Buckingham, 14th September, 2016

A guide to develop competency-oriented Lean Learning Factories systematically

European Lean Educator Conference 2016

Judith Enke
Michael Tisch
Joachim Metternich

aInstitute of Production Management, Technology and Machine Tools, Technische Universität Darmstadt, Otto-Berndt-Str. 2, 64287 Darmstadt, Germany

www.prozesslernfabrik.de
Agenda

1. Motivation
2. Definition of Learning Factories
3. Guide for development of Learning Factories
4. Summary
## Agenda

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><strong>Motivation</strong></td>
</tr>
<tr>
<td>2</td>
<td><strong>Definition of Learning Factories</strong></td>
</tr>
<tr>
<td>3</td>
<td><strong>Guide for development of Learning Factories</strong></td>
</tr>
<tr>
<td>4</td>
<td><strong>Summary</strong></td>
</tr>
</tbody>
</table>
Learning Factory as an Image of the real Factory to improve Problem Solving Capabilities

**Real Factory**

- New Technologies
- Globalisation
- Volatile Environments

**Design of a complex learning system** for the challenges of future production

**Learning Factory**

Competency development of specialists and managers for the challenges of present and future production
## Potential for education and training: Effective competence development

<table>
<thead>
<tr>
<th>Aspects of methodical modelling of successful learning processes</th>
<th>Learning factory as a learning system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contextualisation, situated context</td>
<td>Partial model of real factory provides a rich learning context</td>
</tr>
<tr>
<td>Activation of learner</td>
<td>Generation and application of knowledge in the learning factory (learner active phases)</td>
</tr>
<tr>
<td>Problem solving</td>
<td>Solving of real problem situations in the learning factory</td>
</tr>
<tr>
<td>Motivation</td>
<td>Motivation by the reality character and the possibility to act hands-on immediately.</td>
</tr>
<tr>
<td>Collectivisation</td>
<td>Self-organised learning in groups is a suitable model in learning factories</td>
</tr>
<tr>
<td>Thinking and doing</td>
<td>Alternation of hand-on phases in the learning factory and systematization phases</td>
</tr>
</tbody>
</table>

Agenda

1. Motivation
2. Definition of Learning Factories
3. Guide for development of Learning Factories
4. Summary
A learning factory is a learning environment where processes and technologies are based on a real industrial site which allows a direct approach to product creation process. Learning factories are based on a didactical concept emphasizing experimental and problem-based learning. The continuous improvement philosophy is facilitated by own actions and interactive involvement of the participants.

European Initiative on Learning Factories (2013)
<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purpose</td>
<td>teaching and/or training and/or research</td>
</tr>
<tr>
<td>Process</td>
<td>authentic + multi stage + technical and organizational</td>
</tr>
<tr>
<td>Setting</td>
<td>changeable + <strong>real or virtual</strong></td>
</tr>
<tr>
<td>Product</td>
<td><strong>physical or service</strong></td>
</tr>
<tr>
<td>Didactics</td>
<td>concept based + formal and informal learning + own actions of trainees + on-site or remote learning***</td>
</tr>
<tr>
<td>Operating Model</td>
<td>sustainable plan allows the ongoing operation (desired)</td>
</tr>
</tbody>
</table>

Learning Factories in the narrow and in the broader sense

Learning Factory in the narrow sense

Learning Factory in the broader sense

Value chain in the learning factory

Communication channel

real

service

physical

virtual

on-site

remote

In a morphology each dimension is described in detail.

Current problems of learning factory design

1. No derivation of applied didactic concepts
2. High uncertainty in pilot situations
3. Missing target orientation of teaching modules
4. Transfer of problem solving procedures in real industrial situations
Agenda

1 Motivation
2 Definition of Learning Factories
3 Guide for development of Learning Factories
4 Summary
Learning factories are designed on three different levels

1 – Macro level
(Learning Factory)
Design of the Learning Factory infrastructure including the production environment as well as fundamental parts of intended learning processes

2 – Meso level
(teaching module)
Design of teaching modules including the explication of specific sub-competencies and the definition of general teaching-learning sequences

3 – Micro level
(learning situation)
Design of specific teaching-learning situations

1\textsuperscript{st} didactic transformation

Question to be answered:
What are relevant learning targets and contents for involved stakeholders?

2\textsuperscript{nd} didactic transformation

Question to be answered:
How can those learning targets and the content be addressed in the learning factory?

Macro, meso and micro level are connected to each other

1 – Macro level (Learning Factory)

2 – Meso level (teaching module)

3 – Micro level (learning situation)

The guideline supports a Learning Factory design which suits the development of intended competencies

1st didactic transformation
- Focus setting
- Content selection of most relevant aspects
- Identification of intended competencies

Learning targets
- Identification of intended competencies

Configuration/Design
- Configuration of a suited Learning Factory by planning instruction, interaction, and media

The process learning factory CiP was established in 2007
Learning modules can be designed using a competency transformation chart to define and operationalise learning targets.

<table>
<thead>
<tr>
<th>Competency</th>
<th>Topic 1</th>
<th>Sub-competency 1</th>
<th>Corresponding action</th>
<th>Knowledge base</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Topic 2</td>
<td>Sub-competency 2.1</td>
<td>Corresponding action</td>
<td>Knowledge base</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sub-competency 2.2</td>
<td>Corresponding action</td>
<td>Knowledge base</td>
</tr>
<tr>
<td></td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

### Extract from the competency transformation chart

**Learning module: Lean Quality**

<table>
<thead>
<tr>
<th>Competency</th>
<th>Sub-competencies</th>
<th>Action</th>
<th>Knowledge base</th>
</tr>
</thead>
<tbody>
<tr>
<td>The participants have the ability to explain the methods and tools for the implementation of <strong>Jidoka</strong>* and for the solution of problems and to apply selected methods and tools.</td>
<td>...</td>
<td>Design of an Andon-system (physical implementation)</td>
<td>Knowledge, that visual and acoustical signals and an Andonboard are needed; knowledge of the examined workplaces; knowledge of the functionality of Andon; knowledge of the meaning of the colors</td>
</tr>
<tr>
<td>Ability to develop an Andon-concept for Production</td>
<td>...</td>
<td>Planning of an escalation process for the problem escalation with Andon</td>
<td>Knowledge of the person in charge and of the available time; knowledge of the theoretical sequence of an escalation process (point in time for information, order of notification)</td>
</tr>
</tbody>
</table>
| ... | ... | ... | ...

*Jidoka: Part of the Toyota Production System which deals with the elimination and prevention of defects and rework*
To address actions from the transformation chart in the learning factory two different sequences of activities are possible:

1. **Introduction** → **Systematisation** → **Reflection** → **Examination**
2. **Introduction** → **Exploration** → **Systematisation**

Designing sequences of activities
Learning module: Lean Quality
Sequence: Andon concept

Introduction: Andon* as part of Jidoka

Systematisation: Theoretical Input on Andon (preconditions, escalation process, …)

Experimentation: Development of a Andon concept for the Process Learning Factory

Reflection: Presentation of results, debate about different design options

*Andon: Concept of the problem solving process to stop production, alert and escalate in case of problems
For particular learning situations two different sequences of activities are possible

Exemplary design of particular learning situations
Learning module: Flexible employee use system
Action: Preparing for implementation

**Step I**

Partial Competence (technical and methodological)

The participants possess the ability to implement the Flexible Employee Use System (FMS) in a production environment

**Action**

The participants prepare for the implementation

**Knowledge Element** (Professional and conceptual knowledge)

Stabilization of the processes, separate manual from automated processes, minimize routes, tact-alignment, construction of the desired layout, training of the employees

The participants implement FMS

**Step II**

Create action exercises

Scenario for the action exercises – Sequential development of the actions defined in step I

- The participants created a rough implementation plan (Framework)
- The participants perform time studies

- The participants analyze forecasts of customer demands
- The participants determine the required number of employees
- The participants analyze if the system for this customer takt...

- The participants determine the necessary production steps
- The participants tact the workplaces for the determined customer-tact

**Step III**

Create the assignment for the action exercises

**Action setting**

Batch pieces per day

<table>
<thead>
<tr>
<th>J</th>
<th>F</th>
<th>M</th>
<th>A</th>
<th>M</th>
<th>J</th>
<th>A</th>
<th>S</th>
<th>O</th>
<th>N</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>200</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>500</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>300</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>300</td>
<td></td>
</tr>
<tr>
<td>200</td>
<td>400</td>
<td>500</td>
<td>600</td>
<td>400</td>
<td>500</td>
<td>200</td>
<td>100</td>
<td>300</td>
<td>400</td>
<td>500</td>
</tr>
</tbody>
</table>

Additional Information

1 Shift/Day
8h Working Hours
1h
2 Employees need 60 sec.

**Task**

- Ensure that the assembly department can respond to fluctuating customer demand in the coming year

**Setting**

- Assembly
- 3 Groups

Agenda

1 Motivation
2 Definition of Learning Factories
3 Guide for development of Learning Factories
4 Summary
For the development of learning factories the guide promotes a competency-oriented preparation, execution and postprocessing.

1. **Preparation**
   - Competency transformation
     - \( K_i \): Competence \( i \)
     - \( h_{ij} \): the \( j \)-te Handling of the \( i \)-ten Competence
     - \( W_{ij} \): the \( j \)-te Knowledge element of the \( i \)-ten Competence
     - Competencies – Action – Knowledge
     - \( K_1 \): \( h_{11} - h_{1m} \) \( W_{11} - W_{1o} \)
     - ... 
     - \( K_n \): \( h_{n1} - h_{nm} \) \( W_{n1} - W_{no} \)

2. **Execution**
   - Carry-out Training Program
   - Observe Action Exercises, Check reasoning knowledge
   - Not observable, or queryable

3. **Postprocessing**
   - Complete Target-Actual Comparison
     - TARGET (expected actions from 1A)
     - ACTUAL (observed actions from 2B)
     - Deviation
       - Non-achieved Goals, identified weaknesses, Improvement potential
   - Continuously improve training

References

Eberhard Abele, Joachim Metternich, Michael Tisch, George Chryssolouris, Wilfried Sihn, Hoda ElMaraghy, Vera Hummel, Fabian Ranz: *Learning Factories for research, education, and training*; Procedia CIRP 32 (2015); p. 1-6

Michael Tisch, Fabian Ranz, Eberhard Abele, Joachim Metternich, Vera Hummel: *Learning Factory Morphology – Study Of Form And Structure Of An Innovative Learning Approach In The Manufacturing Domain.* TOJET (2015), Special Issue 2 for INTE 2015


Thank you for your kind attention!

If you have any questions, do not hesitate to contact us.

Prof. Dr.-Ing. Eberhard Abele
Prof. Dr.-Ing. Joachim Metternich
Institute of Production Management, Technology and Machine Tools
Technische Universität Darmstadt
Otto-Berndt-Straße 2
64287 Darmstadt

Phone: +49 61 51 | 16 20107
E-Mail: enke@ptw.tu-darmstadt.de
Internet: www.prozesslernfabrik.de