
„IPEK Methods for Education of Creative Designers“
o. Prof. Dr.-Ing. Dr. h. c. Albert Albers / OI Norbert Burkardt
IPEK • Institute of Product Engineering Karlsruhe
Teaching Staff

- 2 professors
- 7 research groups
  - 3 senior engineers
  - 54 scientists
  - 20 technical staff
- education
  - since 1996 50 Ph.D.
  - 14 lectures
  - over 300 student assistants
  - ~3000 coached students
  - 200 Master / Bachelor Works
The IPEK way of Teaching for Innovation

Target:

Education of Creative Designers – Enabled to design Innovative Products
Influencing Factors on Creativity

Experience

Creativity

Knowledge

Phantasy
High Expectations in Education

- ... The government has to treat its universities neither as secondary schools nor as special schools...
  [Wilhelm von Humboldt (1767-1835)]

- ... Researching education and educational research form the universities...
  [Albert Albers]

Our demand: **Research and development** of methods and processes for product engineering including their **evaluation** using real systems and prototypes and their **integration** into excellent **education and teaching**.

Importance of „Competence“ in Education

- **Competencies are skills of individuals** [According to Weiner (2004)]
  - to solve certain **problems**
  - to **use** related motivational, volitional and social skills
  - to enable successful and responsible **problem solving** in various situations

- **Deficiencies in Academic Education**
  - Which are the **predominant deficiencies of applicants?**
Assessment of Competencies

1. Professional Competence
   - fundamentals in various disciplines
   - internalization of the most important basics
   - ...

2. Methodological Competence
   - design methodology
   - problem solving methods
   - Various methods such as QFD, DoE, CAD, CAQ...
   - ...

3. Social Competence
   - individual techniques of working
   - communication and team ability
   - visualization & presentation skills
   - leadership
   - ...

4. Elaboration
   - ability in transferring ideas
   - project orientation
   - reduction of costs
   - decision making

5. Creativity
   - problem-sensitivity
   - creativity techniques
   - courage for new solutions
   - ...

Directly Feasible Assessment Criteria

Indirectly Feasible Assessment Criteria

Hindered Assessment Criteria
IPEK Teaching Approach
KaLeP • Karlsruhe Teaching Model of Product Engineering

KaLeP – Karlsruhe teaching model of product engineering

Teaching
- lecture
- tutorial
- project work

Environment
- providing a realistic environment

Key Skills
- integration into project work
KaLeP: Karlsruhe Education Model for Product Engineering, Machine Design 1-4

- **Lecture**
  - Content: theory
  - **Theoretical basics**
  - Style: ex-cathedra
  - Place: lecture hall
  - Students: 800

- **Tutorial**
  - Content: theory
  - **Particular cases**
  - Style: ex-cathedra
  - Place: lecture hall
  - Students: 800

- **Project**
  - Content: project tasks
  - **Practical comprehension**
  - Style: team work & coaching
  - Place: team work spaces
  - Students: 5 (x160)
  - Tools: CAD, PDM, wiki
Focused Assessment of Communication- and Teamwork-Competencies

- Essential promotion of social competencies
  - Problem: **Enormous range** of social competence
  - Challenges: **Imparting and assessment** of social competencies in education

- Communication- and teamwork-competencies as essential elements of social competence
  - **Essential pre-condition** for employment in engineering
  - Teamwork as **essential element** for integrated product development
  - Holistic approach to product development: **Humans in the center**
Focused Assessment of Communication-and Teamwork-Competencies

- **Cooperation project:** Inst. für Technikdidaktik KIT Karlsruhe, ITB Bremen, LMU Munich
- Identification and definition of **indicators** for professional teamwork
  - Professional **communication and conversation** in human interactions
  - Identification and definition of **tasks and roles** of a successful team
  - Application of **teamwork-methods** (MS Project, Wiki) for coordinated actions
  - Identification, definition and assessment of **individual and team achievements** for holistic approaches and results
- Indicators **successful implemented** in elements of **KaLeP:** Karlsruhe Education Model for Product Engineering
## KaLeP: Karlsruhe Education Model for Product Engineering

<table>
<thead>
<tr>
<th>course focus</th>
<th>systems</th>
<th>methods</th>
<th>processes</th>
</tr>
</thead>
<tbody>
<tr>
<td>course title</td>
<td>machine design</td>
<td>methods of product development</td>
<td>integrated product development</td>
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<tr>
<td>settings</td>
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<tr>
<td></td>
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<td>competence acquisition</td>
<td>high</td>
<td>medium</td>
<td>very high</td>
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<td>design methods</td>
<td>team developm.</td>
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<td>creativity techniques</td>
<td>team leading</td>
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<td>communication</td>
<td>techniques</td>
<td>project</td>
</tr>
<tr>
<td></td>
<td>idea transfer</td>
<td></td>
<td>management</td>
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<td>800</td>
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<td>curriculum</td>
<td>bachelor</td>
<td>bachelor</td>
<td>master</td>
</tr>
</tbody>
</table>
IPEK Teaching Approach
Excerpt of IPEK Lectures

- mechanical design I-IV
- product development
- integrated product development
- powertrain systems A+B
- lightweight design
- friction systems
- mechatronic systems

focus groups
lectures
team work
MD I / MD II: Get the Taste of Machine Elements
Analysieren und Dokumentieren
Teamwork
Machine Design III / IV: Project Work

- Lectures covering the basics of Mechanical Design with >800 students (Systems Engineering, Bearings, Gears, Clutches, etc.)
- Tutorials and workshops to gain practical experience
- Accompanying 4 months of project work, typical fields of mechanical engineering


- St-o-A Review
- Concept
- Full Product
- Presentation

Cross-team cooperation → Wiki
First meeting of student group

Team work → Wiki → CAD, PDM

Team work → Wiki → CAD, PDM

Feedback Discussion
Promotion of Teamwork-Competencies

- Machine design: design project
  - High complexity of task
  - Designing a racing motor scooter
- Application of teamwork-methods
  - MS Project and Wiki
  - Essential pre-condition for success
  - Teamwork as essential element

Prof. Albert Albers – KaLeP: Karlsruher Lehrmodell für Produktentwicklung – Ein Ansatz zur Kompetenzerfassung in der Ingenieurausbildung
High Complexity of Design Project
Assessment of Teamwork-Competencies

- Evaluation of teamwork-methods
  - Evaluation and assessment of **type and level of use** in design project
  - Mandatory **documentation and verification** of correct use
  - Documentation is **subject of assessment**
  - Special **weighting evaluation key** in use for assessment
  - **Comparison** with feasible assessment of professional competencies

- Assessment of communication- and teamwork-competencies
- Assessment of social competencies
Focused Assessment of Communication- and Teamwork-Competencies

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- Indicators **successful implemented** in elements of **KaLeP:** Karlsruhe Education Model for Product Engineering
GEARE - Global Engineering Alliance for Research and Education

- KIT (IPEK)
  Karlsruhe, Germany
- Purdue University,
  West Lafayette, IN, USA
- SJTU Shanghai Jiaotong University,
  Shanghai, China

- Exchange program for undergraduate students (internship and study abroad)
- Exchange program for graduate students (thesis research in international teams)
- Long distance project-work
Exchange program for undergraduate students: Exemplary Timetable 2009/2010

Spring 2009

20.04. - 25.07.09

Karlsruhe: Study

Study

Fall 2009

01.09. - 19.12.09

USA: Industrial Internship

Purdue

Spring 2010

05.01. - 08.05.10

USA: Study

SJTU

China: Study

China: Industrial Internship

30.01. - 30.04.10
Design Task MD IV Workshop - Result
(Sponsored by „EUROPA Park“)
Designed at KIT (4. Semester)
Design Task MD IV Workshop - Result
Prototyping at Purdue (5.Semester)
Example mkl examination MD I – IV SS 2012
(time 3 hours)

Task:
Design of a Drilling Machine
(Box Column Drill)
Students Result
Students Result
Contact and Channel Approach (C&C²-A)

Example for Design Methodology in MD IIV Bachelor
Motivation for C&C²-A in practice

- Form and function are often looked at from **two separate points of view**; their relationships is rarely documented and, very often, unknown prior to understanding a technical problem.

- **Form**
  - geometrical
  - material
  - information
Motivation for C&C²-A in practice

- Form and function are often looked at from **two separate points of view**; their relationships is rarely documented and, very often, unknown prior to understanding a technical problem.

Functions

- Interactions
- Effects
- Properties
Motivation for C&C²-A in practice

- Description of the relationship between function and form

C&C-Models describe this relationship

**Function**
- Interactions
- Effects
- Properties

**Form**
- geometrical
- material
- information
Modelling and Abstraction

- **Modelling and dissecion** of a technical system strongly depends on **knowledge** and **experience** of a designer.

- Models are always created for a certain **purpose**.

- Models of a technical System always visualize a **short, pragmatic image of the original**, which is dependend on the person that creates it.
Main function of screw in state 1

Function: Prepare Fixation of Metall-Rail and Cement

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td><strong>WSP1</strong>: Metal rail / screw-head [geometry &amp; material parameters]</td>
<td></td>
</tr>
<tr>
<td><strong>WSP2</strong>: Bit / screw-head [geometry &amp; material parameters]</td>
<td></td>
</tr>
<tr>
<td><strong>CSS1/2</strong>: in screw [geometry &amp; material parameters]</td>
<td></td>
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</tbody>
</table>

**C1**: Properties from metal rail, fixation, climate …

**C2**: Properties from tool, person, climate, …

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[Diagram of system boundary, screw, WSP1, WSP2, bit, force F1, force F2, boundary condition]
1st patent: CSS ballistic shaft
Submitted: 31.04.2006
Reduction of torque load

2nd patent: Design 1. pitch
Submitted: 15.03.2007

H = \left( \tan \left( \frac{\alpha}{2} \right) + FB \right) X + 0,2mm - RK

Allows fixation of 2,5mm S355 Steel
Activities of problem solving „SPALTEN“

Example for Design Method PE (Master, Mandatory for ME

IPEK – Institute of Product Engineering

PS-Activities incl. examples & suitable methods

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Problemlösungsmethodik SPALTEN

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</thead>
<tbody>
<tr>
<td><strong>S</strong> ituationsanalyse</td>
<td><strong>SP</strong> problemeingrenzung</td>
<td><strong>PA</strong> Alternative Lösungssuche</td>
<td><strong>AL</strong> Lösungsauswahl</td>
<td><strong>TA</strong> tragweitenanalyse</td>
<td><strong>EU</strong> entscheiden und Umsetzen</td>
<td><strong>NL</strong> nachbereiten und Lernen</td>
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<td><strong>PE</strong></td>
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<td><strong>TA</strong></td>
<td><strong>EU</strong></td>
<td><strong>NL</strong></td>
</tr>
</tbody>
</table>
SPALTEN
Activity flow and interrelations SA to AL

Process of the P-analysis

solution search

PL Team (PLT) → SA → IC* → information about the problem → Problem

PE → IC* → PLT ok. ?

AL → IC* → targets → way unclear → way clear → TA

Way → No Problem

Problem

*IC: information check
SPALTEN
Activity flow and interrelations SA to AL

Solutions search  Solution implementation

AL  IC  PLT ok?  LA  IC  PLT ok?  TA  IC  PLT ok?  EU  IC  PLT ok?  NL

Solution motivation  Risk Scenario  Action plan

Solution implementation

LV1  LV2  LV3

Solution motivation

Problem?

Problem?

Problem?

No problem
Master Studies: Integrated Product Development
Structure Project Work

Company

Projectmanager

N.N.

Projectmanagement

N.N.  N.N.  N.N.

Company

N.N.

N.N.

N.N.

Technologie

Innovation

Team 1

Team 2

Team 3

Team 4

Team 5
IP Powertrain 2015 Project
Team development

16.11.2004 Symposium zum Stand der Forschung
24.11.2004 Präsentation Profile und Konzepte
12.01.2005 Präsentation Konzeptausarbeitung
25.02.2005 Abschluss - präsentation

Teampotential
Erfolg
Normierung
Aufbruch
Frustration
Integrated Product Development Project Example

Task Project „GreenKeeper“ IP 03/04

Development of an innovative product for the company STIHL, which extends the product portfolio in the target market „Lawn & Garden“ in a promising way.
Integrated Product Development
Project Example

Konkreter Projektverlauf

<table>
<thead>
<tr>
<th>Task</th>
<th>TTM-Project</th>
<th>Market Launch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kick-Off</td>
<td>Carrier Support SystemHT</td>
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<tr>
<td>Profiel</td>
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<td></td>
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<tr>
<td>Concept</td>
<td></td>
<td>Series development at STIHL</td>
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<tr>
<td>Embodiment</td>
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</tbody>
</table>
Integrated Product Engineering Model (iPeM)
Example for Process Model in IP (Master, Main Course)
What is the fundamental challenge in developing processes?

- There are two fundamental different views on product development processes!

  → 2 fundamental approaches of PDP modeling
Management orientated approaches

1. Generation ‘Supplier to Costumer’

Stage-Gate-Approach of 2. Generation

Stage-Gate-Approach of 3. Generation

No instructions for the developer
# Integrated Product Engineering Model (iPeM)

## System of Objectives

<table>
<thead>
<tr>
<th>Activities of Product Engineering</th>
<th>Activities of Problem Solving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Planning</td>
<td>S</td>
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<tr>
<td>Profile Detection</td>
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<tr>
<td>Idea Detection</td>
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<tr>
<td>Modeling of Principle Solution &amp; Embodiment</td>
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<tr>
<td>Validation</td>
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<tr>
<td>Production System Eng.</td>
<td></td>
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<tr>
<td>Production</td>
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<tr>
<td>Market Launch</td>
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<tr>
<td>Analysis of Utilization</td>
<td></td>
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<tr>
<td>Analysis of Decommission</td>
<td></td>
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</table>

## System of Resources

### Phase Model

![Phase Model Diagram](image)

- **System of Objects**
  - Operating System
    - Activities of Problem Solving
      - System of Objectives
        - Project Planning
        - Profile Detection
        - Idea Detection
        - Modeling of Principle Solution & Embodiment
        - Validation
        - Production System Eng.
        - Production
        - Market Launch
        - Analysis of Utilization
        - Analysis of Decommission

- **Phase Model**
  - Activities timeline
  - Time:
    - Today

Innovation
Innovation am Beispiel des Automobils

c. 1900

heute

www.porsche.de
Example grape wine/fruit tree sprayer
Analogies: grape wine/fruit tree sprayer
Analogy objects

→ collecting and recycling
Fruit tree sprayer
Tunnel spray procedure

barrel → pump → espalier fruit → air; earth → recycling flow → spray cycle
Analogies: grape wine sprayer
Analogies: grape wine sprayer
using the example of an industrial truck

ABSTRACTION AND "FALSE ASSIGNMENT"
Success by use of methods

- industrial truck

- original assignment: “Constructive adaptation of a differential gear for ground transportation to higher load“
Success by use of methods

Variation of mechanical compensation gearbox:

- single-stage worm gear with differential
- worm gear with spur wheel section behind the differential
- worm gear with planetary gears behind the differential
- transmission sections in front of and behind the differential
Success by use of methods

→ Task after clarifying and abstraction:

“Construction of a drive unit for a mechanical track guided ground transportation system“
Concept ground transportation system

- pole
- pivotal point
- drive wheel
- center pivot plate
- guiding spike
- rear track rollers
- guide- and conductor line
- pole

IPEK

Institut für Produktenwicklung
am KIT e. Prof. Dr. Ing. Dr. in. h.c. A. Albare
Prototype ground transportation system
Success by use of methods

concept validation

product
ground transportation system
IPEK Teaching Activities

- KIT lectures (Academic Education)
- Carl Benz School (International Department)
- Hector School (Executive Master Program)
- Advanced Training for Experts
  (For Example Light Weight Design, e-mobil BW GmbH)
Innovation – walking on your own roads

„Never you can pass by somebody if you are stepping in his footprints“