Naturwissenschaftlich Technische Fakultät

UNIVERSITÄT SIEGEN

Competence Research:

Teaching Embedded Micro/Nano Systems

1. Background
2. Competence Model
3. Current Work
4. Summary

steffen.jaschke@uni-siegen.de
andre.schaefer@uni-siegen.de

Motivation

- Several years ago, the New York Times estimated that the average American came into contact with 100 microprocessors daily [Wolf et Madsen, 2000]

- "Computer-based embedded systems have been designed for more than 30 years and the need for adequate education in embedded systems is deemed more important now than ever." [Grimheden et Törngren, 2005]

- "Embedded systems are under-represented in teaching and in public discussion" [Marwedel, 2011]

steffen.jaschke@uni-siegen.de
andre.schaefer@uni-siegen.de

Talks

- Practical Embedded Systems Engineering Syllabus for Graduate Students with Multidisciplinary Backgrounds
- Embedded System Design 2.0: Rationale Behind a Textbook Revision
- Innovative System and Application Curriculum on Multicore Systems
- Teaching Embedded Software Concepts Using Android
- Teaching Cross-Platform Design and Testing Methods for Embedded Systems using DICE
- Bringing Soccer to the Field of Real-Time Embedded Systems Education

Challenges

- Which competencies do the students need
- How to develop these competencies
- How to structure teaching/learning processes

steffen.jaschke@uni-siegen.de
andre.schaefer@uni-siegen.de

DFG-Project: Competence development with embedded micro- and nanosystems (KOMINA)

UNIVERSITÄT SIEGEN

Faculty IV: Natural and Engineering Sciences

Department of Electrical Engineering and Computer Science
Didactics of Informatics and E-Learning (Prof. Dr. Sigrid Schubert) [Steffen Jaschke]
Institute of Microsystems Technology (Prof. Dr. Rainer Brück) [André Schäfer]

FAU FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG

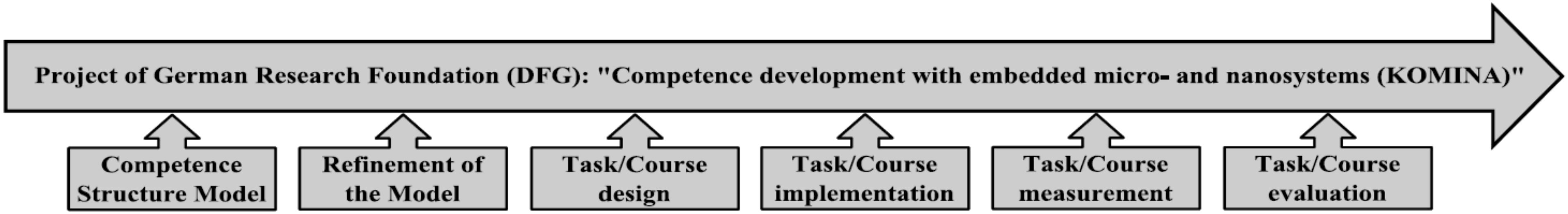
Faculty of Engineering

Department of Computer Science
Computer Architecture (Prof. Dr. Dietmar Fey)

steffen.jaschke@uni-siegen.de
andre.schaefer@uni-siegen.de

Project KOMINA

- Computer engineering education
- Theoretically founded courses/tasks
- Embedded systems engineering
  - Focus on micro- and nanosystems (EMNS)



steffen.jaschke@uni-siegen.de
andre.schaefer@uni-siegen.de

Paradigm shift

- Miniaturization leads to nano-structured components

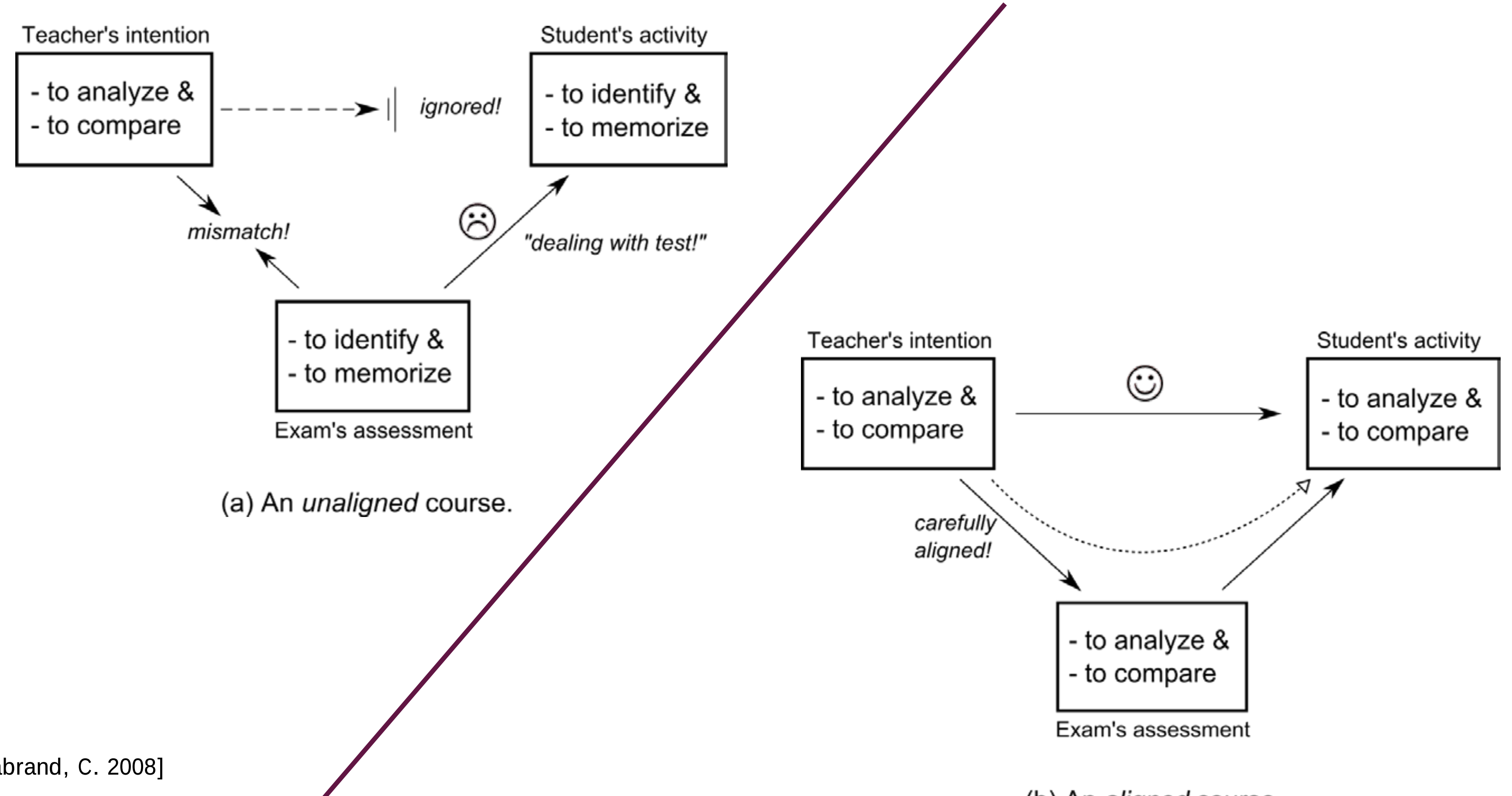
- New manufacturing processes in a Bottom-Up approach
  - on molecular level (self-assembly, …)
  - but NOT the field of computer engineers activity

- Consideration of physical constraints on even high levels of abstraction
  - DFG SPP 1500

- Nanotechnology and its effects are not yet part of teaching in Computer Engineering

steffen.jaschke@uni-siegen.de
andre.schaefer@uni-siegen.de

Outcome orientation / Constructive alignment



(a) An *unaligned* course.

(b) An *aligned* course.

[Brabrand, C. 2008]

steffen.jaschke@uni-siegen.de
andre.schaefer@uni-siegen.de

Competence research

- Competencies ≠ knowledge

Competencies

- skills and abilities
- solving problems in variable situations
- motivational, volitional and social willingness

steffen.jaschke@uni-siegen.de
andre.schaefer@uni-siegen.de

Taxonomy assignment

- which concrete abilities must the students have?
  - Field Programmable Gate Array (FPGA)
  - be able to <u>understand</u> a Field Programmable Gate Array (FPGA) based processor.
  - be able to <u>implement</u> a Field Programmable Gate Array (FPGA) based processor.
  - be able to <u>evaluate</u> a Field Programmable Gate Array (FPGA) based processor.
- define the teachers/systems intention with concrete verbs
  - to state clearly the examination requirements in order to motivate students learning
- Taxonomy of Anderson & Krathwohl (Bloom)

steffen.jaschke@uni-siegen.de
andre.schaefer@uni-siegen.de

Level	Alternative names
1. Remember	recognizing, recalling
2. Understand	interpreting, exemplifying, classifying, summarizing, inferring, comparing, explaining
3. Apply	executing, implementing
4. Analyze	differentiating, organizing, attributing
5. Evaluate	checking, critiquing
6. Create	generating, planning, producing

[Anderson/Krathwohl, 2009]

steffen.jaschke@uni-siegen.de
andre.schaefer@uni-siegen.de

Normative proceeding

- Module descriptions
  - Embedded Systems
  - Computer engineering
- Curricula recommendations
  - ACM/IEEE Computer Science Curriculum
  - German Informatics Society
- Collection of competencies
- Cluster
  - Thematic division
  - Solution approaches

steffen.jaschke@uni-siegen.de
andre.schaefer@uni-siegen.de

Cluster of competence dimensions

- C1: Competencies as preconditions
- C2: Development competencies
- C3: Competencies for multi-level development
- C4: Non-cognitive competencies

steffen.jaschke@uni-siegen.de
andre.schaefer@uni-siegen.de

Naturwissenschaftlich Technische Fakultät

UNIVERSITÄT SIEGEN

C1	**Competencies as preconditions**
C1.1	Mathematics
C1.2	Physics
C1.3	Computer Science
C1.4	Electrical Engineering
C1.5	Material Science
C1.6	English
C1.7	Scientific work
C1.8	Learning organization

steffen.jaschke@uni-siegen.de
andre.schaefer@uni-siegen.de

Naturwissenschaftlich Technische Fakultät

UNIVERSITÄT SIEGEN

C2	**Development competencies**
C2.1	Organization of the development process
C2.2	Requirement analysis
C2.3	System design
C2.4	Implementation
C2.5	Optimization and Test

Examples of C2.2 Requirement analysis:

- *are able to explain the relevance of the terms fault tolerance, reliability, and availability. (ACM/IEEE)*
- *are able to outline the range of methods for implementing fault tolerance in an operating system. (ACM/IEEE)*

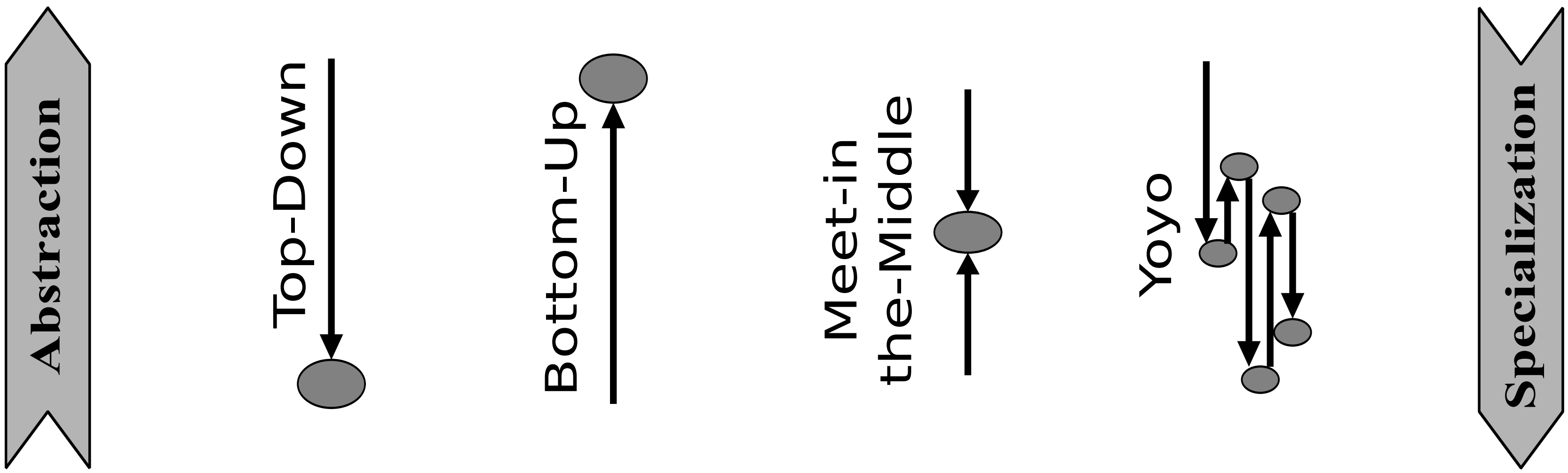
steffen.jaschke@uni-siegen.de
andre.schaefer@uni-siegen.de

C 2.3: System design:

- remember formal- and computer-aided design methods for the design of embedded systems
- understand most important technologies and concepts for designing and analyzing computer-aided systems
- understand structure and function of all important basic circuits and arithmetic logic units
- understand computer systems as stratified abstract machines
- understand, analyze unknown circuits, create own circuits

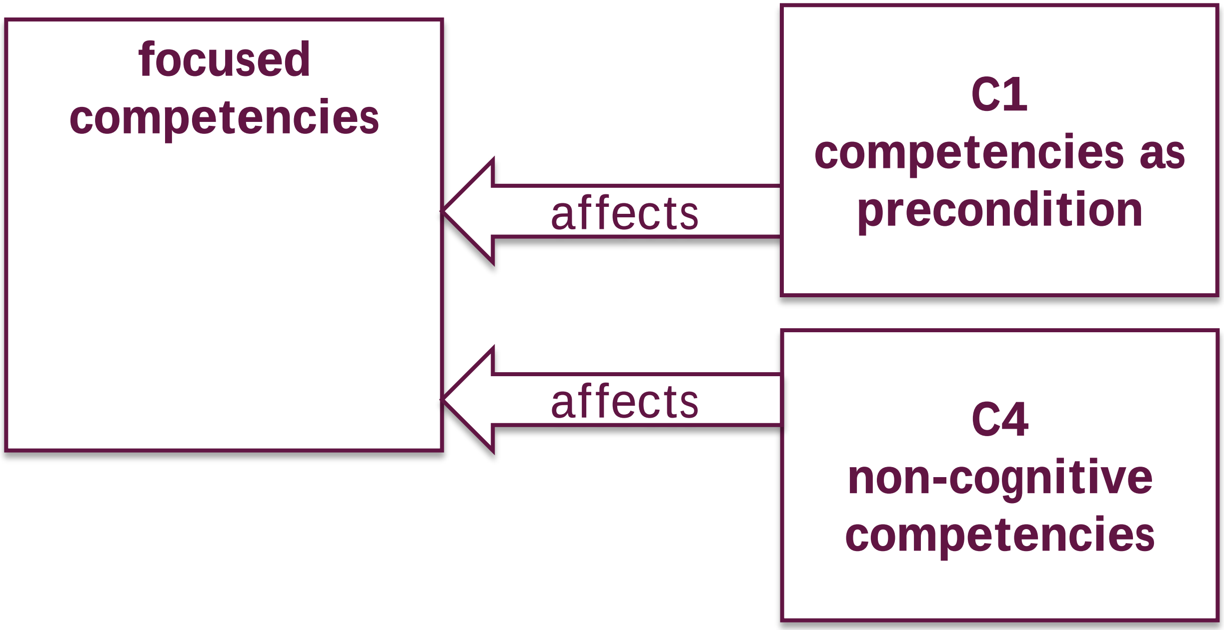
steffen.jaschke@uni-siegen.de
andre.schaefer@uni-siegen.de

C3	**Competencies for multi-level development**
C3.1	Top-Down-Design
C3.2	Bottom-Up-Design
C3.3	Meet-in-the-Middle-Design
C3.4	Yoyo-Design



steffen.jaschke@uni-siegen.de
andre.schaefer@uni-siegen.de

C4	**Non-cognitive competencies**
C4.1	Attitudes
C4.2	Social-communicative competencies
C4.3	Motivational and volitional skills



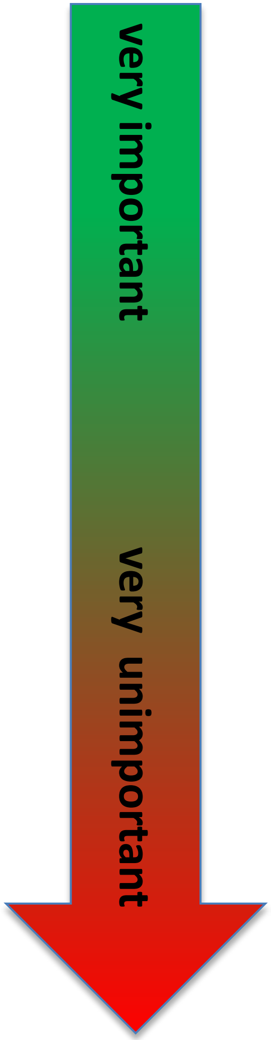
steffen.jaschke@uni-siegen.de
andre.schaefer@uni-siegen.de

First results

- Empirical refinement of the competence structure model

- The experts rate the importance of the given competencies of the NCSM:
  - Very important
  - Rather important
  - Rather unimportant
  - Very unimportant

- Survey of 96 experts
- 36 results



steffen.jaschke@uni-siegen.de
andre.schaefer@uni-siegen.de

Naturwissenschaftlich Technische Fakultät

UNIVERSITÄT SIEGEN

First results

C 4.3 Motivational and volitional skills (1.1-1.4)

C 2.1 Organization of the development process (1.4)

C 3.2 Bottom-Up-Design (1.4)

...

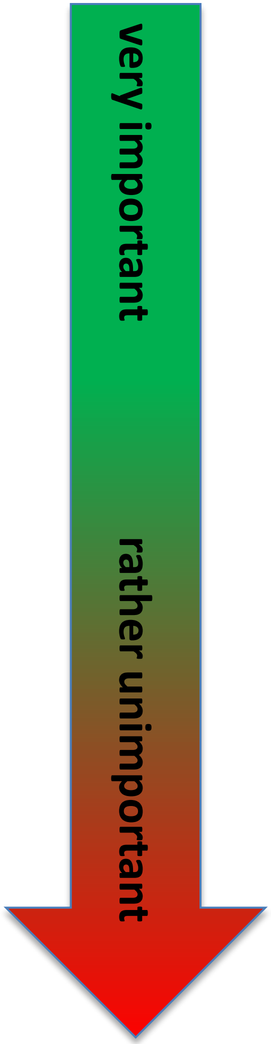
...

...

...

C 3.2 Bottom-Up-Design (2.7)

C 1.5 Material Science (3.1)



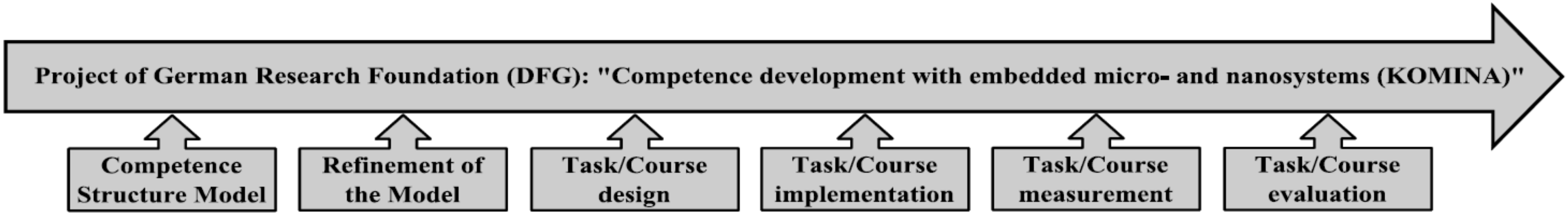
steffen.jaschke@uni-siegen.de
andre.schaefer@uni-siegen.de

Alignment of the hardware-practical course

- Current status
  - 16-Bit microprocessor on FPGA

Objectives

- Provide a wider range of competencies (C1-3)
  - Focus on the most important competencies
- Project-group based work (C4)
- Life-world related tasks like Android programming (C4)



Naturwissenschaftlich Technische Fakultät

UNIVERSITÄT SIEGEN

FPGA-Online

- Reduce cost
- Independent of time and place
- Competence development

steffen.jaschke@uni-siegen.de
andre.schaefer@uni-siegen.de

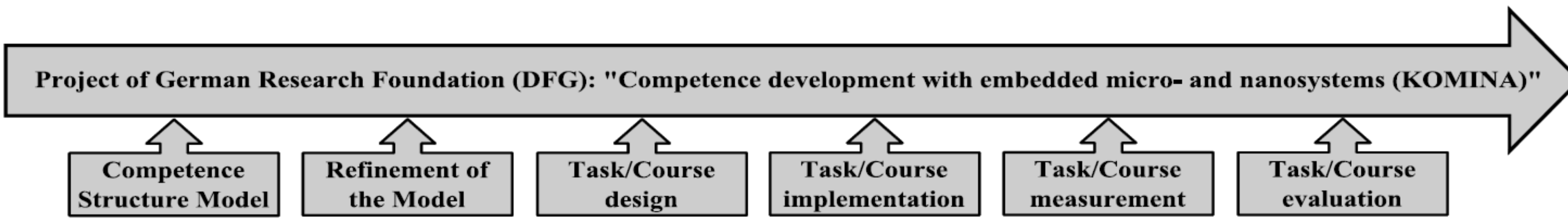
Competence structure model

- Normative developed
  - C1-C4
- Empirical refinement in progress (Dec. 2011)
  - The most defined sub competencies are important

Course design

- Analyze of existing courses
- Alignment of concepts to the competence structure model

Further work



steffen.jaschke@uni-siegen.de
andre.schaefer@uni-siegen.de

Naturwissenschaftlich Technische Fakultät

UNIVERSITÄT SIEGEN

Thank you for your attention!

Wolf, W. and Madsen, J. 2000. Embedded systems education for the Future. *Proc. IEEE* 88, 1, 23–30.

Grimheden, M. and Törngren, M. 2005. What Is Embedded Systems and How Should It Be Taught?—Results from a Didactic Analysis. *Trans. on Embedded Computing Sys* 4, 3, 633–651.

Marwedel, P. 2011. *Embedded System Design. Embedded Systems Foundations of Cyber-Physical Systems*. Embedded Systems. Springer Science+Business Media B.V, Dordrecht.

ACM/IEEECS, Ed. 2008. *Computer Science Curriculum 2008. An Interim Revision of CS 2001*.

GI, Ed. 2011. *Curriculum Technische Informatik in Bachelor- und Masterstudiengängen Informatik. Empfehlung der Gesellschaft für Informatik e. V.* Gesellschaft für Informatik e. V., Bonn

Anderson, L. W., Krathwohl, D. R., Airasian, P. W., Cruikshank, K. A., Mayer, R. E., Pintrich, P. R., Raths, J., and Wittrock , M. C. 2009. *A taxonomy for learning, teaching, and assessing. A revision of Bloom's taxonomy of educational objectives.* Longman, New York.

Brabrand, C. 2008. Constructive Alignment for Teaching Model-Based Design for Concurrency. In Transactions on Petri Nets and Other Models of Concurrency, 1-18.

Wagener, A. 2005. *Fertigungsnahe Entwurfsunterstützung für die Mikrosystemtechnik*. *Dissertation*, Siegen.

Schubert, S. and Stechert, P. DL 2010. Competence model research on informatics system application. In *IFIP working conference, new developments in ICT and education*, K.-W. Lai, D. Benzie, IFIP working conference and C. Reffay, Eds. UMR STEF pour IFIP, Cachan, 1–14.

steffen.jaschke@uni-siegen.de
andre.schaefer@uni-siegen.de