A systematic approach for designing learning environments for energy efficiency in industrial production
Agenda

- Energy Efficiency in Industry
- ETA Learning Factory
- Learning Environments for Energy Efficiency
- The LE³-Guide
- Application of the LE³-Guide
Introduction

Energy efficiency in industry

Ambitious saving targets for the industry

- Solution rather complex
- Each factory unique
- Holistic approaches rarely taken into consideration

Industry continues to be the major energy consumer in Germany!

Machine and automotive manufacturing

- Increase in production leads to increase in energy consumption
- Significance of the sector regarding the energy transition is increasing
Background: Research-Projecht: ETA-Factory

*Today:* Isolated optimization of different sub-systems of a factory

**Building** 25%

**Process chain** 20%

**Machine** 30%

Savings < 30%

Our vision: Holistic factory optimization including all sub-systems

Interaction of:
- Machines
- Process chains
- Buildings

Synergies by energy controlling and recovery measures

Potential ~ 40%
ETA-Factory – Impact you can feel
For excellent research, knowledge transfer & sustainable results

Using the ETA-Factory for demonstrating Best-Practice-Examples of industrial energy efficiency.

Establishing a Competence- and Transfer Center together with our industrial partners.

Excellent Education of future engineers and professional development in the areas of architecture, civil and mechanical engineering.
ETA Learning Factory

Target groups

**Industry**
- Factory & Production Planners
- Managers
- Controllers
- Energy Managers
- Machine Designers
- Shop-floor workers

**Technical Planners**
- Architecture
- Heating & Air Conditioning
- Energy Networks
- Pressurized Air

**Students**
- Bachelor, ’raise enthusiasm’
- Master, ’deepen knowledge’

**General Visitors**
- Politicians
- Association Members
- Funding Parties

Source: tab Fachmagazin TGA
Learning environments for energy efficiency

Required skills for the energy efficiency topic

<table>
<thead>
<tr>
<th>Background &amp; Sensitizing</th>
<th>Tools &amp; Techniques</th>
<th>Technology understanding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motivation</td>
<td>Energy policies and principles</td>
<td>Financing models</td>
</tr>
<tr>
<td>Identification of potentials</td>
<td>Elimination of energy wastes</td>
<td>Planning of implementations</td>
</tr>
<tr>
<td>Energy data</td>
<td>Cross-section technologies</td>
<td>Energy efficiency technologies</td>
</tr>
</tbody>
</table>

Different learning environments are necessary to focus on the relevant subsystems and target groups
- Building technology
- Machining processes
- Cleaning processes
- Hardening processes
- Process chain

There is the danger of focusing too much on a presentation of innovations than didactic principles.
**Main objectives of the LE³-Guide:**

Guidance for the design of learning environments for energy efficiency
- Target group oriented
- Adapted to the boundary conditions

**Result of the LE³-Guide:**

Requirements Catalogue
- Proposals and indications for the design

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**How could a learning environment for a particular target group look at given boundary conditions?**

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**Learning Environment Designer**

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**Requirements Catalogue**
- Prioritized Learning Objectives
- Features & Specifications
LE³-Guide
General Conditions

Learning Environment Designer

1. Questionnaire I: General Conditions
   - Purpose
   - Target Group
   - Resources

2. Basic Type of LE
   - Learning Objectives & Design Features

3. Questionnaire II: Learning Objectives & Design Features

4. Check List
   - Requirements Catalogue
     - Prioritized Learning Objectives
     - Features & Specifications
Definiton of basic types of learning environments depending on
- Purpose
- Target group

<table>
<thead>
<tr>
<th>Categorization based on the answers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Basic Type</strong></td>
</tr>
<tr>
<td>A1</td>
</tr>
<tr>
<td>B1</td>
</tr>
<tr>
<td>B2</td>
</tr>
<tr>
<td>B3</td>
</tr>
<tr>
<td>C1</td>
</tr>
<tr>
<td>C2</td>
</tr>
<tr>
<td>D1</td>
</tr>
<tr>
<td>D2</td>
</tr>
</tbody>
</table>
LE³-Guide
Learning Objectives & Design Features

Learning Environment Designer

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5. Requirements Catalogue
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   - Features & Specifications

6. Check List
**LE³-Guide**

**Learning Objectives & Design Features**

To each type different learning objectives are assigned

<table>
<thead>
<tr>
<th>Learning objectives for energy efficiency</th>
<th>Fascination</th>
<th>Sensitization</th>
<th>Analyzation</th>
<th>Transformation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A1</td>
<td>B1</td>
<td>B2</td>
<td>B3</td>
</tr>
<tr>
<td></td>
<td>C1</td>
<td>C2</td>
<td>D1</td>
<td>D2</td>
</tr>
<tr>
<td><strong>Motivation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Typical energy costs related to the technology known</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Energy efficiency potentials in the subject known</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>etc.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Fundamentals</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Important physical factors and units known</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Types of energy waste</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>etc.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Tools &amp; Techniques</strong></td>
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<td>Sankey</td>
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<td>X</td>
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<tr>
<td>Theoretical Limit</td>
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<td></td>
<td>X</td>
</tr>
<tr>
<td>etc.</td>
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</table>
## LE³-Guide
### Learning Objectives & Design Features

To each type different learning objectives are assigned

<table>
<thead>
<tr>
<th>Feature</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Abstraction level</strong></td>
<td>Schematic without reference to a product</td>
</tr>
<tr>
<td><strong>Extent of participation</strong></td>
<td>Without interaction</td>
</tr>
<tr>
<td><strong>Complexity</strong></td>
<td>Directly apparent</td>
</tr>
<tr>
<td><strong>Modularity</strong></td>
<td>Inflexible</td>
</tr>
<tr>
<td><strong>Transportability</strong></td>
<td>Not mobile</td>
</tr>
<tr>
<td><strong>Visualization (energy)</strong></td>
<td>Static</td>
</tr>
<tr>
<td><strong>Haptics (energy)</strong></td>
<td>None</td>
</tr>
<tr>
<td><strong>Acoustics (energy)</strong></td>
<td>None</td>
</tr>
<tr>
<td><strong>Accompanying material</strong></td>
<td>None</td>
</tr>
</tbody>
</table>
LE³-Guide
Questionnaire II

Learning Environment Designer

1. Questionnaire I: General Conditions
   - Purpose
   - Target Group
   - Resources

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LE³-Guide
Requirements Catalogue

Learning Environment Designer

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5. Requirements Catalogue
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   - Features & Specifications
6. Check List

Purpose | Target Group | Resources
## Requirements Catalogue: Applicable in green- and brownfield

### Form sheet:

<table>
<thead>
<tr>
<th>Learning environment type:</th>
<th>Knowledge Transfer</th>
<th>Physical Design</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Priority</strong></td>
<td><strong>Learning objective</strong></td>
<td><strong>DoF 1</strong></td>
</tr>
<tr>
<td>A</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 x Sum (max. 45)</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 x Sum (max. 30)</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 x Sum (max. 15)</td>
<td>1 x Sum (max. 15)</td>
</tr>
</tbody>
</table>

### Scale for a brownfield application:

<table>
<thead>
<tr>
<th><em>Degree of Fulfillment:</em> Only for brownfield-applications, do not fill in greenfield-uses</th>
<th>Not fulfilled</th>
<th>Slightly fulfilled</th>
<th>Partially fulfilled</th>
<th>Largely fulfilled</th>
<th>Completely fulfilled</th>
<th>Total points &amp; action required:</th>
<th>No action required</th>
<th>Minor optimizations possible</th>
<th>Major optimizations possible</th>
<th>Action mandatory</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
<td></td>
<td>&gt; 80</td>
<td>&lt; 80</td>
<td>&lt; 65</td>
<td>&lt; 45</td>
</tr>
</tbody>
</table>
Use Case: Brownfield application for a hydraulic system demonstrator

ETA Learning Factory
- Training curriculum is highly influenced by new research results
- Example: Technology demonstrator for a hydraulic system of machine tools
- Presentation of different design options
- Focus was on the operability of the system
- Didactic subjects were secondary

Goal
Integration of the demonstrator into the training curriculum
### LE³-Guide

**Use Case: Brownfield application for a hydraulic system demonstrator**

#### Basic type of learning environment according to Questionnaire I

<table>
<thead>
<tr>
<th>Learning environment type: <strong>B2</strong></th>
<th>Physical Design</th>
<th>Knowledge Transfer</th>
<th>Prioritization</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Learning objective</td>
<td>DoF 1*</td>
</tr>
<tr>
<td><strong>A</strong></td>
<td></td>
<td>Technical components known</td>
<td>Visualization (energy)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Energy saving potentials in the subject known</td>
<td>Complexity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Potential in comparison to other technologies known</td>
<td>Extent of participation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 x Sum (max. 45)</td>
<td>3 x Sum (max. 45)</td>
</tr>
<tr>
<td><strong>B</strong></td>
<td></td>
<td>Own potential influence known</td>
<td>Haptics (energy)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Able to assess cause-effect relationships</td>
<td>Acoustics (energy)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Able to identify energy waste types</td>
<td>Transportability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 x Sum (max. 30)</td>
<td>2 x Sum (max. 30)</td>
</tr>
<tr>
<td><strong>C</strong></td>
<td></td>
<td>Fundamental knowledge of the relevant measurement technology</td>
<td>Abstraction level</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The most important technical terms known and delineated</td>
<td>Modularity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Technology benchmark detected</td>
<td>Accompanying material</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 x Sum (max. 15)</td>
<td>1 x Sum (max. 15)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total (max. 90)</td>
<td>Total (max. 90)</td>
</tr>
</tbody>
</table>

Prioritized learning objectives & design features of an ideal implementation.
**LE³-Guide**

**Use Case: Brownfield application for a hydraulic system demonstrator**

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### Basic type of learning environment according to Questionnaire I

#### Learning environment type: B2

<table>
<thead>
<tr>
<th>Priority</th>
<th>Knowledge Transfer</th>
<th>Physical Design</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Learning objective</td>
<td>Feature</td>
</tr>
<tr>
<td>A</td>
<td>Technical components known</td>
<td>Visualization (energy)</td>
</tr>
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<td></td>
<td>Energy saving potentials in the subject known</td>
<td>Complexity</td>
</tr>
<tr>
<td></td>
<td>Potential in comparison to other technologies known</td>
<td>Extent of participation</td>
</tr>
<tr>
<td></td>
<td>3 x Sum (max. 45)</td>
<td>36</td>
</tr>
<tr>
<td>B</td>
<td>Own potential influence known</td>
<td>Haptics (energy)</td>
</tr>
<tr>
<td></td>
<td>Able to assess cause-effect relationships</td>
<td>Acoustics (energy)</td>
</tr>
<tr>
<td></td>
<td>Able to identify energy waste types</td>
<td>Transportability</td>
</tr>
<tr>
<td></td>
<td>2 x Sum (max. 30)</td>
<td>24</td>
</tr>
<tr>
<td>C</td>
<td>Fundamental knowledge of the relevant measurement technology</td>
<td>Abstraction level</td>
</tr>
<tr>
<td></td>
<td>The most important technical terms known and delineated</td>
<td>Modularity</td>
</tr>
<tr>
<td></td>
<td>Technology benchmark detected</td>
<td>Accompanying material</td>
</tr>
<tr>
<td></td>
<td>1 x Sum (max. 15)</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>Total (max. 90)</td>
<td>74</td>
</tr>
</tbody>
</table>

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Prioritized learning objectives & design features of an ideal implementation

Assessment of the current implementation
Implemented optimizations

Integration of a web-based visualization:

Control stand for a better interaction:
LE³-Guide
Conclusion & Outlook

Current State:
- Support for the designer of a learning environment
  - New developments (greenfield)
  - Revisions (brownfield)
- Addresses the problems of lacking target group orientation and comprehensibility
- Procedure is working manually

Outlook:
- Implementation as a software tool
- Improve of user friendliness
- Validation and revision

Source: Charlotte Coneybeer
Thank you for your interest!

For further questions we are happy to be at your disposal.

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E-Mail: info@ptw.tu-darmstadt.de
Internet: www.ptw.tu-darmstadt.de
Introduction
EU Energy Efficiency Objectives

Energy Costs
- Significant proportion of the total costs
- Rising energy costs expected

Political Relevance
- Political climate targets
- Changes in legislation (e.g. Ecolabels)

Social Responsibility
- Contribution to environmental protection
- Internal corporate objectives

EU Primary Energy Consumption Projections

Source: European Commission