# Some future challenges for digital manufacturing

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# Overview

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2. Challenges beyond Industry 4.0
3. Focus on challenges in education
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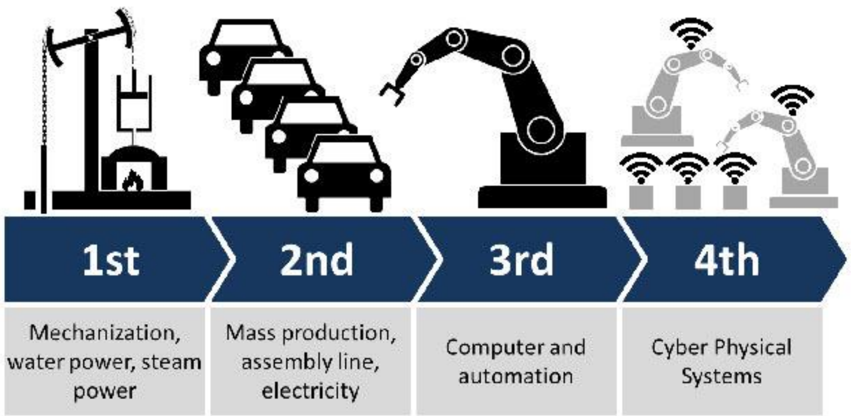
# 1. Industry 4.0 as a starting point …

## The 4 industrial revolutions

- 1st revolution (1765): concept of mechanization, water and steam powers
- 2nd revolution (1870): introduction of electricity, transportation for mass production
- 3rd revolution (1969): computer and automation, telecommunication …
- 4th revolution (today): global interconnection of machines and objects, advanced process automation (generalization of robots, agile/reconfigurable factories, 24/24 operation)


Context of Industry 4.0 (source: Gartner)

**New cooperation strategies linked to the <u>digital transformation</u> of industry and <u>digital engineering</u>**

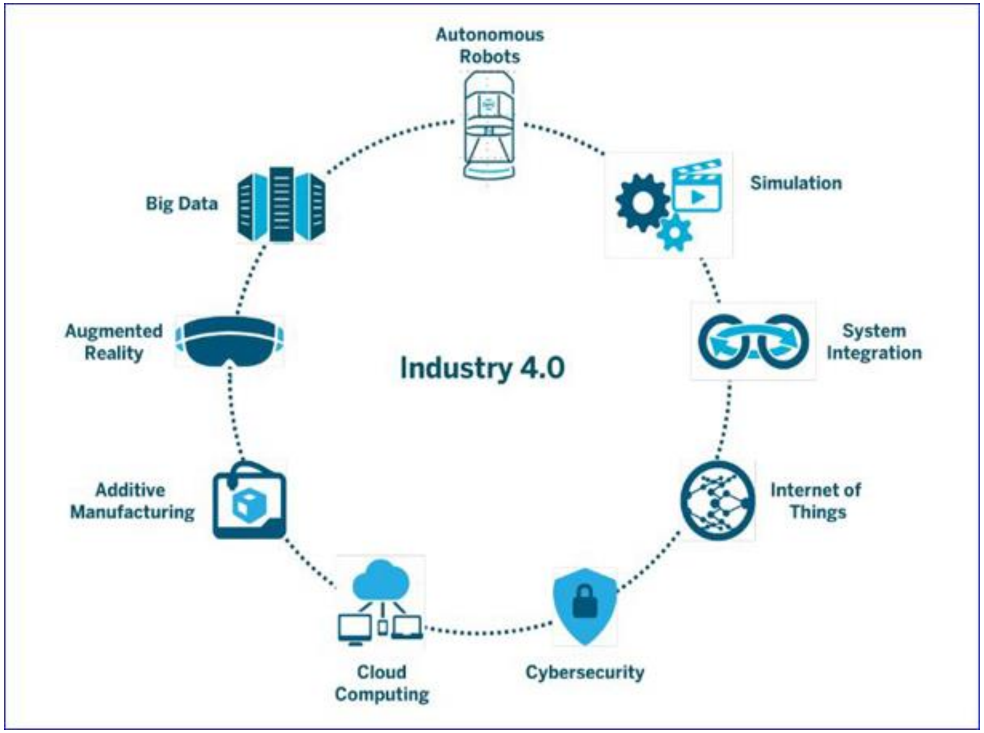



The 4 industrial revolutions (Source: Wikipedia/Christoph Roser at AllAboutLean.com)

# 1. Industry 4.0 as a starting point …

## Goals of Industry 4.0

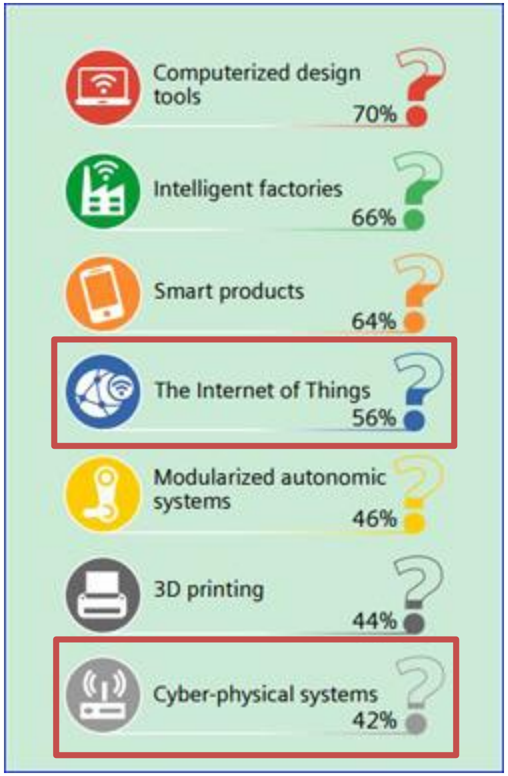
- create digital-based **smart factories**
- improve industrial processes efficiency
- integrate the entire product life-cycle




**Industry 4.0 perimeter (Source: BCG - Institute_Aethon.com)**

# 1. Industry 4.0 as a starting point …

- **design principles**: interoperability, virtualization, decentralization, real-time capability, service-orientation, modularity
- contribution of innovations issued from IoT, digital technologies, robotics, augmented reality, additive manufacturing, AI, numerical simulation, big data …

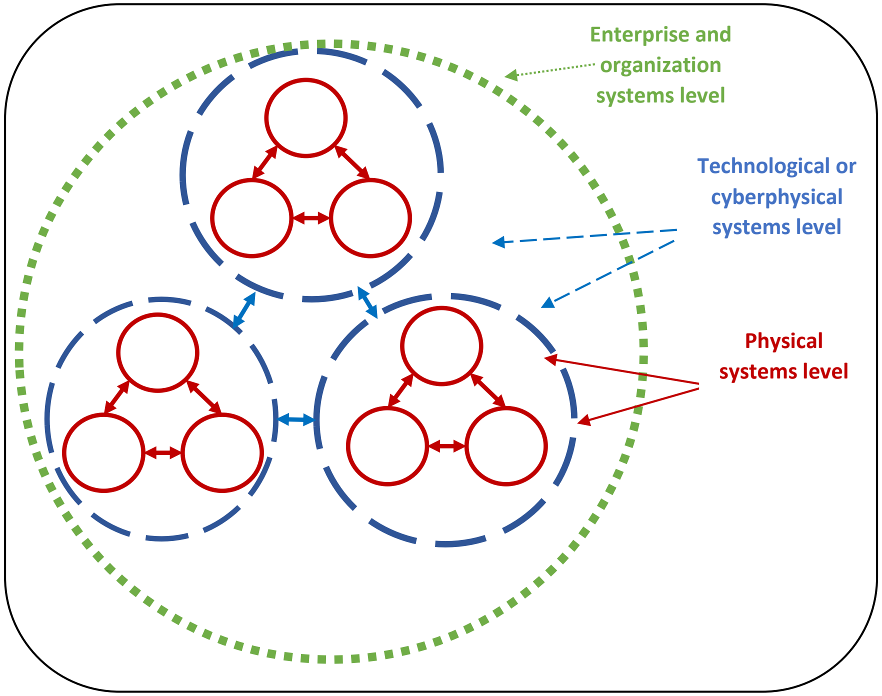



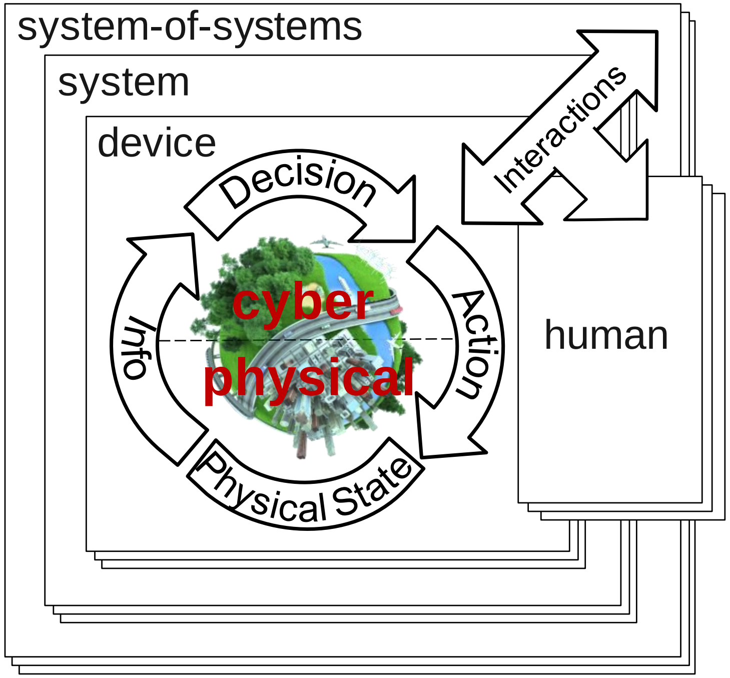

**How is Industry 4.0 understood?**
**(Source IDG Connect - Siemens)**

# 1. Industry 4.0 as a starting point …

## Concept of cyber-physical systems

– aims at the integration of computation and physical processes.



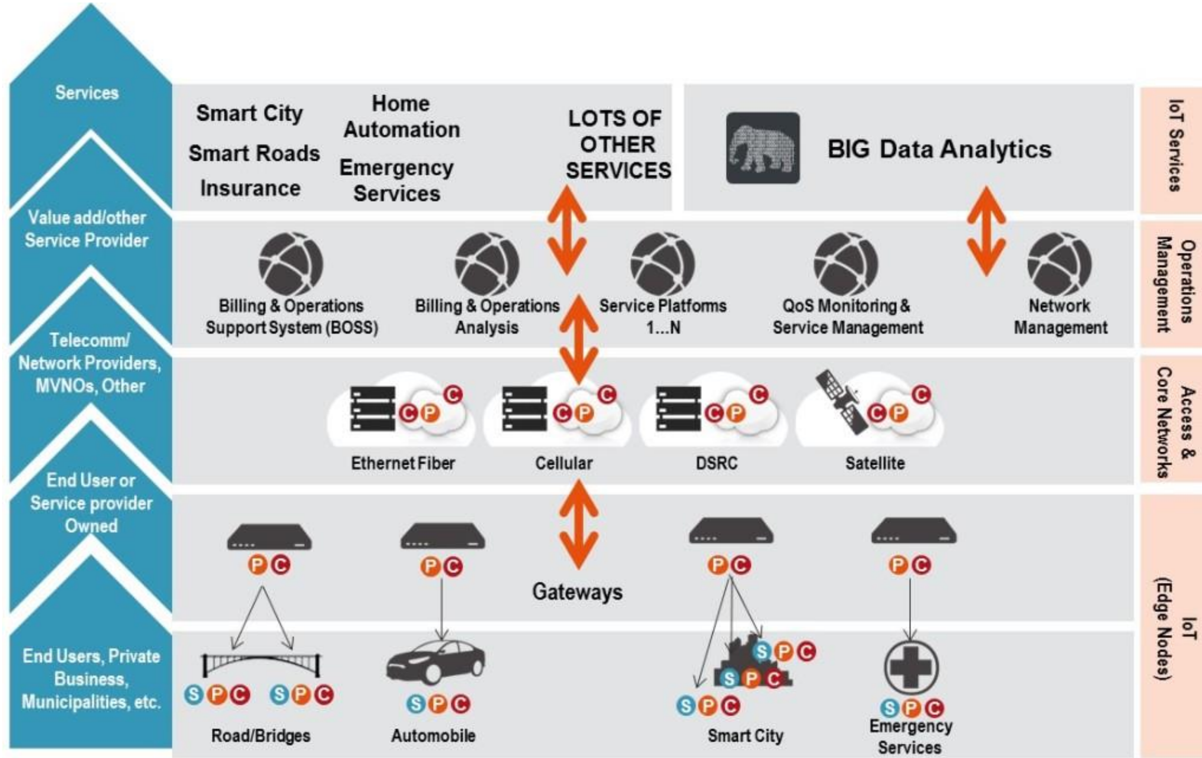

(source: NIST CPSPWG )

➡ **3 development phases**: identification (RFID tag), integration of sensors and actuators, development of sensors and actuators

# 1. Industry 4.0 as a starting point …

## IoT

- IoT aims at connecting all our devices and managing data flows from these devices
- IoT challenges are related to **cloud computing** and **big data analytics**
- big data enables extracting value from very large volumes of a wide variety of data




Four layers of Internet of Things (IoT) with (S): sensors/actuators, (P): embedded processing, (C): connectivity (BAN/PAN/LAN/WAN) (source http://design.avnet.com/axiom/autorama-connecting-your-car-to-the-internet-of-tomorrow/)

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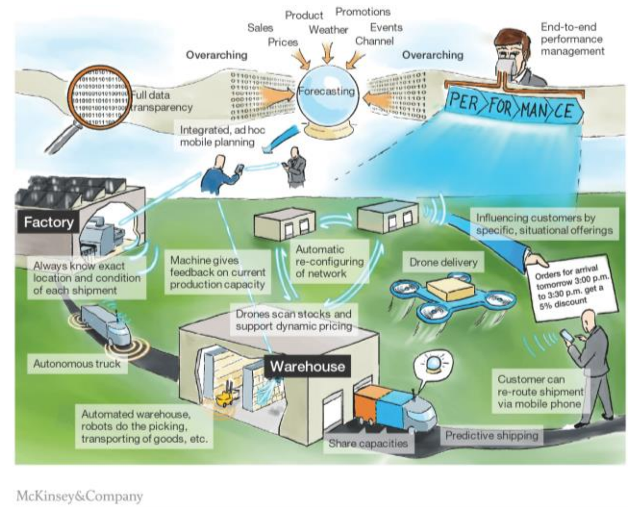
# 2. Challenges beyond Industry 4.0

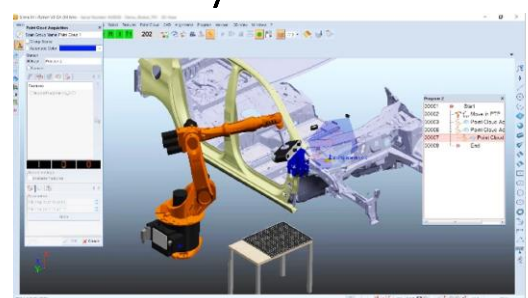



## Move from:

- smart factories
- digital supply chain
- digital products, services and business models
- data analytics and action as a core competency

## to:

- flexible and integrated value chain networks
- virtualized processes, virtualized customer interface
- industry collaboration as a key driver



## Example

- How **digitization can make the supply chain more efficient**, sustainable, agile, and customer-focused, more resilient and responsive? [*www.strategyand.pwc.com*]

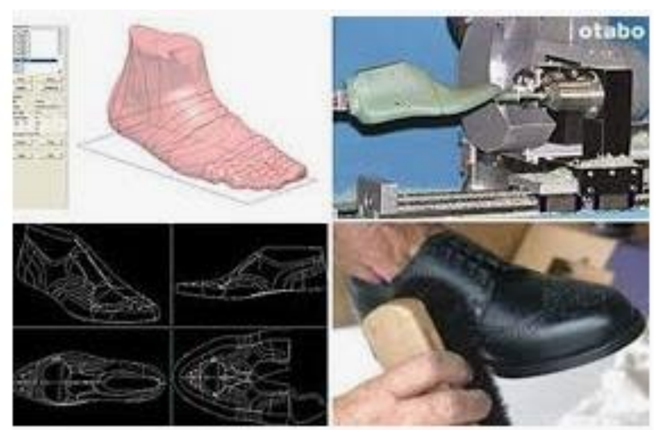
# 2. Challenges beyond Industry 4.0

## Improve even more:

– **optimization**: a smart factory should lead to an almost zero down time in production
– **customization**: creating a flexible customer-oriented market will help meet the population's needs fast and smoothly

– **research and education towards digital engineering**:
  - push research in various fields … under the global vision of complex systems

➲ **CIRP contributes developing Working Groups in emerging new areas**



# 2. Challenges beyond Industry 4.0

## Improve even more:

– **research and education towards <u>digital engineering</u>**:
  - education needs to address these topics under the framework of **complex systems**. A new industry will require a new set of skills.

☑ Consequently, education and training will take a new shape that provides such an industry with the required skilled labour [*www.cleverism.com*]

➲ **needs for quality education on digital manufacturing across the world and CIRP will contribute in that challenge, emphasizing the need for an <u>integrated vision</u>**

# 2. Challenges beyond Industry 4.0

## Challenges that have to be considered as part of the global paradigm and "side effect" of digitization [*www.cleverism.com*]

– **Security**: one of the most challenging aspects is the IT security risk. Research in cybersecurity is crucial
– **Capital**: industry transformation in relation with digitization will require a huge investment in new technologies
– **Privacy**: In an interconnected industry, producers need to collect and analyse data:
  - threat to customer's privacy
  - Need for a more transparent environment for companies


– **Employment**: workers will need to acquire different or all-new sets of skills. Different forms of education must be introduced.
  ➲ **One of the key challenges for education**: data-scientist (Statistics, Mathematics, Computer Science, Machine Learning, Economics), predictive maintenance engineers, mechanical engineers specialized in optimization and simulation …

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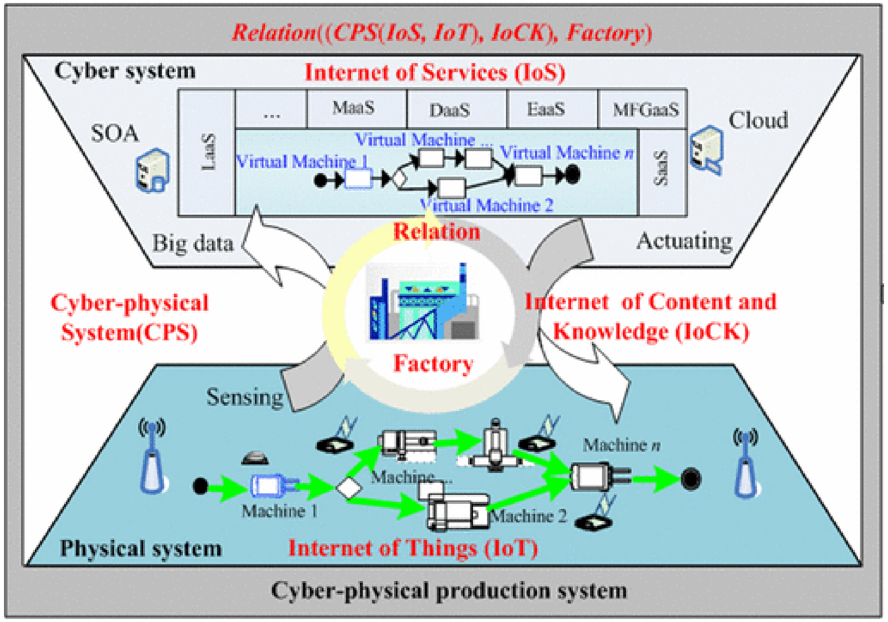
# 3. Focus on challenges in education

## Quality education on digital manufacturing across the world

– Work on digital engineering curriculum, providing students with an integrated vision of digital industry:
  - ➲ acquire knowledge in ICT, IoT, data analytics, being aware of the big data environment
  - ➲ acquire knowledge in smart materials, smart sensors, biomaterials, advanced production technologies (additive manufacturing, AI, robotics)

☑ but within the global framework of SoS (System of Systems)

- a SoS is a system constituted of independent systems, characterized by operational, managerial and evolutionary independence, potentially geographically distributed [*Maier, M.W., 1996*]
- thus requiring a new system engineering approach, being aware that there is not only one client or contractor [*Hein & Jankovic, 2018*]



# 3. Focus on challenges in education

## Quality education on digital manufacturing across the world

- **Towards a digital manufacturing curriculum as a multidisciplinary approach**: give tools for engineering complex system design while addressing challenges
  - integration of artificial intelligence
  - data analytics & machine learning
  - cyber-physical systems
  - cybersecurity
  - product and service system of systems
  - operational complex systems design
  - agile supply chain …
- These trends will broaden the role of system engineers in industry, requiring:
  - system synthesis
  - but also the blending of different domains such as health management, operational system management, predictive maintenance,

serving as a link between these different domains on a higher level of one system

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# 4. CIRP contributions

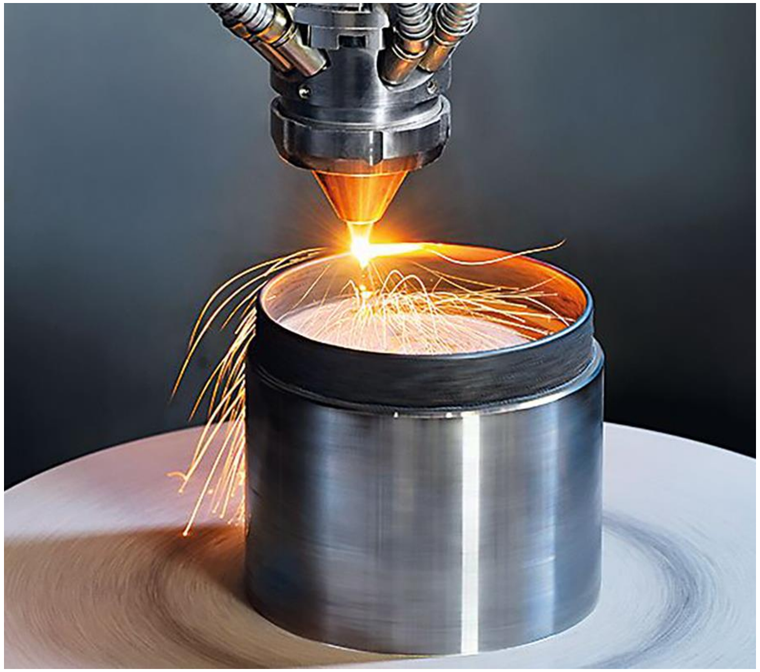
## 4.1 A few words about CIRP (International Academy for Production Engineering)

**CIRP … World leading organization in production engineering research**

- **CIRP was founded in 1951** with the aim to address scientifically, through international co-operation, issues related to modern production science and technology
- **CIRP vision**: "To promote research and development among its members from Academia and Industry to contribute to the global economic growth and well being of society"
- **CIRP mission**: "To develop the highest level international network of eminent researchers and industrialists for the purpose of marshalling their knowledge and insights"
- **CIRP** has some 300 Fellows, 150 associate members, 150 Corporate members, all together about 600 members from more than 50 countries all over the world

# 4. CIRP contributions

## 4.1 A few words about CIRP
## (International Academy for Production Engineering)



### CIRP main actions

- promote the **industrial application** of the fundamental research work
- disseminate knowledge through **engineering education**

# 4. CIRP contributions

## 4.2 CIRP contribution – Research point of view

– CIRP addresses and/or will address key research areas that directly impact digital manufacturing or that can induce significant improvements in combination with digital technologies, and which must be emphasized in the future beyond Industry 4.0:

- **artificial intelligence**: data generation, big data analytics, machine learning, smart robots, smart sensors
- **connectivity and security**: **cyber-physical systems**, human-machine interfaces, IoT, data protection
- **advanced manufacturing technologies**: smart, high performance, high precision and **additive manufacturing**, robotics, sustainable processes
- **advanced materials and nanotechnologies**: smart sustainable materials, nanotechnology, biomaterials
- **life science theories**: **biologisation of manufacturing**, biosensors, bioactuators

# 4. CIRP contributions

## 4.3 CIRP contribution to education on digital manufacturing

- take benefit of the fact that majority of CIRP members are also educators …
- … convinced of the need for knowledge dissemination through engineering education
- CIRP is aware of emerging topics, skill requirement for future manufacturing engineers and how to deliver them changing education technologies, e.g.:
  - use of blended/on-line L&T tools, learning factories
  - emerging technologies for L&T such as immersive technologies
  - necessary skills into the future
  - sustainability, circular economy – how to embed it in engineering curriculum
- **Actions**:
  - create a repository of L&T and pedagogical approaches based on existing practices in the areas of inspired learning and teaching (curriculum, learning factories …), building educational communities, digital technology use, feedback and assessment
  - create a L&T forum
  - establish as a longer term perspective a CIRP education academy in order to establish global L&T practices (creating MOOCs …)