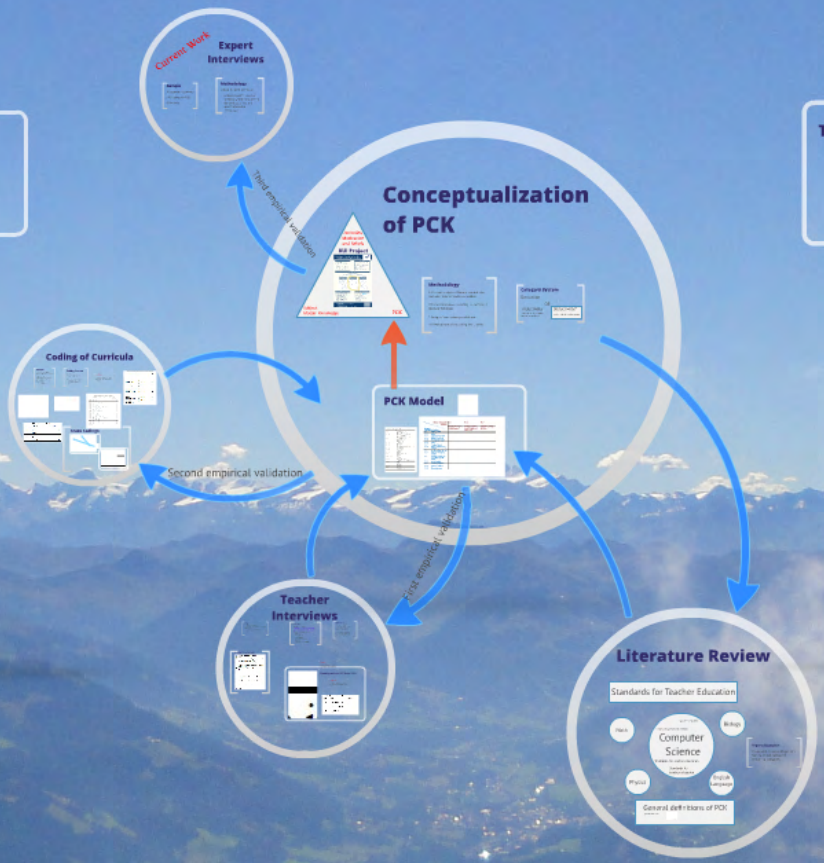
Peter Hubwieser, Marc Berges, Johannes Magenheim, Nicolas Schaper,
Ronnie Brinda, Melanie Margaritis, Sigrid Schubert, Louis Ohrndorf

Pedagogical Content Knowledge for Computer Science in German Teacher Education Curricula

WiPSCE 2013, Aarhus, DK, 13.11.13



Thank you very much for your attention!

Any questions?

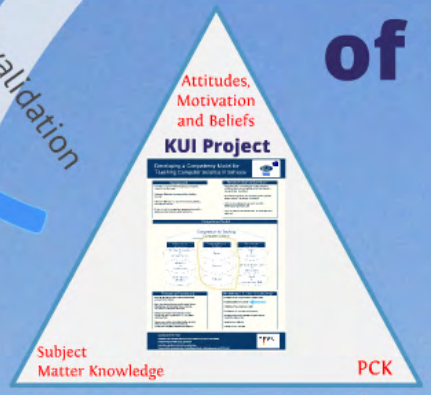
Peter Hubwieser, Marc Berges, Johannes Magenheim, Niclas Schaper,
Kathrin Bröker, Melanie Margaritis, Sigrid Schubert, Laura Ohrndorf

Pedagogical Content Knowledge for Computer Science in German Teacher Education Curricula

WiPSCE 2013, Aarhus, DK, 13. 11.13

Conceptualization of PCK

Third empirical validation



Methodology

1. Content analysis of German curricula for computer science teacher education
2. Expert interviews according to the Critical Incident Technique
3. Design of competency models and
4. Development of measuring instruments

Category System

Derivation

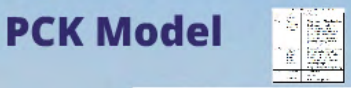
inductively

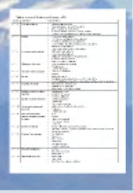
OR

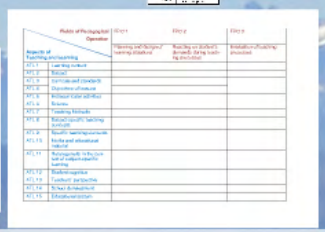
deductively?

CS has to be derived in advance

PCK Model







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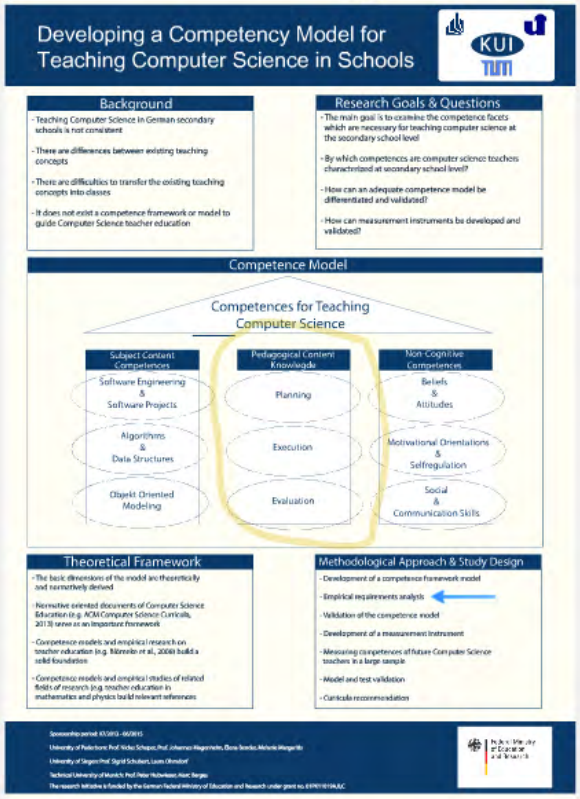
Attitudes,
Motivation
and Beliefs

KUI Project



Subject
Matter Knowledge

PCK

Developing a Competency Model for Teaching Computer Science in Schools

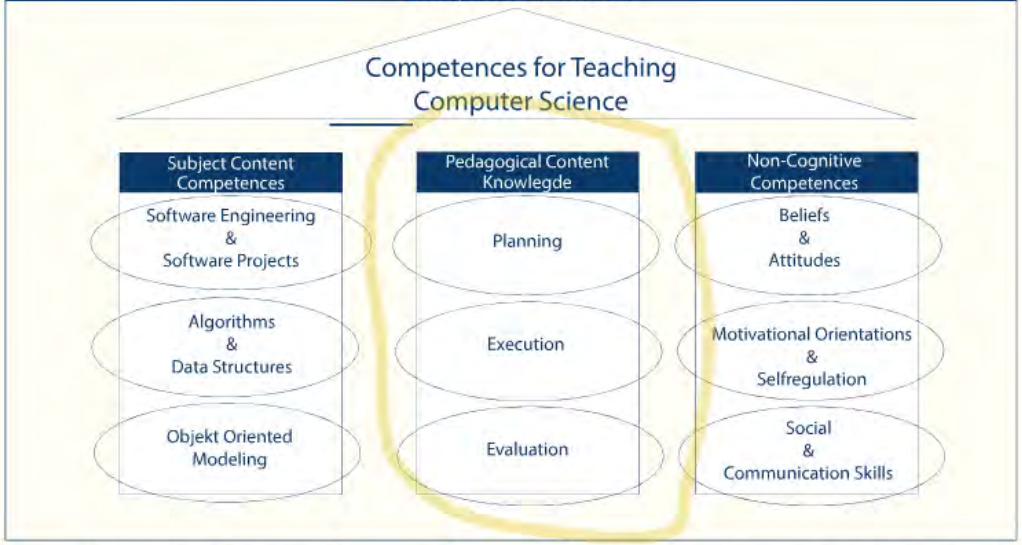
Background

- Teaching Computer Science in German secondary schools is not consistent
- There are differences between existing teaching concepts
- There are difficulties to transfer the existing teaching concepts into classes
- It does not exist a competence framework or model to guide Computer Science teacher education

Research Goals & Questions

- The main goal is to examine the competence facets which are necessary for teaching computer science at the secondary school level
- By which competences are computer science teachers characterized at secondary school level?
- How can an adequate competence model be differentiated and validated?
- How can measurement instruments be developed and validated?

Competence Model



Theoretical Framework

- The basic dimensions of the model are theoretically and normatively derived
- Normative oriented documents of Computer Science Education (e.g. ACM Computer Science Curricula, 2013) serve as an important framework
- Competence models and empirical research on teacher education (e.g. Blömeke et al., 2008) build a solid foundation
- Competence models and empirical studies of related fields of research (e.g. teacher education in mathematics and physics build relevant references

Methodological Approach & Study Design

- Development of a competence framework model
- Empirical requirements analysis
- Validation of the competence model
- Development of a measurement instrument
- Measuring competences of future Computer Science teachers in a large sample
- Model and test validation
- Curricula recommendation

Sponsorship period: 07/2012 - 06/2015

University of Paderborn: Prof. Niclas Schaper, Prof. Johannes Magenheim, Elena Bender, Melanie Margaritis
University of Siegen: Prof. Sigrid Schubert, Laura Ohmdorf
Technical University of Munich: Prof. Peter Hubwieser, Marc Berges

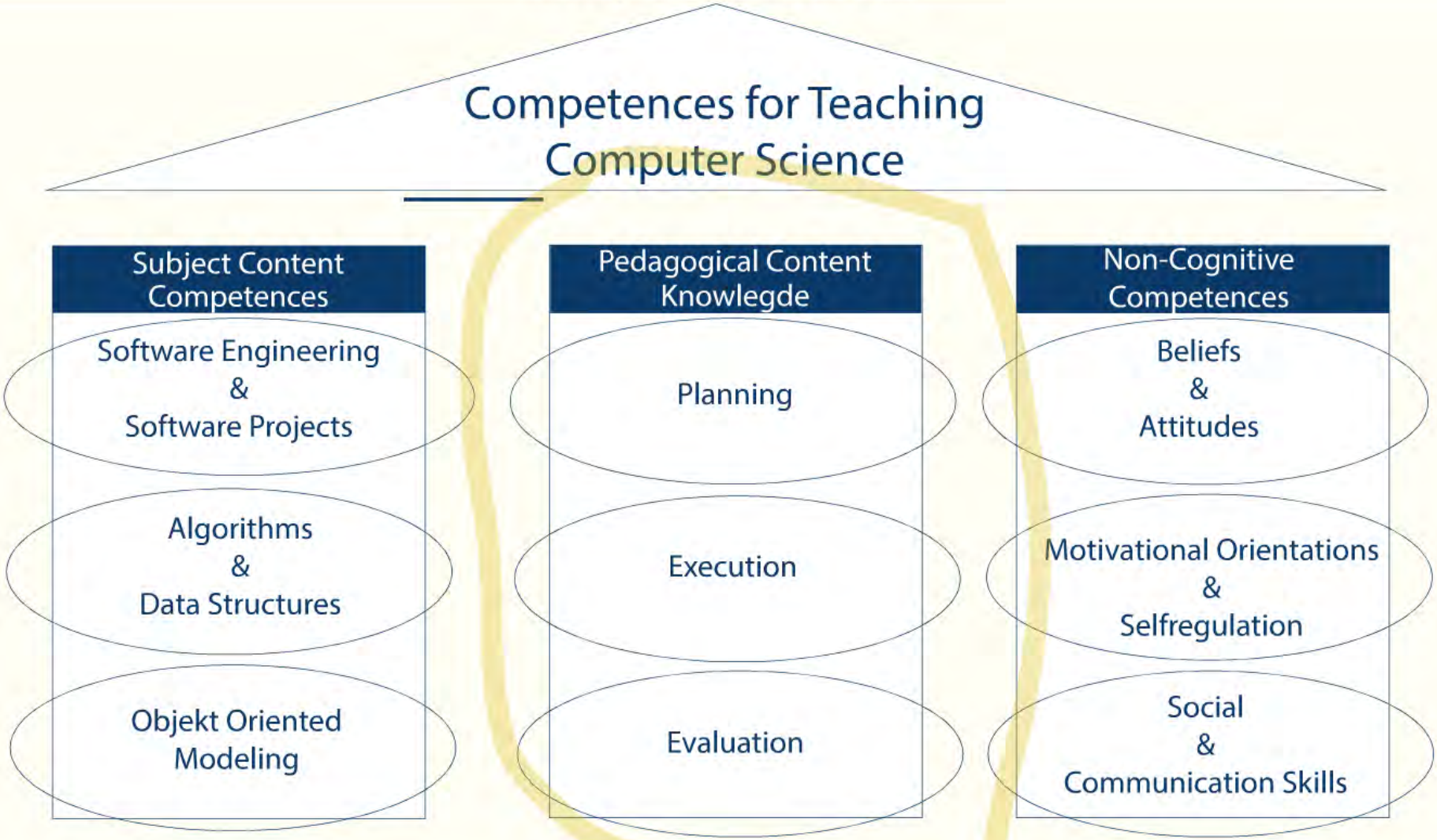
The research initiative is funded by the German Federal Ministry of Education and Research under grant no. 01PK11019A,B,C

Federal Ministry of Education and Research

guide Computer Science teacher education

validated?

Competence Model



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1. Content analysis of German curricula for computer science teacher education

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3. Design of competency models and

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Category System

Derivation

inductively

The different CS of coders have to be combined

OR

deductively?

CS has to be derived in advance

Literature Review

Standards for Teacher Education

Math

Specific models

Conceptualizations of PCK

Computer Science

Textbooks for teacher education

Standards for teacher education

Biology

Physics

English Language

Expert discussion

2 days with Johannes Magenheim
Sorting, consolidating and explaining categories

General definitions of PCK

[Shulman 1986, 1987]

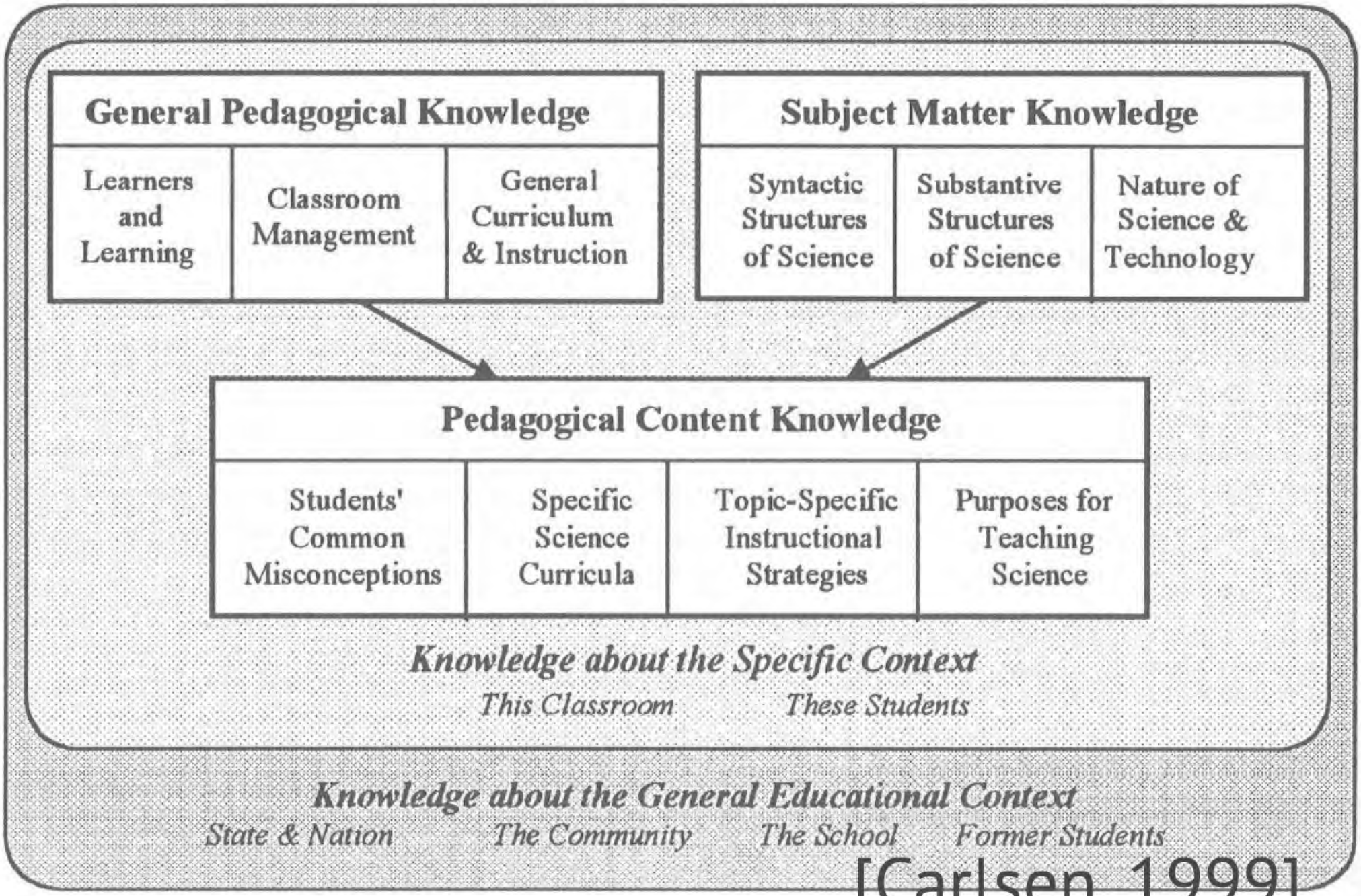
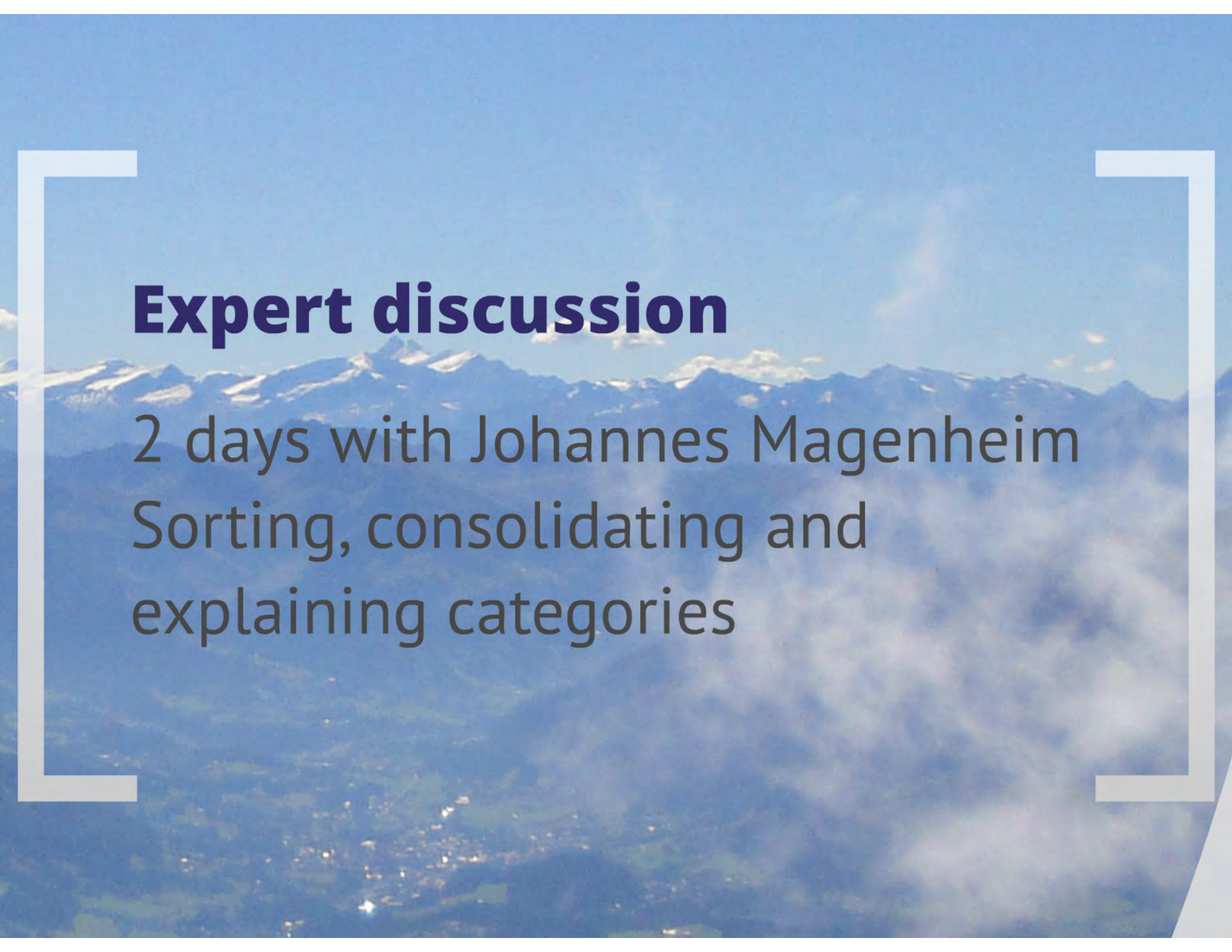


Figure 1: Carlsen's domains of teacher knowledge [6]



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PCK Model

Table 2. Fields of Pedagogical Operation (FPO)

Cat. No.	*Field description*	*Subcategories*
FPO 1	Planning and design of learning situations	- Time planning (Time allocation); - Explanation of the planning: subject-specific consistency, reasonability of the approach, psychological argumentation - Granularity: long term lesson planning, planning the entire curriculum, planning a lesson
FPO 2	Reacting on student's demands during teaching processes	- Reacting based on understanding, flexible use of connected knowledge in critical situations, responding to students appropriately, responding flexibly - Mastering complexity - Keeping compliant with planning
FPO 3	Evaluation of teaching processes	- Techniques, - Criteria - Derive consequences

Table 3. Aspects of Teaching and Learning (ATL)

Cat. No.	*Category*	*Subcategories*
ATL 1	**Learning content**	- Multiple representations - Category systems for learning content - Specific school-related content - Selection and justification of learning content - Didactical (re-) construction of subject-matter knowledge
ATL 2	**Subject**	- Relations to other subjects - Definition of computer science education - History of computer science education - Relationship of the subject to the scientific discipline - Objectives of the subject - Legitimacy and relevance of the subject
ATL 3	**Curricula and standards**	- Curriculum development - Relation to other subjects - Approach and structure of the curriculum - Selection and commitment - Actual examples of curricula
ATL 4	**Objectives of lessons**	- Focus on education standards - Competencies - Learning objectives
ATL 5	**Extracurricular activities**	- External collaboration - Contests
ATL 6	**Science**	- Subject discipline - Computer science education as a scientific discipline - Relationship between teaching of the subject and the scientific discipline
ATL 7	**Teaching Methods**	- Organizational arrangements - Methodological principles - Subject-specific teaching methods
ATL 8	**Subject-specific teaching concepts**	- Introductory lessons - Programming classes - Historical approach
ATL 9	**Specific teaching elements**	- Lab-based teaching - Experiments - Tasks and assignments
ATL 10	**Media and educational material**	- Application of hardware and software - Textbooks - Unplugged media
ATL 11	**Heterogeneity in the context of subject-specific learning**	- Age - Gender - Ethnical background - Family socialization - Disabilities
ATL 12	**Student cognition**	- General subject-related cognitive aspects - Individual learning Diagnostics, performance evaluation and assessment - Cognitive activation
ATL 13	**Teachers' perspective**	- Collaboration - Core tasks - Qualification - Motivation - In-service training - Teaching experience
ATL 14	**School development**	- Policies - Quality management - School profile
ATL 15	**Educational system**	- School type - Enrollment - Organizational aspects of subject

Fields of Pedagogical Operation / **Aspects of Teaching and Learning**		FPO 1	FPO 2	FPO 3
		Planning and design of learning situations	Reacting on student's demands during teaching processes	Evaluation of teaching processes
ATL 1	Learning content			
ATL 2	Subject			
ATL 3	Curricula and standards			
ATL 4	Objectives of lessons			
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ATL 6	Science			
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Aspects of Teaching a

ATL 1	
ATL 2	
ATL 3	
ATL 4	
ATL 5	
ATL 6	
ATL 7	
ATL 8	
ATL 9	
ATL 10	
ATL 11	
ATL 12	
ATL 13	
ATL 14	
ATL 15	

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First e

Teacher Interviews

Sample

11 guide-line based interviews
collected during a large in-service teacher training course in July 2010

drawing from 150 attending teachers

Methodology

Introductory open question:
"If you consider the preparation of CS lessons, how would you normally proceed, which problems would you face and how would you solve these problems?"

Stimulation of the following categories:
- preconditions
- learning objectives
- learning content
- teaching methods
- media, sources of information
- assignments
- collaboration with other teachers.

Data gathering

recording on mobile phones

11 interviews from 20 to 35 minutes

4 female and 7 male teachers

transcribed by student workers

coded inductively by two authors

applying qualitative content analysis

combining the 2 category systems in discussion

Resulting Category System 2010

1) Conditions: preconditions, frame conditions
2) Goals
3) Approach: example driven, time planning, programming, writing outline, writing script, planning homework, identifying difficulties, by own mistakes
4) Sources: textbook, curriculum, additional material, internet, teacher training, books/journals from subject-matter, colleagues, existing knowledge, material from own studies, pre-planned lessons
5) Collaboration: in school, with other departments, between schools
6) Time planning
7) Methods and organizational arrangements: individual learning, student activity, presentation, classroom teaching, teacher-class dialog, worksheet, entry in exercise book, project work, file, repetition, group work, differentiation, talk by students
8) Media: beamer, blackboard, moodle, computer, software, overhead projection, textbook, whiteboard, illustrations
9) Problems: technical difficulties, too much content, room, assuring learning, standards, pre-requisite knowledge, official support, class size
10) Assessment: written, oral, project, not graded
11) Evaluation

Overall Result

Matching the categories showed that all categories of 2010 were covered by the model

Matching with our PCK Model 2013

Table 4. Exemplary codings for the top level categories

Cat. No.	Category	Quotes from the interviews
ATL 1	Learning content	[illegible]
ATL 3	Curricula and standards	[illegible]
ATL 8	Subject-specific teaching concepts	[illegible]
ATL 10	Media and educational material	[illegible]
[illegible]	Heterogeneity in the professional context	[illegible]
[illegible]	Teacher's perspective	[illegible]
ATL 15	Educational system	[illegible]

Overall Result

Matching the categories showed that all categories of 2010 were covered by the model

Table 5. Addressed categories that were not stimulated

Cat. No.	Category	Coded Interviews
ATL 12	Student cognition	11
ATL 9	Specific teaching elements	10
ATL 3	Curricula and standards	9
ATL 8	Subject-specific teaching concepts	5
ATL 15	Educational system	[illegible]
ATL 2	Subject	1

Sample

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drawing from 150 attending teachers

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Stimulation of the following categories:

- preconditions
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- learning content
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- media, sources of information
- assignments
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1) **Conditions**: preconditions, frame conditions
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5) **Collaboration**: in school, with other departments, between schools
6) **Time planning**
7) **Methods and organizational arrangements**: individual learning, student activity, presentation, classroom teaching, teacher-class dialog, worksheet, entry in exercise book, project work, file, repetition, group work, differentiation, talk by students
8) **Media**: beamer, blackboard, moodle, computer, software, overhead projection, textbook, whiteboard, illustrations
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11) **Evaluation**.

Overall Result

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Cat. No.	*Category*	*Quotes from the interviews*
ATL 1	Learning content	I look for an important goal as a headline for the lesson and afterwards for a few keywords that have to be covered, that I have to discuss
ATL 3	Curricula and standards	Then I look at the sub-topics of the curriculum, how far that fits. If it fits, I put away the curriculum because I don't need it any more.
ATL 8	Subject-specific teaching concepts	I program that for myself, and then I prepare the teaching from it.
ATL 10	Media and educational material	Finally I then look in the textbook, which things, which tasks might fit here, I look at the introduction of the book, do I like it or don't I.
ATL 11	Heterogeneity in the professional context	I must take into account the preconditions that the students have. Because of course someone who has less prerequisite knowledge and has not yet understood certain things is not able to do the job in the same way than anybody else.
ATL 13	Teacher's perspective	I cooperate with a colleague, thank goodness, which is probably rather rare because there are hardly any schools that have two people who master this subject.
ATL 15	Educational system	So I have two subsequent hours for each lesson in all cases.

Matching with our PCK Model 2013

Overall Result

Matching the categories showed that all categories of 2010 were covered by the model

Table 5. Addressed categories that were not stimulated

Cat. No.	*Category*	*Coded interviews*
ATL 12	Student cognition	11
ATL 9	Specific teaching elements	10
ATL 3	Curricula and standards	9
ATL 8	Subject-specific teaching concepts	5
ATL 15	Educational system	4
ATL 2	Subject	1

Overall Result

Matching the categories showed that all categories of 2010 were covered by the model

Coding of Curricula

Sample

45 teacher education curricula
from the websites of German universities

Module descriptions
courses of subject-matter didactics

5 did not comprise such course
38 were analysed

deductive content analysis

Coding Process

4 coding persons
most curricula were coded by 1 person
12 curricula (~10%) by 2 persons
calculating intercoder-reliability was critical

Overall Result

Matching the categories showed that all found categories were covered by our PCK model.

Table 4. Curricula with more than 12 coded categories

GY = Gymnasium (Grammar School, Academic High School), RS = Realschule (Middle School), WRS = Werkrealschule/Hauptschule (Commercial Middle School), HS = Hauptschule (Main School), GS = Gesamtschule (Integrated School)

University	School Types	PCK Categories	PCK Coverage
Universität Siegen	GY, HS, RS	15	83%
Pädagogische Hochschule Weingarten	WRS, RS, HS	15	83%
Technische Universität Kaiserslautern	GY, RS	14	78%
Universität Paderborn	GY, GS	14	78%
Universität Saarbrücken	GY	14	78%
Pädagogische Hochschule Karlsruhe	WRS, RS, HS	14	78%
Pädagogische Hochschule Schwäbisch Gmünd	WRS, RS, HS	13	72%

Figure 1. Coded categories in the curricula

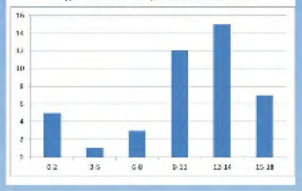


Table 5. Coding Frequency of FPO categories

Code	Category	Coding Frequency
FPO 1	Planning and design of learning situations	71%
FPO 3	Evaluation of teaching processes	50%
FPO 2	Reacting on students remarks during teaching processes	21%

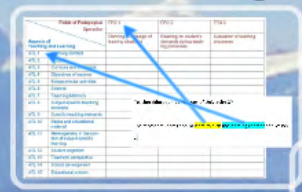
Table 6: Coding Frequency of ATL categories

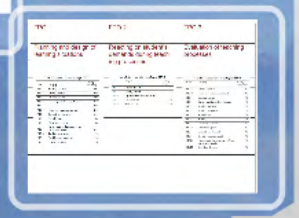
No.	Category	Coding Frequency
ATL 1	Learning content	89%
ATL 3	Curricula and standards	82%
ATL 6	Science	82%
ATL 2	School subject	76%
ATL 8	Subject-specific teaching concepts	66%
ATL 7	Teaching Methods	66%
ATL 4	Objectives of lessons	66%
ATL 10	Media and educational material	61%
ATL 12	Student cognition	61%
ATL 13	Teachers' perspective	55%
ATL 9	Specific teaching elements	39%
ATL 11	Heterogeneity in the content of subject-specific learning	37%
ATL 15	Educational system	34%
ATL 5	Extracurricular activities	34%
ATL 14	School development	32%

Table 7: Coding Frequency of Cognitive Processes

Code	Category	Coding Frequency
CPD 5	Apply	82%
CPD 5	Evaluate	79%
CPD 4	Analyze	74%
CPD 2	Understand	68%
CPD 6	Create	63%
CPD 1	Remember	50%

Cross Codings





Second

Sample

43 teacher education curricula
from the websites of German universities

Module descriptions
courses of subject-matter didactics

5 did not comprise such course
38 were analysed

deductive content analysis

Coding Process

4 coding persons

most curricula were coded by 1 person

12 curricula (>30%) by 2 persons

calculating intercoder-reliability was critical

- granularity was different (although agreed before)
- existing coefficients not applicable (Cohen's and Brennan & Prediger's Kappa, Krippendorff's Alpha)

Overall Result

Matching the categories showed that all found categories were covered by our PCK model

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Pädagogische Hochschule Schwäbisch Gmünd	WRS, RS, HS	13	72%

Figure 1. Coded categories in the curricula

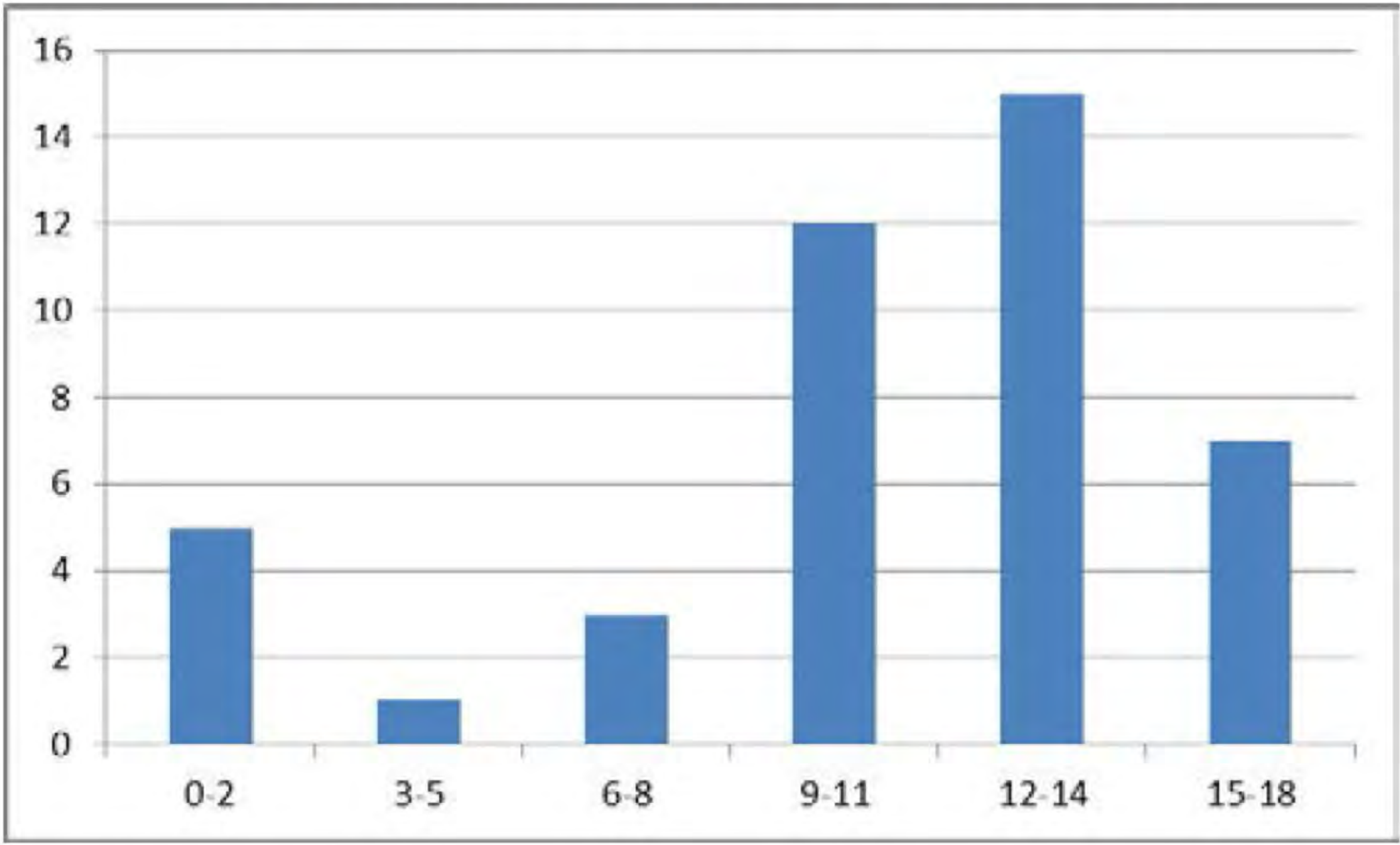

Table 5. Coding Frequency of FPO categories

Code	*Category*	*Coding Frequency*
FPO 1	Planning and design of learning situations	71%
FPO 3	Evaluation of teaching processes	50%
FPO 2	Reacting on students demands during teaching processes	21%

Table 6: Coding Frequency of ATL categories

No.	*Category*	*Coding Frequency*
ATL 1	Learning content	89%
ATL 3	Curricula and standards	82%
ATL 6	Science	82%
ATL 2	School subject	76%
ATL 8	Subject-specific teaching concepts	66%
ATL 7	Teaching Methods	66%
ATL 4	Objectives of lessons	66%
ATL 10	Media and educational material	61%
ATL 12	Student cognition	61%
ATL 13	Teachers' perspective	55%
ATL 9	Specific teaching elements	39%
ATL 11	Heterogeneity in the context of subject-specific learning	37%
ATL 15	Educational system	34%
ATL 5	Extracurricular activities	34%
ATL 14	School development	32%

Table 7: Coding Frequency of Cognitive Processes

Code	*Category*	*Coding Frequency*
CPD 3	Apply	82%
CPD 5	Evaluate	79%
CPD 4	Analyze	74%
CPD 2	Understand	68%
CPD 6	Create	63%
CPD 1	Remember	50%

ATL 14	School development	32%

Cross Codings

Aspects of Teaching and Learning \ Fields of Pedagogical Operation		FPO 1	FPO 2	FPO 3
		Planning and design of learning situations	Reacting on student's demands during teaching processes	Evaluation of teaching processes
ATL 1	Learning content			
ATL 2	Subject			
ATL 3	Curricula and standards			
ATL 4	Objectives of lessons			
ATL 5	Extracurricular activities			
ATL 6	Science			
ATL 7	Teaching Methods			
ATL 8	Subject-specific teaching concepts			
ATL 9	Specific teaching elements			
ATL 10	Media and educational material			
ATL 11	Heterogeneity in the context of subject-specific learning			
ATL 12	Student cognition			
ATL 13	Teachers' perspective			
ATL 14	School development			
ATL 15	Educational system			

Teacher Education Curriculum of University XY

...

The teacher students should learn to plan the learning content of a lesson

...

FPO 1	FPO 2	FPO 3
Planning and design of learning situations	Reacting on student's demands during teaching processes	Evaluation of teaching processes

Cross codings

Fields of Pedagogical Operation / Aspects of Teaching and Learning		FPO 1	FPO 2	FPO 3
		Planning and design of learning situations	Reacting on student's demands during teaching processes	Evaluation of teaching processes
ATL 1	Learning content			
ATL 2	Subject			
ATL 3	Curricula and standards			
ATL 4	Objectives of lessons			
ATL 5	Extracurricular activities			
ATL 6	Science			
ATL 7	Teaching Methods			
ATL 8	Subject-specific teaching concepts			
ATL 9	Specific teaching elements			
ATL 10	Media and educational material			
ATL 11	Heterogeneity in the context of subject-specific learning			
ATL 12	Student cognition			
ATL 13	Teachers' perspective			
ATL 14	School development			
ATL 15	Educational system			

Teacher Education Curriculum of University XY

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FPO 1

Planning and design of learning situations

Table 8. Frequency of cross-coding for FPO 1

Code	*Category*	*Coding Frequency*
ATL 7	Teaching Methods	50%
ATL 12	Student cognition	42%
ATL 1	Learning content	39%
ATL 8	Subject-specific teaching elements	34%
ATL 6	Science	32%
ATL 10	Media and educational material	29%
ATL 3	Curricula and standards	18%
ATL 2	School Subject	16%
ATL 4	Objectives of lessons	16%
ATL 11	Heterogeneity in the context of subject-specific learning	11%
ATL 13	Teachers' perspective	5%
ATL 9	Specific teaching elements	5%
ATL 15	Educational system	3%

FPO 2

Reacting on student's demands during teaching processes

Table 9. Frequency of cross-coding for FPO 2

Code	*Category*	*Coding Frequency*
ATL 12	Student cognition	8%
ATL 7	Teaching Methods	5%
ATL 8	Subject-specific teaching elements	3%
ATL 1	Learning content	3%
ATL 2	School Subject	3%

FPO 3

Evaluation of teaching processes

Table 10. Frequency of cross-coding for FPO 3

Code	*Category*	*Coding Frequency*
ATL 12	Student cognition	32%
ATL 10	Media and educational material	21%
ATL 1	Learning content	18%
ATL 8	Subject-specific teaching elements	16%
ATL 7	Teaching Methods	16%
ATL 13	Teachers' perspective	11%
ATL 2	School Subject	11%
ATL 6	Science	11%
ATL 4	Objectives of lessons	8%
ATL 15	Educational system	5%
ATL 3	Curricula and standards	5%
ATL 9	Specific teaching elements	5%
ATL11	Heterogeneity in the context of subject-specific learning	3%
ATL14	School development	3%

Table 8. Frequency of cross-coding for FPO 1

Code	*Category*	*Coding Frequency*
ATL 7	Teaching Methods	50%
ATL 12	Student cognition	42%
ATL 1	Learning content	39%
ATL 8	Subject-specific teaching elements	34%
ATL 6	Science	32%
ATL 10	Media and educational material	29%
ATL 3	Curricula and standards	18%
ATL 2	School Subject	16%
ATL 4	Objectives of lessons	16%
ATL 11	Heterogeneity in the context of subject-specific learning	11%
ATL 13	Teachers' perspective	5%
ATL 9	Specific teaching elements	5%
ATL 15	Educational system	3%

Table 9. Frequency of cross-coding for FPO 2

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ATL 2	School Subject	3%

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ATL 4	Objectives of lessons	8%
ATL 15	Educational system	5%
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ATL 9	Specific teaching elements	5%
ATL11	Heterogeneity in the context of subject-specific learning	3%
ATL14	School development	3%

PCK Model

Table 2. Fields of Pedagogical Operation (FPO)

Cat. No.	Field description	Subcategories
FPO 1	Planning and design of learning situations	- Time planning (Time allocation), - Explanation of the planning: subject specific consistency, reasonability of the approach, psychological argumentation - Granularity: long term lesson planning, planning the entire curriculum, planning a lesson
FPO 2	Reacting on student's demands during teaching processes	- Reacting based on understanding, flexible use of connected knowledge in critical situations, responding to students appropriately, responding flexibly - Mastering complexity - Keeping compliant with planning
FPO 3	Evaluation of teaching processes	- Techniques, - Criteria - [illegible] consequences

Table 3. Aspects of Teaching and Learning (ATL)

Cat. No.	Category	Subcategories
ATL 1	**Learning content**	- Multiple representations - Category systems for learning content - Specific school-related content - Selection and justification of learning content - Didactical (re-) construction of subject-matter knowledge
ATL 2	**Subject**	- Relations to other subjects - Definition of computer science education - History of computer science education - Relationship of the subject to the scientific discipline - Objectives of the subject - Legitimacy and relevance of the subject
ATL 3	**Curricula and standards**	- Curriculum development - Relation to other subjects - Approach and structure of the curriculum - Selection and commitment - Actual examples of curricula
ATL 4	**Objectives of lessons**	- Focus on education standards - Competencies - Learning objectives
ATL 5	**Extracurricular activities**	- External collaboration - Contests
ATL 6	**Science**	- Subject discipline - Computer science education as a scientific discipline - Relationship between teaching of the subject and the scientific discipline
ATL 7	**Teaching Methods**	- Organizational arrangements - Methodological principles - Subject-specific teaching methods
ATL 8	**Subject-specific teaching concepts**	- Introductory lessons - Programming classes - Historical approach
ATL 9	**Specific teaching elements**	- Lab-based teaching - Experiments - Tasks and assignments
ATL 10	**Media and educational material**	- Application of hardware and software - Textbooks - Unplugged media
ATL 11	**Heterogeneity in the context of subject-specific learning**	- Age - Gender - Ethnical background - Family socialization - Disabilities
ATL 12	**Student cognition**	- General subject-related cognitive aspects - Individual learning Diagnostics, performance evaluation and assessment - Cognitive activation
ATL 13	**Teachers' perspective**	- Collaboration - Core tasks - Qualification - Motivation - In-service training - Teaching experience
ATL 14	**School development**	- Policies - Quality management - School profile
ATL 15	**Educational system**	- School type - Enrollment - Organizational aspects of subject

Fields of Pedagogical Operation / **Aspects of Teaching and Learning**		FPO 1	FPO 2	FPO 3
		Planning and design of learning situations	Reacting on student's demands during teaching processes	Evaluation of teaching processes
ATL 1	Learning content			
ATL 2	Subject			
ATL 3	Curricula and standards			
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ATL 9	Specific teaching elements			
ATL 10	Media and educational material			
ATL 11	Heterogeneity in the context of subject-specific learning			
ATL 12	Student cognition			
ATL 13	Teachers' perspective			
ATL 14	School development			
ATL 15	Educational system			

Current Work

Expert Interviews

Sample

18 cognitive Scenarios

3 PCK Stages (FPOs)

40 Experts

Methodology

Critical Incident Technique

Critical incident: event or problem, which stimulates or demands activities and operations by the interviewee

Sample

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3 PCK Stages (FPOs)

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Critical incident: event or problem, which stimulates or demands activities and operations by the interviewee

Methodological Approach & Study Design

- Development of a competence framework model
- Empirical requirements analysis 
- Validation of the competence model
- Development of a measurement instrument
- Measuring competences of future Computer Science teachers in a large sample
- Model and test validation
- Curricula recommendation


Thank you very much for your attention!
Any questions?