>EVOLUTION OF PROGRAMME STRUCTURES AND TEACHING METHODOLOGIES FOR CHEMICAL ENGINEERS ?

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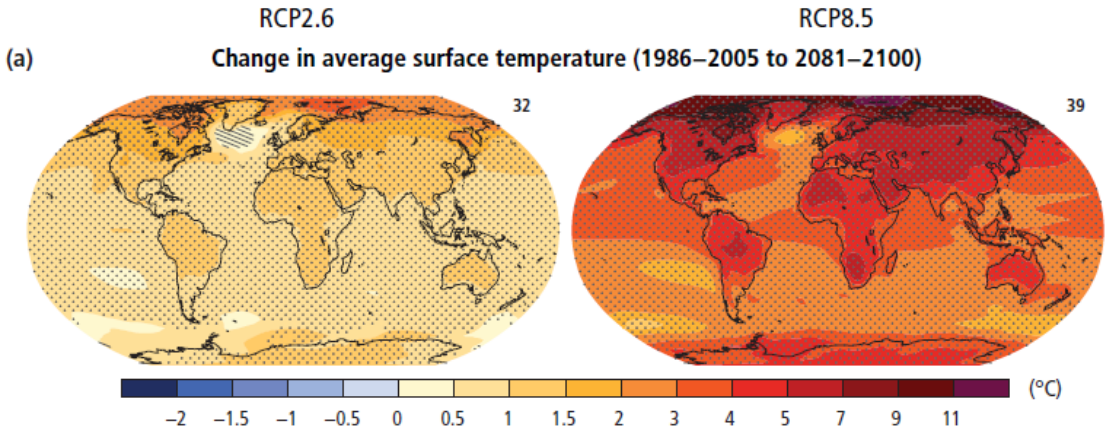
>INTRODUCTION

- Changing world
  - Depletion of resources, global warning
  - Globalisation of markets, increased competitiveness
  - Importance of digitalization
- Evolution of (Chemical) Engineering professions
  - Expansion of application areas
  - Mobility, flexibility
  - Importance of HSE, Ethics, digitalization,…
- Evolution of learners
  - Y and Z generations
  - Digital native students
- Evolution of teaching methodologies
  - Contributions of neurosciences and cognitive sciences
  - Availability of knowledge
  - New technologies

L'usine du future pour les industries de procédés, white book, SFGP, 2019, www.sfgp.asso.fr

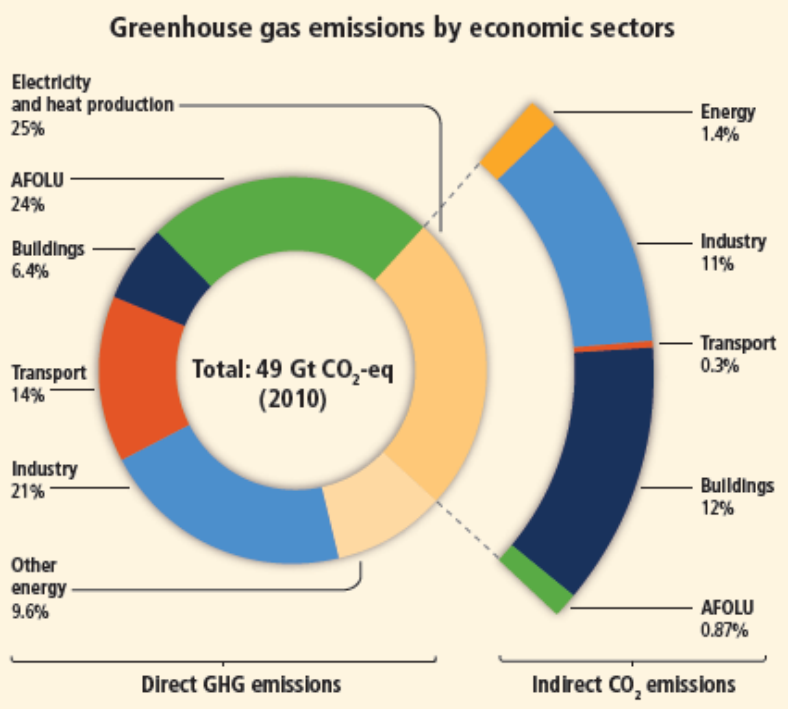
>CHANGING WORLD

- Global warning !



The Intergovernmental Panel on Climate Change, 2015

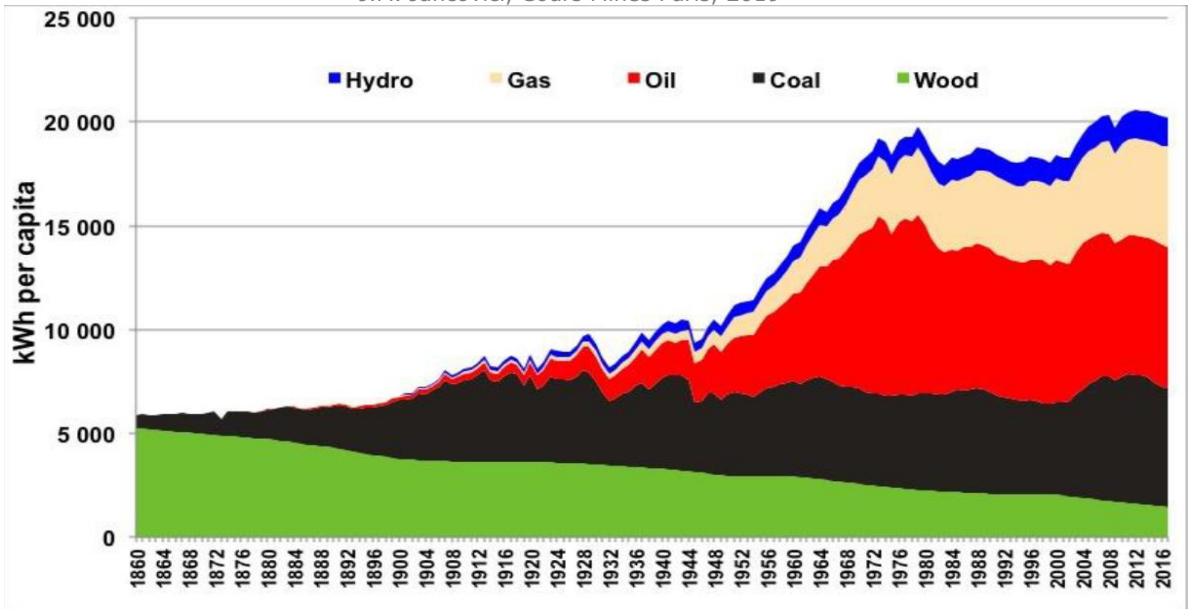
- Industry, transports… need to reduce their impact !



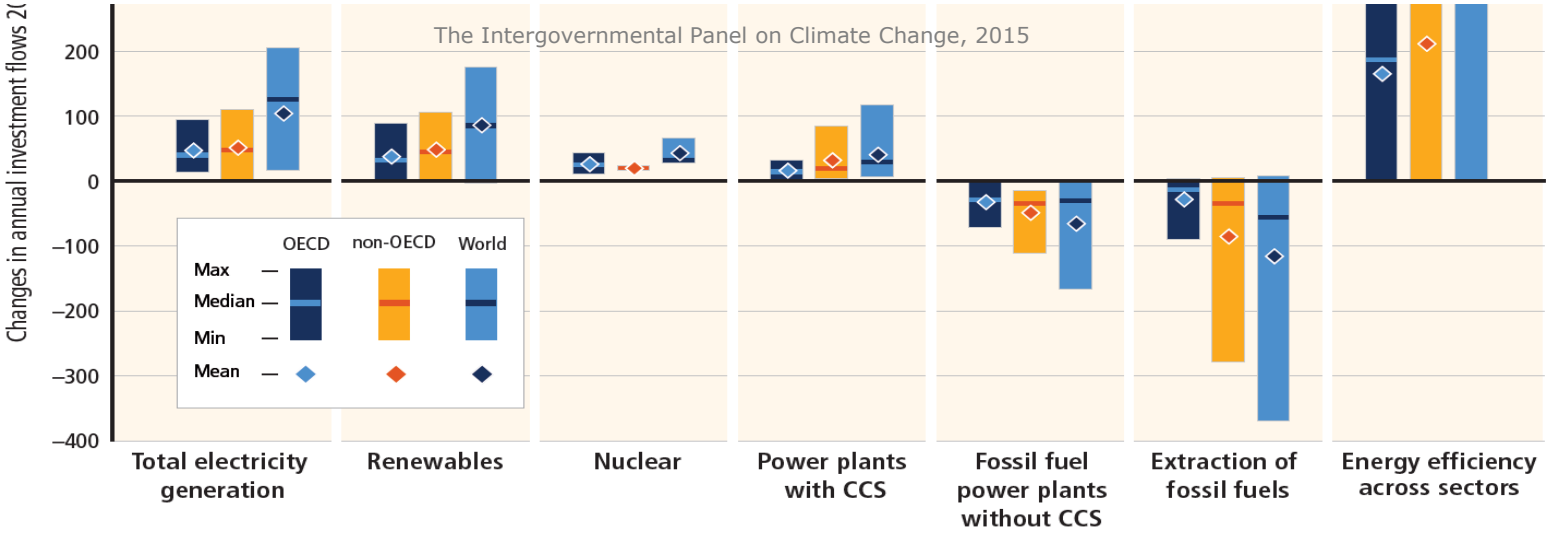
>CHANGING WORLD

- New sources of energy & investments !
- Need for future chemical engineers !

J.M. Jancovici, Cours Mines Paris, 2019



The Intergovernmental Panel on Climate Change, 2015



>FUTURE NEEDS

- Energetic & ecologic transition
  - New energy sources and storages, thermal integration, carbon-free industry, sustainable engineering solutions for environmental systems
  - New processes, biosourced materials, circular economy
- Interdisciplinarity
  - New paths, new domains
- Digital transformation
  - Acquisition, Data processing,
  - Neural networks,
  - 3D printing,
- Factory of the future
  - Connected factory
  - On-demand production,
  - Dynamic processes
  - Intensification

>EVOLUTION OF PROFESSION

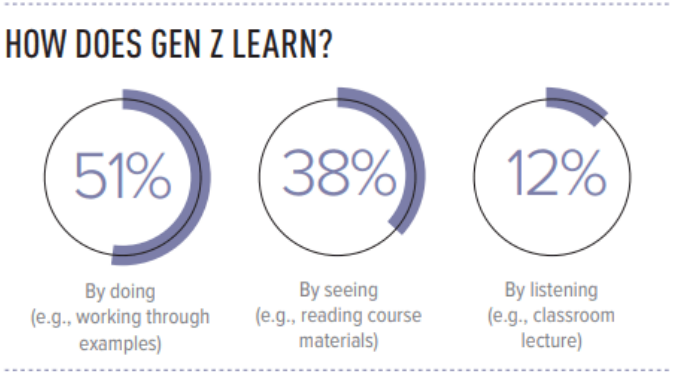
- The future chemical engineers will have to deal with
  - Information inflation
    - 5000 publications per day (in 2015)
  - Interdisciplinarity
    - To manage complex problems
  - Internationalization of markets and supplies
    - Multiculturalism
  - Environmental aspects
    - Circular economy
  - Social responsibilities
    - Innovation and risk control
  - Decision making
    - With incomplete or limited information
  - Critical thinking and creativity
    - Innovation, relations with research
  - Ability to anticipate
    - Good knowledge of current societal and technological evolutions

>EVOLUTION OF LEARNERS

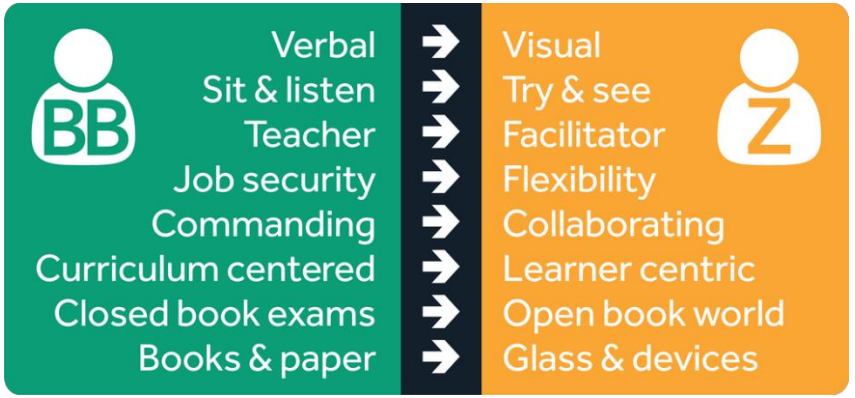
- Generation Y, or digital natives, or Why,
  - People born between 1980 and 2000, and whom we have been training for a few years now.
  - This generation is characterized by:
    - Connectivity and (relative…) ease with digital tools. They think (or even live) on the net and know that the more people there are, the better they are. Social networks are also part of daily life;
    - Impatience: they are always connected to the digital world, their access to information is instantaneous;
    - Inventiveness: improvement is no longer continuous, interculturality and interdisciplinarity encourage innovation;
    - Particular relationship to the authority, including teachers. Authority is no longer linked to a status but must be demonstrated by competence and behavior.

>EVOLUTION OF LEARNERS

- Generation Z (zapping), which succeeds
  - Students born after the 2000s,
  - Characterized by:
    - Connectivity and (relative…) ease with digital tools as well, but also connectivity with his peers, wherever they are. The notion of network is important;
    - Ability to do several things at once, we talk about "slashers";
    - New posture in the face of learning: they grew up with MOOCs, tutorials on YouTube;
    - Particular relationship to errors, it is normal to be wrong.



https://www.bncollege.com/



https://mccrindle.com.au/

>INTRODUCTION

- Should we change something in chemical engineering education ?

- If yes :
  - Evolution of programmes
  - Evolution of teaching methodologies
  - Conclusion
  - Recommendations

>PROGRAMME OUTCOMES ?

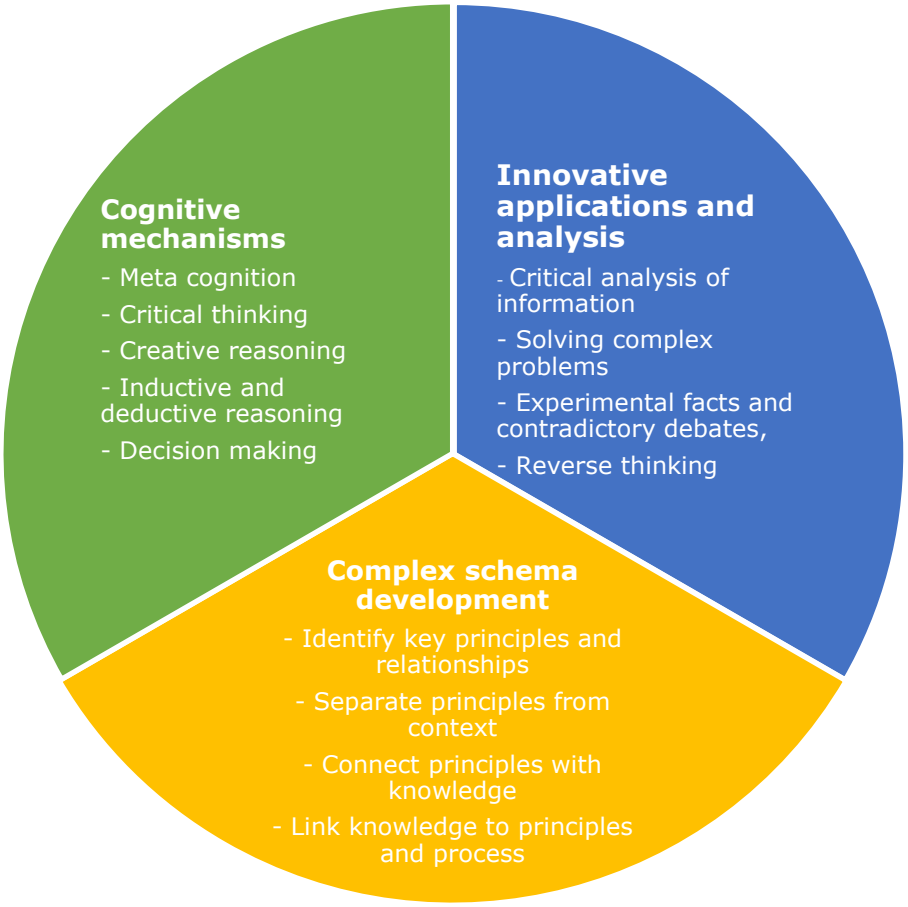
- Importance of basic knowledge & understanding !
  - As recognized by both industrialists & academics (https://research.ncl.ac.uk/iteacheu/, https://chme.nmsu.edu/files/2016/09/2015che_academicindustryalignmentstudy.compressed.pdf)
  - But should include new trends (bio, products, sustainability, dynamics, digital …)
- Engineering skills
  - Should not be reduced (labs, projects, interdisciplinarity…)
  - Internships, co-op studies, participation of industrialists in teaching
- Personal & Professional skills
  - Creativity, problem solving, critical thinking, originality, emotional intelligence, collaboration, interculturalism, …
- All are described for 3 years (180 ECTS) or 5 years (300 ECTS) programmes

>PERSONAL & PROFESSIONNAL SKILLS

Top skills

1. Solving complex problems
2. Critical thinking
3. Creativity
4. Human management
5. Coordination with others
6. Emotional intelligence
7. Judgement and decision
8. Service orientation
9. Negotiation
10. Cognitive flexibility

Industrie du futur : du système technique 4.0 au système social, Académie des Technologies, 2017

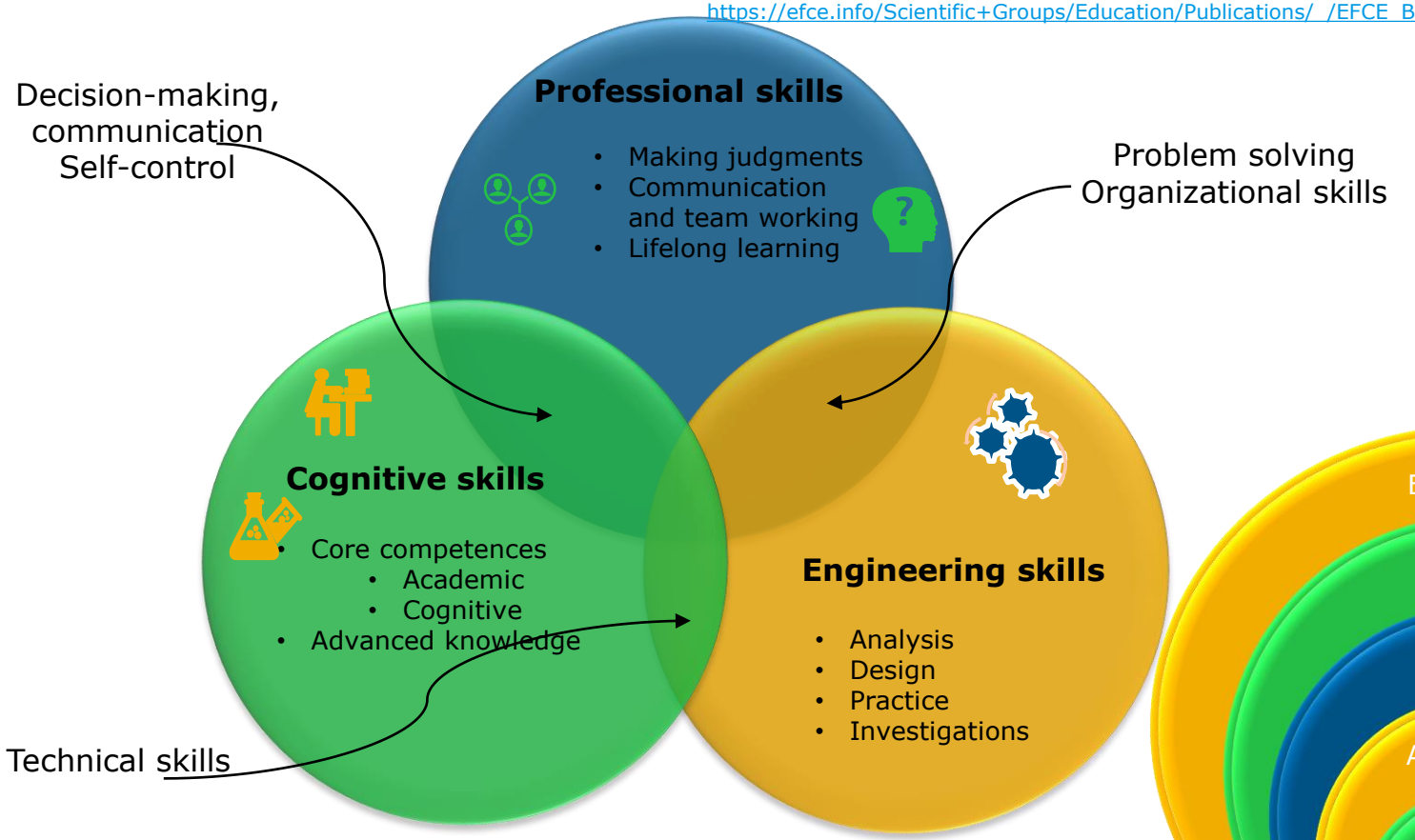


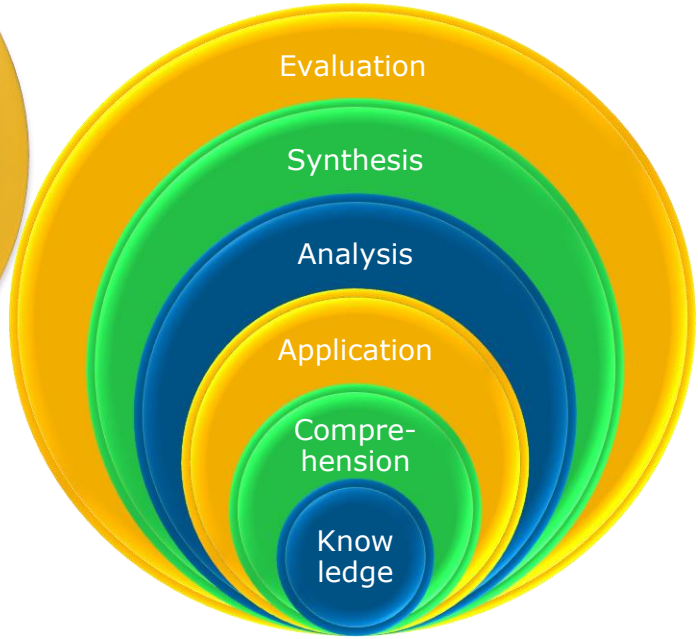
Innovations in Knowledge and Learning: Postsecondary Education Reform to Support Employment and Inclusive Growth, ADB, 2017

>PROGRAMME STRUCTURE

- Programme outcomes, as proposed by WPE of EFCE)

European Network for Accreditation of Engineering Education, Standards and Guidelines, 2015
https://efce.info/Scientific+Groups/Education/Publications/_/EFCE_Bologna_Recommendations_2020.pdf



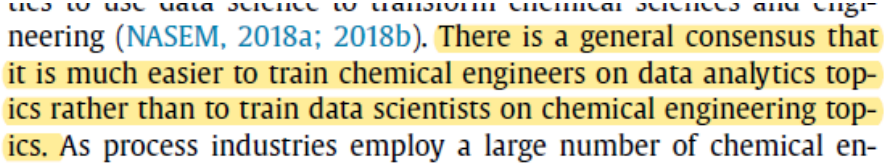


- Described in competences !

Bloom, B. S., Engelhart, M. D., Furst, E. J., Hill, W. H., Krathwohl, D. R., 1956, Taxonomy of educational objectives: The classification of educational goals. Handbook I: Cognitive domain. New York: McKay

>FUTUR PROGRAMME OUTCOMES

- Basic knowledge & understanding
  - Core topic structure remains adapted to new processes,
  - Balances, Thermodynamics, Transports, Separations, Reactions, Unit Operations
  - Mathematics, Physics, Chemistry, Biology, Informatics & digitalization, Sustainability !


tics to use data science to transform chemical sciences and engineering (NASEM, 2018a; 2018b). There is a general consensus that it is much easier to train chemical engineers on data analytics topics rather than to train data scientists on chemical engineering topics. As process industries employ a large number of chemical en-

- Engineering skills
  - Analysis (complex processes, systems & products),
  - Design (of a process or product, also complex),
  - Investigations (application of emerging technologies)
  - Practice (software, equipment, ethics, HSE, economy)

- Professional skills
  - Can not be developed passively…

Links to research & industry

Active teaching

Advances and opportunities in machine learning for process data analytics, Computers and Chemical Engineering, **126**, 2019

>PROFESSIONAL & PERSONNAL SKILLS ?

ADAPTATION TO THE REQUIREMENTS OF A COMPANY AND OF A SUSTAINABLE SOCIETY

1. economic dimension, respect for social and environmental requirements, respect for quality, competitiveness and productivity, commercial requirements, economic intelligence
2. ethical and professional responsibilities into one's conduct, to take into account the issues of labor relations, health and safety at work and diversity
3. the ability to act for the energy and ecological transition of companies
4. the capacity to act for the emergence of a sustainable society and the dissemination of science

ORGANISATIONAL, PERSONAL AND CULTURAL DIMENSION :

1. the ability to fit into professional life, to integrate into an organization, to lead it and to make it evolve : exercising responsibility, commitment and leadership, project management, ability to collaborate and communicate within diversified and multidisciplinary teams
2. the ability to undertake and innovate, within personal projects or through initiative and involvement within the company, in entrepreneurial projects
3. the ability to work in an international and multicultural context: mastery of several foreign languages and associated cultural openness, ability to adapt to international contexts and to cooperate on collective global issues
4. the ability to know oneself, to evaluate oneself, to manage one's skills (particularly in a lifelong learning perspective), to make professional choices

>SKILLS DEVELOPMENT ?

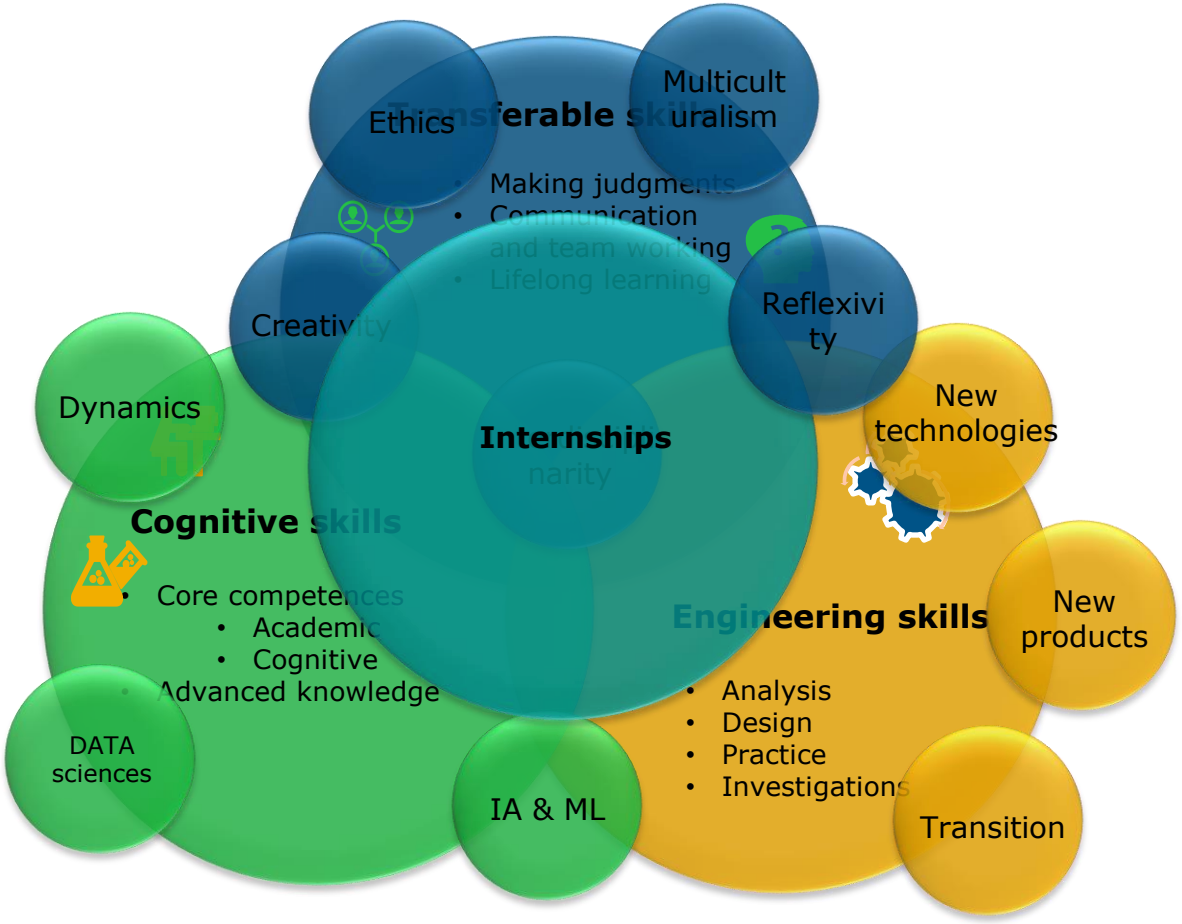
- Jacques Tardif (Sherbrooke University) : *Competence (skill) is a complex know-how based on the effective mobilization and combination of a variety of internal (knowledge, know-how or methods, attitudes, etc.) and external resources within a family of situations*
  - a complex know-how
  - internal and external resources
  - effective mobilization and combination
  - a family of situations

- Authentic situations : Corresponds to a task carried out in a real professional context !

>AUTHENTIC SITUATIONS ?

- Suitable methodologies to promote skills acquisition :
  - Case studies,
  - Practical work,
  - Labs,
  - Projects,
  - Problems solving situation,
  - Assignments,
  - Simulations,
  - Internships in Research
  - Internships in Industry…

>FUTUR PROGRAMME STRUCTURE



The (initial) training time seems insufficient to cover all what will be needed for the future engineers ?

>HOW TO INTEGRATE ?

- Make choices
  - Propose some specialisations ?
- Develop lifelong learning especially as the dynamics of change in industrial production will only become more strained !
- Ensure that internships effectively contribute to skills' acquisition
  - Co-construction of training programmes with industrialists
- And…
  - Use adapted teaching methodologies

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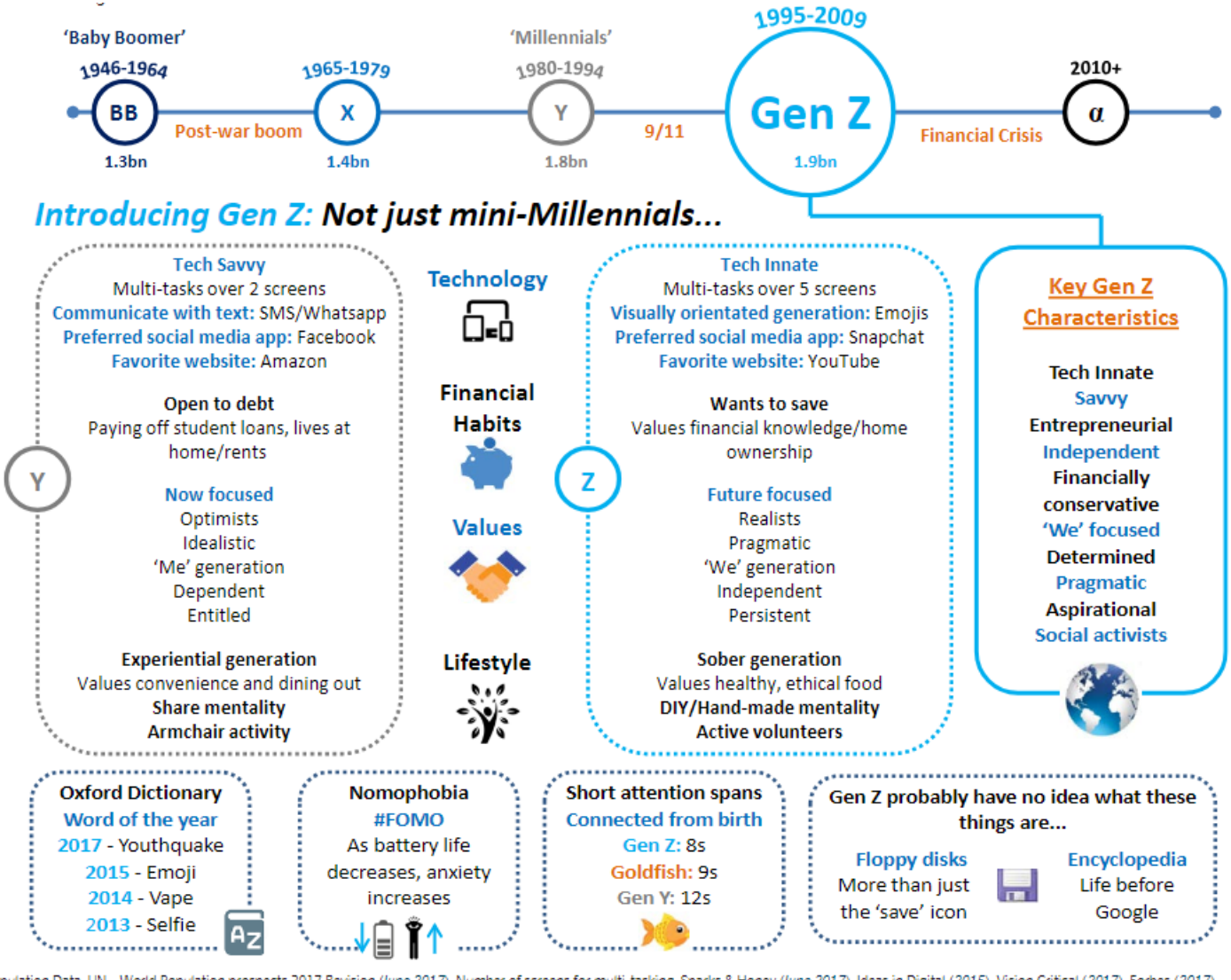
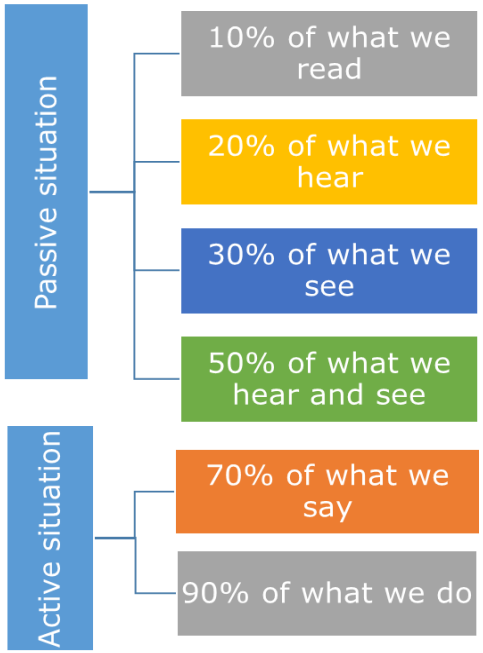


Source: Population Data: UN – World Population prospects 2017 Revision (*June 2017*), Number of screens for multi-tasking: Sparks & Honey (*June 2017*), Ideas in Digital (*2015*), Vision Critical (*2017*), Forbes (*2017*)

>NEUROSCIENCES & COGNITIVE SCIENCES

What we remember after 2 weeks



- Stanislas Dehaene : 4 pillars of learning
  - Mutual attention
  - Active engagement
  - Feedback
  - Distribution of learning phases

Stanislas Dehaene, Apprendre ! - Les talents du cerveau, Le défi des machines, Odile Jacob, Paris, 2018

E. Dale, Audivisual methods in teaching, Dryden, New York, 1969

>MUTUAL ATTENTION

- Alert: When to be careful ?
- Orientation: What to pay attention to ?
- Control: How to process information ?
  - Learn to be careful (you can't do two things at once!)
  - Reciprocal attention: To teach is to pay attention to the attention of the other !
  - … which is not always easy for the higher education teacher, faced with many signals, sometimes contradictory!!
- Learners do not always have the right level of information

>ACTIVE ENGAGEMENT

- A **passive organism does not learn** !
  - Better retention during active lessons!

- Deepen to learn better: foster learning conditions that allow for active learner engagement and cognitive effort..

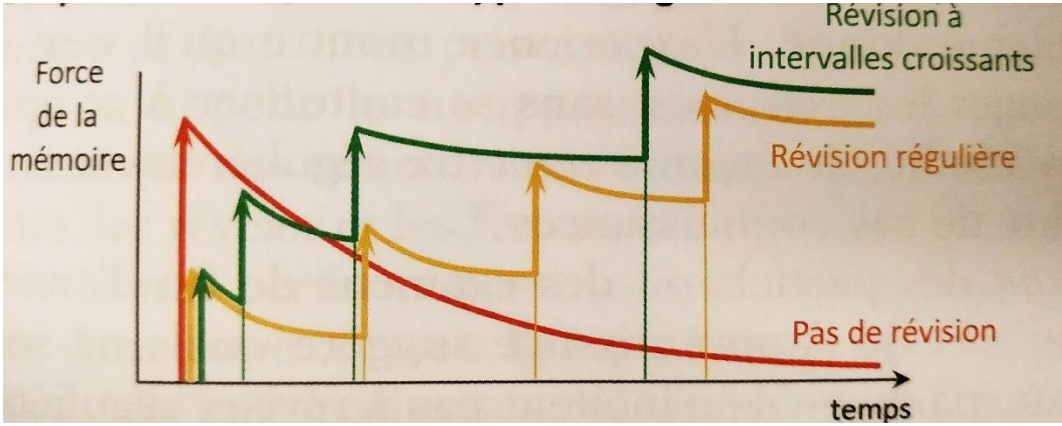
- Arouse curiosity and promote motivation!
  - …But don't leave the learners alone!

>FEEDBACK

- Necessary for learning
  - Example of neural networks,
- Do not confuse error with evaluation
  - It's natural to make mistakes,
  - Promote formative assessments !
  - Regular testes for a better learning : QCM, Socrative, Kahoot…
  - Assignments, Tutorial sessions…
  - Leave time to make mistakes !
- Pay attention to global marks
  - Very global feedback, does not explain the mistakes or errors

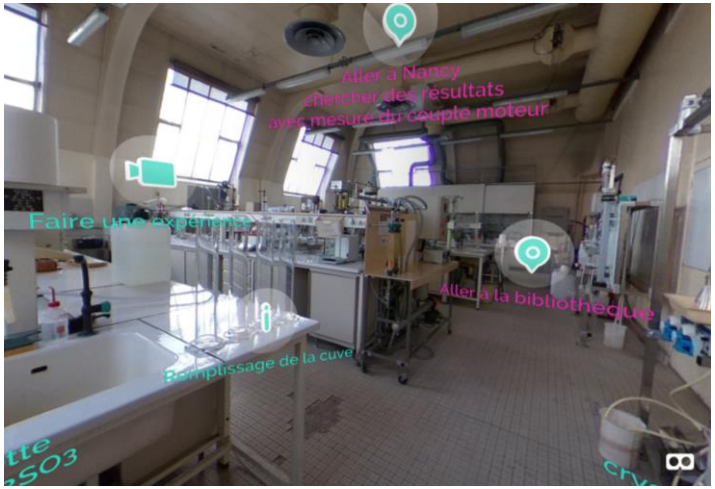
>CONSOLIDATION

- Distribute the learning phases
- Free up brain resources,
  - Consolidate the foundations
- Promote transfer
  - Long-term learning, Applications, analyses, evaluations!
- The key role of sleep in consolidating learning!
- Space out learning!



>ACTIVE TEACHING

- Methodologies
  - Flipped Classroom
  - Problem Based Learning
  - Project Based Learning
  - Serious Games
  - Blended Learning
  - Online courses…
- Tools
  - Learning analytics
  - Tutorials
  - MOOCs
  - Virtual / augmented reality …



>LEARNING SPACES

- Adapted to active teaching methodologies
- Promoting dynamic and interactive pedagogy
  - Laptop computers, remote screens on the walls, swivel chairs with tablets, interactive digital boards…

  - Video capture for distant learning
  - 3D glasses, virtual reality headset…

>WHAT WORKS WELL ?

- PBL & PBL !
- Our definitions :
  - Problems :
    - Disciplinary,
    - Known solution, fairly short problems
    - The problems are solved in session by teams, supervised by the teacher
    - Its role is to support and guide reflection while encouraging learner autonomy and initiative.
  - Projects :
    - Interdisciplinarity
    - Several possible solutions, more ambitious and longer projects
    - The teams identify the objectives, document themselves, train themselves and develop the actions necessary to carry out the project
    - The teacher leads, questions, facilitates and diagnoses

>PROBLEM BASED LEARNING

- Description
  - Promotes active learning and develops teamwork skills, generating a socio-centered dynamic
  - The goal is to solve problems in 3 steps:
    - Analysis and development of an action plan
    - Realization of the action plan, individually or in groups
    - Validation of deliverables and evaluation

- Why is it interesting?
  - Makes the learner more active during the sessions.
  - Increases motivation of learners and teachers
  - Develops permanent skills
  - Improves teamwork skills
  - Contributes to a collective dynamic, to trust and to the co-construction of knowledge & skills

>PROBLEM BASED LEARNING

- First steps
  - Set realistic priority learning objectives for new problems
  - Assign learner roles
  - Allow sufficient resolution time for each step of the problem
  - Develop a progressiveness in the different stages

- Our advices
  - Optimize problem complexity to maintain motivation
  - Define the composition of the teams: a leader associated with learners of different levels, to promote socio-centered learning
  - Adapt roles to the size of your teams
  - Supervise the students according to a common approach such as DQFD (Drive-Question-Facilitate-Diagnose) to develop autonomy and learning

>PROJECT BASED LEARNING

- Description
  - Based on a socio-constructivist approach, allows learners to identify and formulate the questions to be resolved, to build their knowledge and apply it in order to develop skills.
  - Aims to develop the ability to problematize, document, learn by themselves, develop critical thinking, know how to organize, plan, carry out, and communicate.
- Why is it interesting ?
  - The concrete aspect of the project is a source of motivation and commitment
  - The multidisciplinary aspect makes it possible to integrate knowledge and skills, and to develop cross-disciplinary skills
  - It helps understanding the complexity of real world

>PROJECT BASED LEARNING

- First steps
  - Plan the activities to be implemented (assessments, content, tutoring methods, general organization, etc.),
  - Evaluate the time needed for this project-based learning,
  - Cooperate with other teachers,
  - Check if the project can take place in a larger framework

- Our advices
  - Guide students in their approach (DRIVE)
  - Help students to progress (QUESTION)
  - Promote group dynamics (FACILIATE)
  - Observe and analyze what is happening in the group (DIAGNOSTIC)

>EVALUATIONS

- Acquisition of skills: Evaluation of the final product by an oral defense of the project (by the team or individual learners) and/or a report
- Acquisition of individual skills: Implementation of an evaluation between and by peers reporting on the collective and individual part of the work carried out

Group evaluation
Production
Involvement of members
Tutor relationships
Project relationships
Organization
Atmosphere

Individual evaluation
The group helps me
I assume the roles
I am an attentive listener
I actively participate
My interventions are welcomed
I avoid conflicts
I have worked hard enough
My work is valuable
I learned

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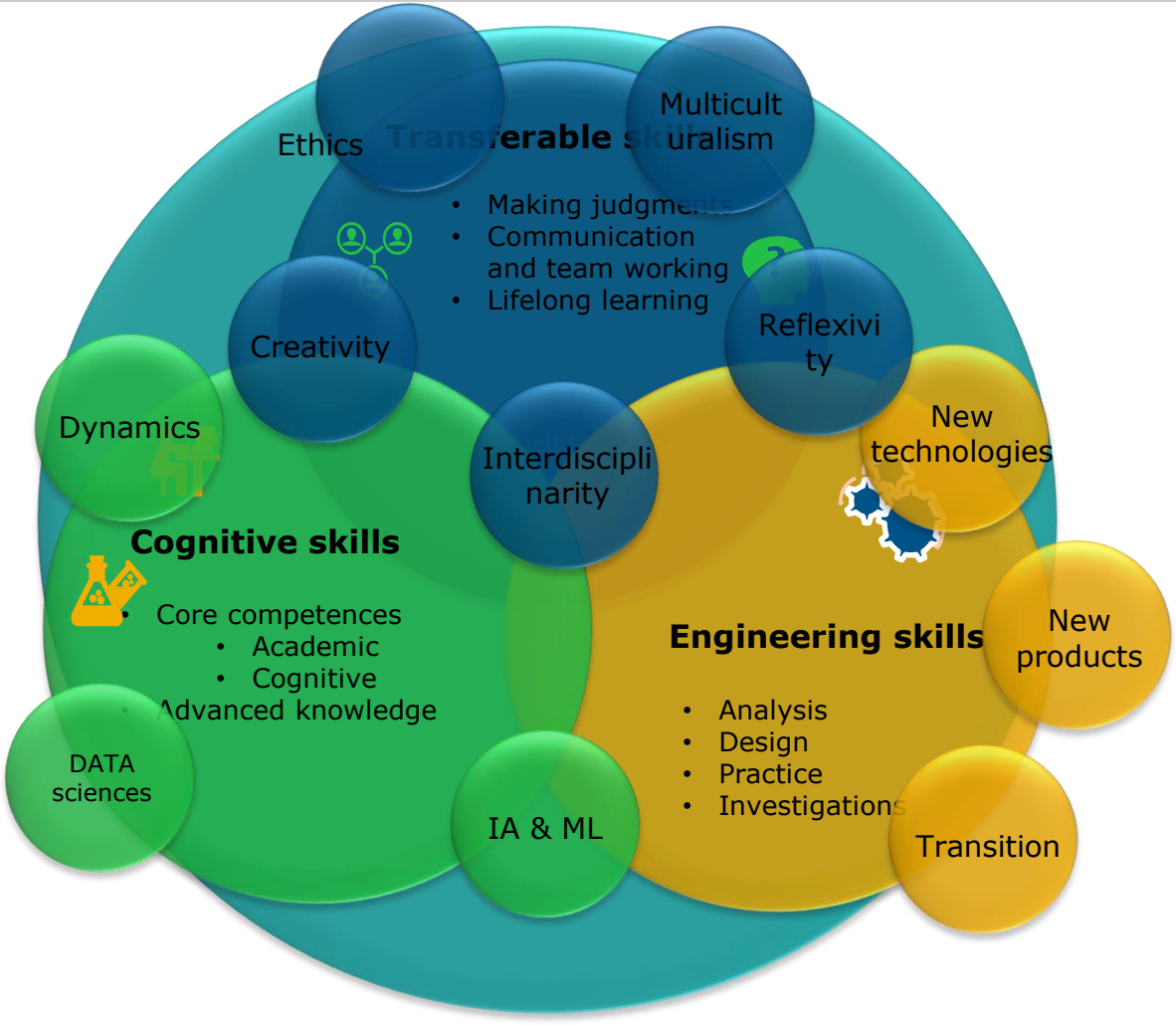
>CONCLUSION

- Chemical engineering concepts are necessary for the emergence of a sustainable society
- New emphasis is needed on transition, professional & personal skill
  - Competencies are to be defined in concertation with employers
  - Some universities have introduced skills assessments
- Active teaching and tools ensure better involvement of the learners, and are known to improve training, favoring acquisition of knowledge and development of skills
- Time, for acquisition and implementation
  - Propose some specializations
  - Be prepared for lifelong learning

>RECOMMENDATIONS

- Institutions
  - Involve industrialists in steering committees
  - Promote teachers' training
  - Encourage the use of active methodologies, tools & learning spaces
- Industrialists
  - Contribute to the reflexions on teaching contents
  - Be involved in acquisition of engineering and professional skills
  - Propose internships, co-op trainings, apprenticeship training
- Teachers
  - Use and develop reflexive teaching
  - Continue to train on innovative technologies and teaching methods
  - Develop & promote lifelong learning activities

>KEEP MOTIVATED IN PEDAGOGY



Promote interdisciplinarity and active teaching !

>TO BE CONTINUED...

>THANK YOU FOR YOUR (ACTIVE !) ATTENTION !