Andreas Jaeger (TU Vienna, Fraunhofer); Fabian Ranz (ESB Reutlingen)

Andreas Jaeger, Ing., MSc., MBA, is researcher at Fraunhofer Austria Research and the Vienna University of Technology since 2011. He is in charge of the further development and operation of the “TU Vienna Learning & Innovation Factory for Integrative Production Education” where he holds trainings and lectures for students of the university and for employees from industry. During his study he worked as a technical project manager in Central and Eastern Europe within a global electronic enterprise for five years. At Fraunhofer he is in charge of a log-term project focusing on the diagnostic and improvement-oriented evaluation of SMEs to initiate and accompany production optimization and innovation projects. Furthermore he contributes in an applied research project related to the human’s role in smart factories.

Fabian Ranz, M.Sc., is a research associate at ESB Business School, Reutlingen University in the field of Industrial Engineering and Logistics Planning and Design. He is responsible for the set-up of the “ESB Logistics Learning-Factory”, what includes infrastructure implementation as well as didactical design. Besides, he is coordinator for the Network of Innovative Learning Factories (NIL). Before joining ESB as a researcher, during his studies in Industrial Engineering Fabian gained experience at several multinational enterprises in engineering, logistics and strategy functions.

The Institute of Management Science, Department for Industrial Engineering and System Design at the Vienna University of Technology, in cooperation with the Fraunhofer Austria Research, Division Production and Logistics Management, and the ESB Reutlingen University, Division for Logistics Planning and Design are active in higher and advanced education in the field of industrial engineering. Both provide problem based, interactive hands-on training in their Learning Factories with the focus on Lean Management and the Product Creation Process.

Research of both institutes concentrates on the development and processing of scientific findings for practical application. Projects are dealing with the analysis, planning and optimization of the structure, organization and management of industrial and service enterprises and their logistics networks.

Fraunhofer Austria, TU Vienna and ESB Reutlingen collaborate in the European-wide applied research project “LOPEC” related to the systematic assessment of the personal excellence in lean logistics and the initiation of lifelong-learning on the shopfloor.
INDUSTRY 4.0 – CHALLENGES FOR THE HUMAN FACTOR IN FUTURE PRODUCTION SCENARIOS

Industry 4.0 predicts that industrial processes, technological infrastructure and all corresponding business processes, with the help of information and communication technology (ICT), will advance to integrated, ad-hoc interconnected and decentralized Cyber-Physical Production Systems (CPPS) with real-time capabilities of self-optimization and adaptability.

Considering this change, the human being will remain in a dominant role, because it is not expected that the human factor with its characteristics and capabilities will be substituted entirely by autonomously acting technology in the foreseeable future. The mechanical intelligence, for instance, is limited to the selection of predefined options, while human creativity, flexibility, the ability to learn and to improve are required to design and configure systems, processes and products. Humans have the expertise and experience to analyze, assess and solve even in exceptional situations.

However, the amount of purely manual tasks for shop floor workers will decrease. Their role will change from a manually executing to a proactive preconceiving worker with increased responsibility. Due to the growing degree of digitalization and interconnectedness, also the tasks and responsibilities for planning and design personnel will continuously expand and become more complex. The work in versatile ad-hoc networks with advanced ICT-tools and assistance systems will lead to increased requirements regarding the knowledge, capability and capacity of the respective employees. The on-going pervasion of IT and emergence of systems with unprecedented complexity specifically require significantly improved capabilities in analysis, abstraction, problem solving and decision making from future labour.

Accordingly, the industry is asking for graduates that are educated interdisciplinary and practice-oriented. Some universities already meet these expectations, using learning factories for realistic, action-oriented classes and trainings. Lecturers are confronted with the challenge to identify future job profiles and correlated qualification requirements, especially regarding the conceptualization and implementation of CPPS, and to adapt and enhance their education concepts and methods adequately and consequently. For the new, virtual world of manufacturing a proper understanding of engineering as well as computer sciences is essential. Industry 4.0 implies this interdisciplinary split. Integrated competencies for product and process planning and design, methodological competencies for systematical idea and innovation management as well as a holistic system and interface competence will be crucial to achieve interconnection of physical and digital processes and machines.

The Vienna University of Technology and the ESB Reutlingen committed to integrate key aspects of Industry 4.0 into their respective learning factories successively. Thus, the students will act as the coordinators of the CPPS and thereby remain in the center of all learning and implementation activities.
Implications for Learning Factories from Industry 4.0
Challenges for the human factor in future production scenarios

Andreas Jäger, MSc, MBA
Prof. Dr. Wilfried Sihn
Fraunhofer Austria Research GmbH
Vienna University of Technology

Fabian Ranz, MSc
Prof. Dr. Vera Hummel
ESB Business School, Reutlingen University
Industry 4.0
The human factor in cooperation with CPPS
Industry 4.0
The human factor in cooperation with CPPS
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

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

Industry 4.0
Industry 4.0
Challenges – Qualification and Education

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

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

Number of namings

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

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

Integrated Product and Process Planning and Design Competence
Industry 4.0
Essential competence requirements

- **Virtual Production**
- **Digital Production**

**Cyber-Physical-Production System**

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

**Global Production & Supplier Collaboration**

**Physical World**
- Automation

**Creativity & Methods Competence for systematic Idea & Innovation Mgmt.**

**Integrated Product and Process Planning and Design Competence**
Industry 4.0
Essential competence requirements

- Cloud Computing
- Virtual Reality
- Data Mining
- Internet of Things
- Wireless Network
- Software Tools
- Cyber-Physical-Production System
- Cyber Space
- Virtual Production
- Digital Production
- Smart Devices
- RFIDs
- Smart Grids
- Embedded Systems
- Social Machines
- Interface
- Real Production
- Virtual Reality
- Learning aptitude
- Versatility
- Creativity
- Experience
- Social interaction
- Internet of Things
- Idea Engineering
- Design – Manufacturing Collaboration
- Integrated Planning Simulation
- Process & Layout Planning
- Ramp Up & Production Execution
- Utilization
- Recycling
- Innovation Management
- Automation
- Global Production & Supplier Collaboration
- Systems and Interface Competence
- Creativity & Methods Competence for systematic Idea & Innovation Mgmt.
- Integrated Product and Process Planning and Design Competence

Cloud Computing
Virtual Production
Real Production
Virtual Reality
Data Mining
Internet of Things
Smart Devices
RFID
Smart Grid
Wearable Computers
Cloud Computing
Virtual Reality
Data Mining
Internet of Things
Wireless Network
Software Tools
Cyber-Physical-Production System
Virtual Production
Digital Production
Smart Devices
RFIDs
Smart Grids
Embedded Systems
Social Machines
Interface
Real Production
Virtual Reality
Learning aptitude
Versatility
Creativity
Experience
Social interaction
Internet of Things
Idea Engineering
Design – Manufacturing Collaboration
Integrated Planning Simulation
Process & Layout Planning
Ramp Up & Production Execution
Utilization
Recycling
Innovation Management
Automation
Global Production & Supplier Collaboration
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

<table>
<thead>
<tr>
<th>Process</th>
<th>Design &amp; Validation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembly and intralogistics systems, Jigs &amp; Fixtures</td>
<td>Design &amp; Realization</td>
</tr>
</tbody>
</table>

- System realization and ramp-up
- Assembly and intralogistics systems, Jigs & Fixtures, Design & Realization

- Customization of adaptable product (high variance)

<table>
<thead>
<tr>
<th>Creativity &amp; Methods</th>
<th>Competence for systematic Idea &amp; Innovation Mgmt.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integrated Product and Process Planning and Design Competence</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Education</th>
<th>Training</th>
<th>Research</th>
<th>Industry Projects</th>
</tr>
</thead>
</table>

- Systems and Interface Competence
- Education
- Training
- Research
- Industry Projects

© reidorbit

Creativity & Methods Competence for systematic Idea & Innovation Mgmt.
ESB Logistics-Learning-Factory
Integrative tie-in of virtual factory and physical system

- 2013: New team & suppliers
- 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
- Order Data
- 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

- Engineering & Operations Cockpit
- Physical System Learning Factory

- Customer orders
- Order Data
ESB Logistics-Learning-Factory

Industry 4.0 – Flexible conveyor system

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

Pictures courtesy of:

- FLEXLOG
- Gehhardt

Systems and Interface Competence

Start IP: 192.0...

Destination IP: 192.1...
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

Integrated Product and Process Planning and Design Competence

Systems and Interface 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...
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

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

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>Formation &amp; initiation</td>
</tr>
<tr>
<td>2011 / 2012</td>
<td>Development &amp; installation</td>
</tr>
<tr>
<td>April 2012</td>
<td>Pilot Run</td>
</tr>
<tr>
<td>10th May 2012</td>
<td>2nd Conference on LF in Vienna</td>
</tr>
<tr>
<td>2012 / 2013</td>
<td>Optimization of training concept</td>
</tr>
<tr>
<td>April 2013</td>
<td>2nd lecture</td>
</tr>
<tr>
<td>2013 / 2014</td>
<td>Integration of PM &amp; creative tools</td>
</tr>
<tr>
<td>May 2014</td>
<td>3rd lecture</td>
</tr>
<tr>
<td>2014 - 2016</td>
<td>Industry 4.0 use cases</td>
</tr>
</tbody>
</table>

Didactic Approach

- Lecture for content preparation
- Hands-on training
- Presentation with feedback
- Independent learning
- Teamwork
- Teambuilding
TU Wien Learning & Innovation Factory
Proceeding

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**

**Funding of physical equipment and digital infrastructure:**
- Austrian Ministry for Science & Research
- 3 years, started in January 2014
- 300k€ for investments
- 170k€ inkind performance

**PhD College:**
- Ressources (Students) for CPPS research
- Transfer of use cases into the Learning Factory
Funding of physical equipment and digital infrastructure:
- Austrian Ministry for Science & Research
- 3 years, started in January 2014
- 300k€ for investments
- 170k€ inkind performance

PhD College:
- Ressources (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
- External procurement
- Laser cutting machine
- Laser welding system
- Bending machine
- Thermoforming machine

Target situation
TU Vienna Learning & Innovation Factory
Expansion of Manufacturing Technologies

Initial situation
- NC-turning machine & milling machine
- External procurement

Preliminary, activity-based costing vs. post calculation with real time data

Comparison of production costs from different manufacturing methods
- Laser cutting machine
- Laser welding system
- Bending machine
- Thermoforming machine

Make-or-buy decision

Target situation

Integrated Product and Process Planning and Design Competence
TU Vienna Learning & Innovation Factory
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
TU Vienna Learning & Innovation Factory
Industry 4.0 Use Case – Siemens Process Designer (Tecnomatix)

Design → Production of Jig

- Variant A: Assembly of Slotcar incl. Time Measurement
- Variant B: Assembly of Slotcar incl. Time Measurement
- Variant n: Assembly of Slotcar incl. Time Measurement
TU Vienna Learning & Innovation Factory
Industry 4.0 Use Case – Siemens Process Designer (Tecnomatix)

Integrated Product and Process Planning and Design Competence

Design → Simulation → Production of Jig

Variant A
Variant B
Variant n

Evaluation of variants before SOP with MTM (TiCon tool)

Assembly of Slotcar
TU Vienna Learning & Innovation Factory
Industry 4.0 Use Case

Integrated Product and Process Planning and Design Competence

from virtual to real

Systems and Interface Competence
TU Vienna Learning & Innovation Factory
Industry 4.0 Use Case

Physical Automated and Digital / Virtual Production Cell

Slotcar Component: Wheel Rim
Articulated Robot
Assembly Line
Transfer Station
Driverless Transport System with integrated Roller Conveyor
NC-Turning Machine
Transport Pallet with RFID Chip
Safty Eye
Control Center
Mobile Device with App
Simulation
Systems and Interface Competence

TU WIEN
Technische Universität Wien
Vienna University of Technology
Thank you!

Questions

Andreas Jäger, MSc, MBA
Fraunhofer Austria Research GmbH
Division Production and Logistics Management
Vienna University of Technology
Institute of Management Science
Division for Industrial and Systems Engineering
Theresianumgasse 27 | A-1040 Vienna | Austria
Mobil: +43 676 888 616 25
andreas.jaeger@fraunhofer.at

Fabian Ranz, MSc
ESB Business School
Hochschule Reutlingen
Logistics Network Planning and Design
Alteburgstraße 150 | 72762 Reutlingen | Germany
Tel.: +49(0)7121 271 3085
Fabian.ranz@reutlingen-university.de
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
- Technology as assistance system

### 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

### Shop Floor
- CPPS

### Planners

Lack of process knowledge
Restricted by technical predefined decisions
Working in an “Artificial Intelligence Environment”
Elimination of manual and tedious work
Technology as assistance system
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
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)
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