , of course, the computer itself

A PHOTO FROM THE DAYS OF THE 'PALAEOLITHIC', FAMILIAR TO SOME OF YOU…

josemmf@usn.no |
17.12.2018

From the 'Palaeolithic' till the present day (2017)

From the 'Palaeolithic' till the present day… (2018)

Understand the pace of development

- Between ~1600 and 1972 - more than 370 years - work was developed with Slide Rules, Logarithm Tables, and (already in the 60's of last century, with mechanical calculators
- Between 1972 and 1980 - first pocket calculators with capacity of scientific computing
- In the 80's - first desktop computers
- So, fundamental engineering has been developed, WITHOUT DIGITAL INSTRUMENTS - no computers, no scientific calculators, no digital communications...
- Well, this looks like as being from the 'Palaeolithic' days, but it was less than… 50 years ago….

The ongoing Digital (R)Evolution

A new period of transformations,
of the several that we already perceive in the History of Humanity

INDUSTRIAL REVOLUTIONS ARE NOT OF TODAY
WHERE'S THE DIFFERENCE? (I)

- **OVER THE CENTURIES - Areas driving change:**
  - Energy, Communications, Liberal financial policies
- Similarities - what was said in the past, evolution and advances…
  - Globalization (!), With locomotives and steamships allowing the 'massive export of goods worldwide';
  - 'Times of dramatic change in the world, with' rapid changes in social and economic patterns ';
  - Pasteur's advances (1822-1895) 'revolutionized the world as it was known';
  - Thomas Edison's inventions (1847-1931) 'changed the world forever'

INDUSTRIAL REVOLUTIONS ARE NOT OF TODAY
WHERE'S THE DIFFERENCE? (II)

- The difference is immediately in the dimension, scope and complexity, in the SPEED OF CHANGE
  - In the dimension of OPPORTUNITIES AND THREATS
  - In the necessary global vision of the world, IN ITS MULTICULTURALITY
  - In the relevance of KNOWLEDGE AND TALENT
- BUT, Today as in the Past, a profound social and economic impact… a need to fight for a more equitable distribution of wealth

INDUSTRIAL REVOLUTIONS ARE NOT OF TODAY
BUT THERE HAS BEEN AN ACCELERATION OVER THE PAST 70 YEARS

- **Third Industrial Revolution and its projection Revolution 4.0**
  - From about 1950, until today and… for the near future…
    - Energy evolution - from post-war nuclear ... to renewables
    - Transistors, Microprocessors, Computers, Automata, the Internet, Wireless Communications, Transport ...
    - Robots, Genome Edition, the Internet of Things, Augmented Reality, 3D Printing, the New Business Model ...

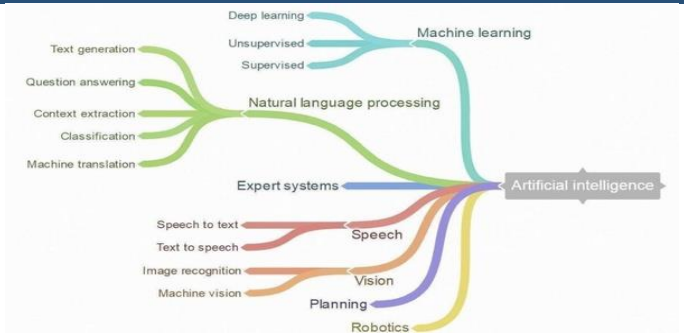
ARTIFICIAL INTELLIGENCE – A VISIONARY CONCEPT OF THE 50'S (I)

- **Alan Turing, 1950, a visionary text…, "I propose to consider the question, 'Can machines think?'** ('Intelligent Machinery', Report for the National Physical Lab, 1948, but paper effectively published only in 1950!) ,- **it is cited as the reference of the beginning of the 'New Era of Intelligent Machines'**
- The designation 'Artificial Intelligence' is due to **John McCarthy,** Dartmouth, USA - in 1955 he created the 'Artificial Intelligence' Group to study '**thinking machines**'; in 1956, he organized a workshop concerning this subject
- AI is today a designation that covers all methods, techniques and technologies that HUMANS develop AND USE to design machines that mimetize or simulate in an independent way much of HUMAN ACTIVITY that requires 'intelligence' - **think; feel; identify; process, interpret; understand; learn; behave; create, plan…**

Some concepts and terms associated to Artificial Intelligence

Artificial Intelligence (AI)	Inteligência Artificial
Machine Learning (ML)	Aprendizagem de Máquina
Deep Learning (DL)	Aprendizagem Profunda
Artificial Neural Networks (ANN)	Redes Neuronais Artificiais
Fuzzy Logic (FL)	Lógica Difusa
Data Mining	Exploração de Dados
Hybrid Modelling	Modelização Híbrida

Artificial Intelligence – overview of applications (IV)



Abhishek Panda, Data Science Intern at KPMG (2018-present), Dec 10, 2018

Artificial Intelligence in YouTube

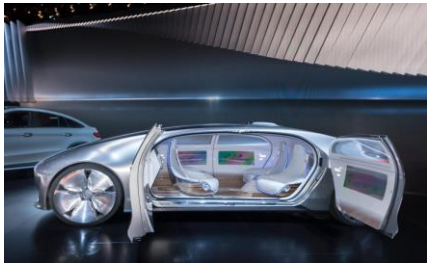
- Discovery Channel - Artificial Intelligence - IBM's AI - 27 August 2018
  - Part 1 - https://www.youtube.com/watch?v=H3P87qCdqk4
    - ✓ IBM's WATSON
  - Part 2 - https://www.youtube.com/watch?v=Krqy-Eso3a8
  - Part 3 - https://www.youtube.com/watch?v=E0uehCrPMlU
  - Part 4 - https://www.youtube.com/watch?v=EJEvwwghTJw

Vehicles of the... present

Unmanned Vehicle,
USN - University South-Eastern
Kongsberg, Norway, September 2019

VEHICLES OF THE… PRESENT

… planned to be shortly in the market, fully equipped (so the makers claim) with an autonomous control system…



In Driverless Vehicles: How unmanned cars are conquering the world
articles | Nov 12, 2018 | Tech & Security | by Digital Corsair

VEHICLES OF THE… FUTURE???
3.5 MILLIONS OF 'EX- LORRY DRIVERS' IN THE USA…

From the 'Palaeolithic' till the future… ??? 2050… ??? Fiction? Or, is it not? !!!

Photograph: Tetra Images, LLC/Alamy Stock Photo, Guardian, 6 September 2019

So, the future Today - the ongoing Digital (R)Evolution

- Products and Instruments of **AI** are entering at great speed all areas of life, as result of this exponential **increase of the capacity of data treatment, of computing and of communications of present digital equipment**
  - With inequivocal impact on methods and on our way of life
- In Industry, we head for (we are already in..) **the Industry 4.0** - the 4th Revolution
- In Academia, it brings in the need for major **pedagogical changes**

Academic Issues

The Substance of chemical engineering education

Educational and life requirements for Millenials and Gen Z

- Today, as in the past, the objective is to offer training to, to prepare young people, aiming at opening up the horizons of their thinking
- BUT, there are fundamental differences concerning the future, relatively to past generations, in that Millenials and Gen Z:
  - Will live longer
  - Will have to work longer years
  - Will have to study longer - go back to School (Whatever School means…)
  - Will, more and more, have to work further away from Homeland
  - Will, in fact, have to think GLOBAL, to the dimension of the PLANET… or further beyond…!

QUALIFICATIONS FRAMEWORKS FOR CURRICULUM DESIGN
THE DIFFERENT LAYERS – WHO DOES WHAT…

- **High level descriptors - Meta Frameworks**
  - Characterized at institutional level of governments and stakeholders
  - They represent the 'legal crust'
- **Complemented by Sectoral descriptors**
  - By area and specialty
  - In close cooperation with higher education institutions and professional associations
  - In transnational cooperation
- **Complemented by descriptors at branch level**
  - Typically developed in **Education Working parties and Academic Consortia**, at European Level, or within regulatory bodies at national level
  - They are the basis for credibility of the whole system

QF-EHEA - Qualifications Framework for the European Higher Education Area (Bergen, 2005)

- **These are high level broad descriptors** that will have to lead to more specific descriptors in each area or specialty within a given area
- A degree structure with **three main cycles and a short cycle** within or linked to the First Cycle, characterized in terms of:
  - ✓ ***knowledge and understanding***
  - ✓ ***applying knowledge and understanding***
  - ✓ ***making judgements***
  - ✓ ***Communication***
  - ✓ ***Learning skills***

The EUR-ACE Framework and Accreditation System
A (most relevant) European Sectoral Framework

- Standards developed, compatible with the QF-EHEA - distinguishes between First and Second Cycle programmes, as defined in the European Qualification Meta Framework
- Identifies expected Programme Outcomes for the following 6 Knowledge and Competence areas:
  - ✓ Knowledge and Understanding
  - ✓ Engineering Analysis
  - ✓ Engineering Design
  - ✓ Investigations
  - ✓ Engineering Practice
  - ✓ Transferable (personal) Skills

Chemical Engineering Education in and for the future
I - Recommendatiions of the EFCE Working Party on Education (I)

- Branch level descriptors must be compatible with the European Meta Frameworks (QF-EHEA) and with the sectoral frameworks (EUR-ACE)
- THAT IS THE CASE OF THE
  - Recommendations of the WPE-Working Party on Education of the EFCE - European Federation of Chemical Engineering (2010)
- They were the result of a comprehensive discussion within the Working Party, envolving ~40 members from 26 countries
- See EFCE Site and Bologna Recommendations (2010) at

  https://efce.info/WPE-p-26.html

CHEMICAL ENGINEERING EDUCATION IN AND FOR THE FUTURE
I - RECOMMENDATIONS OF THE EFCE WORKING PARTY ON EDUCATION (II)

- These recommendations cover
  - Learning outcomes
    - General chemical engineering skills and knowledge
    - Transferable skills
  - Achieving the learning outcomes
    - Core curriculum
    - Teaching and learning
    - Industrial experience
    - Review of the educational process
    - Student assessment
- The core curriculum proposed covers only approx. two thirds of a first and a second level degree study, leaving wide room for flexible programmes

CHEMICAL ENGINEERING EDUCATION IN AND FOR THE FUTURE
I - RECOMMENDATIONS OF THE EFCE WORKING PARTY ON EDUCATION (III)

- A minimum dimension is proposed to
  - Basic sciences, enlarged with life sciences
  - Chemical engineering sciences
  - Chemical engineering core
    - ✓ With engineering design,
    - ✓ With a dissertation for training R&D&I,
    - ✓ With diverse profiles through electives and external training.
- New directions for programmes and education are encouraged to
  - Develop an international dimension and a culture of quality
    - ✓ Prepare programmes for cooperation - joint degrees
  - Incorporate new topics, new knowledge, competences and skills

CHEMICAL ENGINEERING EDUCATION IN AND FOR THE FUTURE
II - TODAY AND FOR THE FUTURE, WE HAVE TO…

- Speak of
  - Life sciences and of biology as one of the four basic sciences,
  - Environmental issues and sustainability
  - (Nano)structures and material science issues
  - Energy - An economy based on alternative energy resources
  - ….
- Give an answer to the demand of Society for specificity and quality
  - New products - competencies in product design
- Of course, speak of Industry 4.0
  - Systems engineering and knowledge based methods for optimised, safe, simple to operate systems
- Value Soft Skills - job related, societal related, behavioural skills

CHEMICAL ENGINEERING EDUCATION IN AND FOR THE FUTURE
III - EUROPEAN RECOMMENDATIONS OF KEY COMPETENCES FOR LIFELONG LEARNING

- Eight essential transversal competences:
  - Literacy competence
  - Multilingual competence
  - Mathematical competence and competence in science, technology and engineering
  - Digital competence
  - Personal, social and learning to learn competence
  - Citizenship competence
  - Entrepreneurship competence
  - Cultural awareness and expression competence

(In Council Recommendations of 22 May 2018 on key competences for lifelong learning, Official Journal of the European Union, 4 June,2018/C 189)

INDUSTRY 4.0 (I)

- SPIRE - Sustainable Process Industry through Resource and Energy Efficiency - Thematic workshop, Towards Industry 4.0: Digital Technologies in Process Industry, 1 October 2018
  - European Roadmap for Industrial Process Automation
  - How to make chemical plants cognitive, with ability to adapt and predict, using well established advanced control technology
  - CoPro: From unit control to optimal management of plants, sites and chemical parks
  - COCOP: Advanced scheduling, platforms, communication architecture of plant-wide monitoring and control, and new digital technologies
  - Monsoon project: Boosting the development and deployment of data enabled predictive control solutions for process industries

INDUSTRY 4.0 (II)

- The IIoT Chemical - Industrial Internet of Things in the Chemical Process Industry
  - Make students familiar with sectoral optimization - networking of synchronized equipments
  - Bring in issues concerning data acquisition, data treatment and data communications in real time
    - Issues such as Advanced data analytics, Fault detection, Pattern recognition...
  - Research advances on
    - (Software) sensors, Virtual reality, Process Dynamics modelling and simulation, Operator training, Process maintenance .....

INDUSTRY 4.0 (III)

- Process modelling and control supported by AI methods
  - Adaptive control systems coupled with 'machine learning' methods '
  - Hybrid modelling - combining first principles and Neural Networks Models híbridos
- An example:

  Knowledge-based hybrid modelling of a batch crystallisation when accounting for nucleation, growth and agglomeration phenomena

ACADEMIC ISSUES

THE LEARNING PROCESS
THE GREAT CHALLENGE OF AND FOR THE NEAR FUTURE

- The challenge of "Don't Lecture!"
- The opportunity of education without boundaries and withou walls
- Challenges and requirements concerning the academic activity
- Challenges and requirements concerning political action

Impact of the digital disruption in Academia
The Challenge of "Don't Lecture" (JM Ferreira, USN, 2019)

- What is a 'lecture'?
- What is a classroom? Any **physical or digital space** where we promote the discussion and transfer of knowledge and where (or through which) competences and skills are developed?
- Where is the Classroom? ***On Campus***; ***Online***; everywhere?
- New requirements of **competences and skills of professors** in this age of AI?
- Professors without classrooms? Classrooms without professor?

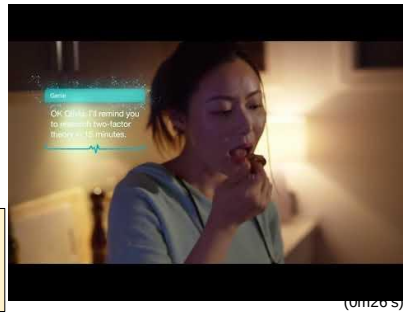
New environments for academic work
I - New type of classrooms

"The fluidity of communications led to (is leading to) to the 'elimination' of conventional classrooms and paved the way for a "**new type of classrooms**"

HBX Live in Action
https://youtu.be/W8lf9piApe0

New environments for academic work
II – Olivia's Digital Assistant supporting her work

"Olivia's Assistant alerted her for the fact that she still had to finish some learning activities for…"



(0m26's)

Deakin Genie
https://youtu.be/zsRPuU53E74

Impact of the digital disruption in Academia…
The opportunity of Education without Borders and without Walls

- We have a growing **offer of platforms for education** through the Web, with MOOCs - Massive Open Online Courses; most well known examples of such platforms are *Coursera* and *edX*.
- We have a growing offer of **high level (scientifically and pedagogically) conferences**, such as the TED (Technology, Entertainment, Design) Talks - they serve worldwide for professional 'refreshing' of high level, senior workers of companies;
- We have platforms for cooperative work, such as the Google Apps, that **'open Windows' and 'break down' classroom walls**

Impact of the digital disruption in Academia... Cooperative activity in Education without Walls

- Promotes the share of information by providing content and support materials
- Enables teacher-student interaction in virtual tutorials and between students (forums, for example)
- Reinforces autonomous learning and self-assessment of learning
- Promotes group work, critical analysis and debate

Impact of the digital disruption in Academia... Issues to give/find an answer or a solution

- Will Digital Transformation be relatively behind in the core area of the University's activity - the Academic Area?
- Or is it already a partial reality, in which it is necessary to coordinate solutions on the ground and overcome resistance to change?
- What risk of CRITICAL THINKING being affected?
- What is the role of teachers in this future?
- How to preserve academic ethics?
  - How to combine learning with assessment?
  - How to fight plagiarism and other frauds?
- What implications on the organizational model of Universities?

Impact of the digital disruption in Academia… Academic Action Requirement

- The academic model must reflect the dual reality - integrated offer of ***on-campus and online*** training
- Teacher training requires continuous interaction, but also **material means and incentives**
- The design of the spaces, **the architecture of the Campi,** must reflect the new reality
- **Socialization initiatives in the community must be adapted,** strengthening group activities, namely in culture and sport
- **Institutional organization and governance must reflect changing relationships** in fulfilling the mission - academic, research and third mission

Impact of the digital disruption in Academia… Political Action Requirement

- Covering the GAP between political discourse and public policy practice, **investing in strategic domains** for the future
- Decide decisively **the trajectory of underfunding** in Higher Education… while **requiring more rational organization and greater productivity** to institutions
- University World News news…. February 21, 2019….

UNITED KINGDOM - Universities funded to train next generation of AI talent
Brendan O'Malley 21 February 2019

Thousands of graduates are to become qualified experts in artificial intelligence (AI) as part of a new joint government-industry package to drive up skills in the AI sector. It is supported by industry funding and up to £110 million (US$143 million) in government investment.

JUST TWO SHORT MESSAGES
FOR YOU TO TAKE HOME

IT IS IMPORTANT TO UNDERSTAND THE NECESSARY REFORM PATH - I

- We all see and feel the tremendous, in many aspects fascinating, ongoing digital transformation of the World
- Please, take on board that in this vital area of Higher Education, these transformations bring in the absolute need for **new pedagogical paradigms**, indeed for serious **PEDAGOGICAL INNOVATION**
- Leading Organizations (Universities) in Europe have already understood this new reality

"Dutch end 'one-sided' research focus and hope world follows",

in THE Newsletter, 2019.12.03

IT IS IMPORTANT TO UNDERSTAND THE NECESSARY REFORM PATH - II

- Grab the opportunities that the digital transformation offers
- Assess the consequences of hesitations
- Assess the consequences of delays in the adoption of methods of organization generally adopted at international level, particularly in Europe
- Assess the consequences of (non) reform

Answer the question -
If we don't change... what will happen?