Implications for Learning Factories from Industry 4.0
Challenges for the human factor in future production scenarios

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Industry 4.0
The human factor in cooperation with CPPS

- Strategy?
- Future?
- CIM 2.0?
- Hype?
- Myth?
- Revolution?
- Current Event?
- Science Fiction?
Industry 4.0
The human factor in cooperation with CPPS
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The human factor in cooperation with CPPS

Scenario 1 (autonomous automation):
Technology guides Human

Scenario 2 (hybrid collaboration):
Human guides Technology
Industry 4.0

The human factor in cooperation with CPPS

Scenario 1 (autonomous automation):
Technology guides Human

Scenario 2 (hybrid collaboration):
Human guides Technology

Strategy?
Future?
CIM 2.0?
Hype?
Revolution?
Current Event?
Science Fiction?
Myth?

Industry 4.0

Senses for perception
Intelligence
Ability to improve
Learning aptitude
Versatility
Creativity
Experience
Social interaction

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Fraunhofer AUSTRIA
Industry 4.0
Challenges – Qualification and Education

- Standardization
- Process and Work Organization
- Available Products
- New Business Models
- Security / Know-How-Protection
- Available Qualified Employees
- Research
- Qualification
- Legal Framework

Number of namings

Source: Survey by plattform-i40 (BITKOM, VDA, ZVEI) January 2013, Responses: 284 / Quote 9.2%

Required competencies and skills?
Future job profiles?
Industry 4.0

Essential competence requirements
Industry 4.0
Essential competence requirements

Cyber Space
- Virtual Production
- Digital Production

Cyber-Physical-Production System

Real Production
- Design – Manufacturing Collaboration
- Integrated Planning Simulation
- Process & Layout Planning
- Ramp Up & Production Execution
- Utilization
- Recycling

Physical World
- Automation

Integrated Product and Process Planning and Design Competence

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Industry 4.0
Essential competence requirements

Cyber Space
- Virtual Production
- Digital Production

Cyber-Physical-Production System

Physical World
- Real Production
- Global Production & Supplier Collaboration
- Design – Manufacturing Collaboration
- Integrated Planning Simulation
- Process & Layout Planning
- Ramp Up & Production Execution
- Utilization
- Recycling
- Innovation Management
- Automation
- Creativity & Methods
- Competence for systematic Idea & Innovation Mgmt.
- Integrated Product and Process Planning and Design Competence

Smart Product
Industry 4.0

Essential competence requirements

Cyber Space
- Intelligence
- Senses for perception
- Ability to improve learning aptitude
- Versatility
- Creativity
- Experience
- Social interaction

Cyber-Physical-Production System Interface
- Cloud Computing
- Virtual Reality
- Data Mining
- Internet of Things
- Wireless Network
- Software Tools

Real Production
- Idea Engineering
- Design - Manufacturing Collaboration
- Integrated Planning Simulation
- Process & Layout Planning
- Ramp Up & Production Execution
- Utilization
- Recycling

Virtual Production

Digital Production

Automation

Virtual Production

Smart Devices

RFID

Sensors & Actuators

Wearable Computers

Smart Devices

Control Center

Embedded Systems

Social Machines

Real Production

Smart Grid

Cloud Computing

Virtual Reality

Data Mining

Internet of Things

Wireless Network

Software Tools

Realization

Virtual Production

Digital Production

Cyber Space

Physical World

Systems and Interface Competence

Creativity & Methods Competence for systematic Idea & Innovation Mgmt.

Integrated Product and Process Planning and Design Competence
Industry 4.0
Job profiles (excerpt) for a cyber-physical working environment
ESB Logistics-Learning-Factory
Holistic Approach from Product to Factory

Customization of adaptable product (high variance)

Process Design & Validation

Assembly and intralogistics systems, Jigs & Fixtures Design & Realization

System realization and ramp-up

Creativity & Methods Competence for systematic Idea & Innovation Mgmt.

Integrated Product and Process Planning and Design Competence

Systems and Interface Competence

Education Training Research Industry Projects

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Integrative tie-in of virtual factory and physical system

- Spring 2014: Hardware installation
- Spring 2014: Software installation
- July 2014: First system run
- Oct 2014: First trainings with students
- Nov 2014: First Industry 4.0 workshop for external
- 2015: New building
- SS 2015: System expansion
- 2015: Regular operation

Customer requirements → CAS / CAD / PDM → Production Program → Configuration of production system → Simulation → Process- and work station design → Manufacturing Execution

Quick Adaption to Turbulences
Exemplary aspects of Industry 4.0

Transparency & Traceability
Smart, low-cost solutions for SME requirements
ESB Logistics-Learning-Factory
Industry 4.0– Flexible conveyor system

- Unlimited layout opportunities with minimized changeover times
- Touch-screen control and monitoring
- Automated topology feedback
- Plug-and-play for goods, power & information flow
- Forerunner-Follower-Identification
- Autonomous routing with no dead-locks
- Integrated Product and Process Planning and Design Competence
- Systems and Interface Competence

Start IP: 192.0...
Destination IP: 192.1...

Pictures courtesy of:
- FLEXLOG
- Gehhardt
- ESB BUSINESS SCHOOL
- TU WEN
- Fraunhofer AUSTRIA
ESB Logistics-Learning-Factory
Industry 4.0 – Flexible conveyor system Use Case

Flexible conveyor for changing logistical requirements

Initial order scenario (quantity, variants, dates)

Realization of ideal plant layout

Turbulences affecting the scenario

Result: adapted production system

Demand change
Supply outage
Equipment defect
Technological change
...

Aspects for Education, Research and Industry

E Short-cyclical re-design of logistical systems, including planning as well as technical realization

R Automated planning of multimodal intralogistics systems (e.g. with unsteady conveyor)

I Development of use applications for the industry

Systems and Interface Competence

Integrated Product and Process Planning and Design Competence
## ESB Logistics-Learning-Factory
### Industry 4.0 – Technical Assistance System

Technical assistance with collaborative robots

<table>
<thead>
<tr>
<th>Conventional robots</th>
<th>Fit for the future robots</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stationary use</td>
<td>Autonomous routing and navigation within the system</td>
</tr>
<tr>
<td>Complex config</td>
<td>High-level programming</td>
</tr>
<tr>
<td>Fenced operation</td>
<td>Shoulder-to-Shoulder collaboration</td>
</tr>
<tr>
<td>Defined task</td>
<td>Flexible deployment</td>
</tr>
</tbody>
</table>

### Use Case ESB Logistics Learning Factory

- **Creativity & Methods Competence** for systematic Idea & Innovation Mgmt.
- **Open-source ROS** for creative solutions & innovation sharing
- **Systems and Interface Competence**
- **2D-Laser for auto-movement**
- **Intuitive teaching:** Job enrichment for operators
- **Tactile sensors and cognitive capabilities**
- **Situative integration into assembly, logistics, QC...**

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Technical assistance with collaborative robots

ESB Logistics-Learning-Factory
Industry 4.0 – Technical Assistance System Use Case

Technical assistance with collaborative robots

Work tasks (required ability)

Design and planning of collaborative Works Systems

MTM-based ergonomic workload analysis

Task-specific teaching and deployment of the assisting system

Result

Demographic-change ready workplaces

Technology follows the worker, not worker the technology

Situative assistance instead of human substitution -> standardized CWSM

Systems and Interface Competence

Aspect for Education, Research and Industry

E Integral workplace optimization and expertise enhancement in the deployment of smart local automation solutions

R Development of „ability and attribute based" standardized modules for collaborative workings systems (CWSM)

I Cost-benefit evaluation of collaborative assisting systems and best-practices of application

[VDI2860] Assembly:
- Mating (e.g., Screwing, Plugging, Gluing, Clipsing)
- Handling (e.g., Picking, Placing)
- Checking (e.g., Measuring)
- Adjusting (e.g., Tuning)
- Support Ops (e.g., Cleaning)

Functions of handling:
- Store
- Adjust quantity
- Move
- Check

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TU Vienna Learning & Innovation Factory
„i-PEP“ (integrative product emergence process)
TU Vienna Learning & Innovation Factory
„i-PEP“ (integrative product emergence process)

2011
Formation & initiation

2011 / 2012
Development & installation

April 2012
Pilot Run

10th May 2012
2nd Conference on LF in Vienna

2012 / 2013
Optimization of training concept

April 2013
2nd lecture

2013 / 2014
Integration of PM & creative tools

May 2014
3rd lecture

2014 - 2016
Industry 4.0 use cases

Didactic Approach

Lecture for content preparation
Hands-on training
Presentation with feedback
Independent learning
Teamwork
Teambuilding
Funding of physical equipment and digital infrastructure:
- Austrian Ministry for Science & Research
- 3 years, started in January 2014
- 300k€ for investments
- 170k€ inkind performance
TU Wien Learning & Innovation Factory
Proceeding

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PhD College:
- Ressources (Students) for CPPS research
- Transfer of use cases into the Learning Factory
TU Wien Learning & Innovation Factory

Proceeding

Funding of physical equipment and digital infrastructure:
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PhD College:
- Resources (Students) for CPPS research
- Transfer of use cases into the Learning Factory

Endowed Professorship:
- Focus: Production of the Future
- Supervision of I4.0 qualification and development activities
TU Vienna Learning & Innovation Factory
Expansion of Manufacturing Technologies

Initial situation
NC-turning machine & milling machine
External procurement
TU Vienna Learning & Innovation Factory
Expansion of Manufacturing Technologies

Initial situation

NC -turning machine & milling machine

Target situation

Laser cutting machine
Laser welding system
Bending machine
Thermoforming machine

External procurement
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Expansion of Manufacturing Technologies

Integrated Product and Process Planning and Design Competence

Initial situation
NC-turning machine & milling machine
External procurement

Preliminary, activity-based costing vs. post calculation with real time data
Comparision of production costs from different manufacturing methods
Make-or-buy decision

Target situation
Laser cutting machine
Laser welding system
Bending machine
Thermoforming machine
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Installation of Software – Siemens Teamcenter

Red Bull Racing Team
Integrated Idea Capture and Management
Collaborative Data Management
Project Management
Digital Product Development
Real-time Engineering Collaboration
TU Vienna Slotcar Teams

Creativity & Methods Competence for systematic Idea & Innovation Mgmt.

Integrated Product and Process Planning and Design Competence
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Industry 4.0 Use Case – Siemens Process Designer (Tecnomatix)

[Diagram showing Design, Production of Jig, and evaluation of variants]

- **Variant A**: Assembly of Slotcar incl. Time Measurement
- **Variant B**: Assembly of Slotcar incl. Time Measurement
- **Variant n**: Assembly of Slotcar incl. Time Measurement
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Industry 4.0 Use Case – Siemens Process Designer (Tecnomatix)

- Design
- Simulation
- Production of Jig

Evaluation of variants before SOP with MTM (TiCon tool)

Variant A
Variant B
Variant n

Assembly of Slotcar

Integrated Product and Process Planning and Design Competence
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Industry 4.0 Use Case

from virtual to real

Integrated Product and Process Planning and Design Competence

Systems and Interface Competence
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Industry 4.0 Use Case

Physical Automated and Digital / Virtual Production Cell

- Slotcar Component: Wheel Rim
- Articulated Robot
- NC-Turning Machine
- Transport Pallet with RFID Chip
- Safety Eye
- Control Center
- Mobile Device with App
- Driverless Transport System with integrated Roller Conveyor
- Simulation

Systems and Interface Competence
Thank you!

Questions

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Industry 4.0
Change of qualification requirements

Know How, Decision-making competence, Problem-solving competence

De-skilling
- Lack of process knowledge
- Restricted by technical predefined decisions
- Working in an „Artificial Intelligence Environment“
- Elimination of manual and tedious work

Enrichment of tasks
- Increased spectrum of responsibilities
- Increased mental work via learning by doing
- Participation in planning and configuring tasks
- Design of rules for decision making
- Gain of information and communication flow
- Systems overview knowledge is required
- Digitalization and virtualization of real objects
- Increased technical requirements

Technology as assistance system

Shop Floor
CPPS
Planners
Activities related to Learning Factories:

- Standardization of the „System Learning-Factory“, including joint development of learning modules on Industry 4.0

- Intensification of academic exchange between the involved institutes on the level of researchers and students, including a summer school on Learning Factories (start: summer 2015)

- Dissemination of related research results in a series of papers on Learning Factories (start: Summer 2014)
Applied Research Project
LOPEC

- Human specific addressed aspects of Industry 4.0:
  - Initiating of lifelong-learning through a blended learning approach
    -> self studying via an LMS
    -> hands-on training in the LF
  - Fostering work-life balance by self-assessment of personal, professional and business objectives
  - Sensitizing of demographic change on shop floor level with the initiation of knowledge transfer between different age groups

Learning Mgmt. System
Self-Assessment Tool
Fraunhofer Austria Lean Assembly