„Measuring Professional Competencies of Future Teachers in Mathematics - an Integrative Empirical Approach”
Outline

Competencies oriented teaching …
- Competence orientation – development of a new paradigm
- A new generation of curricula / educational standards
- The meaning of the term „competence“

Competencies oriented teacher training…
- International state of research
- Outline of the project
- Research questions / innovations
- Competence structure model – teachers´ professional knowledge
- Domain-integrating item packages (SJT)
- Expected results & perspectives
Development of competencies orientation...

- Lack of systematic measuring of achievements concerning formal education processes in Germany up to the 1990s.
- Developing and testing didactic models where input-orientation was the focus of educational planning.
- 1997 marks a turning point with the so-called Konstanzer Beschlüsse of the Standing Conference (KMK): participation of Germany in international school achievement studies.
- Outcome-orientation and following reform measures.
- 2003 obligatory educational standards for core subjects (KMK).

turn: Results of the 3rd TIMS-Study
Aspect of educational policy

Large-scale international comparative studies of the last two decades

- **PIRLS**
- **TIMSS**
- **PISA**

- International comparative studies with representative samples testing students’ performance level
- Correlation of ‘students’ achievement, students’ learning premises, characteristics of school and classroom management founded on theory-based approaches
A new generation of curricula

Former curricula …
- … primarily followed the scientific classification of subject matters and
detailed guidelines defining teaching contents and their array

Which subject matters should be taught?

new curricula formats …
- … describe expected learning results and
place processes on an equal level with contents.

Which beliefs and skills should be developed?
What are „competencies“? A definition

"...a roughly specialised system of abilities, proficiencies, or skills that are necessary to reach a specific goal. This can be applied to individual dispositions or to the distribution of such dispositions within a social group or an institution"

Franz E. Weinert (2001)
Educational standards of mathematics ...

**General Mathematic Competencies**

- Problem solving
- Arguing
- Communicating
- Presenting mathematics
- Modelling
- Content mathematic competencies

**Guiding Ideas**

- L1: Figures and operations
- L2: Space and form
- L3: Sample and structures
- L4: Sizes and measuring
- L5: Data, frequency and probability

**Range of Requirements of General Mathematic Competencies**

1. Reproducing
2. Establishing correlations
3. Generalising and reflecting
Educational standards and core curricula ...

- ... support the planning of lessons by defining their results
  - by describing what students should be able to perform at a certain point
  - by avoiding prescriptions concerning the input.

- ... support the paradigm of „mathematics as an (individual) activity“
  - by emphasising process-oriented competencies and
  - by describing modes of application of mathematical contents („to use …, to apply…, to explain …“).
Competence orientation and lesson planning – the importance of mathematic processes

- **Modelling**
  → At the beginning there are questions concerning everyday life.

- **Problem solving**
  → Coping with (new) innermathematic situations

- **Arguing**
  → securing results, founding theoretical assumptions

- **Conceptualising**
  → Learning mathematics / the emergence of mathematics
Of how many squares and triangles does the packing consist of? Explain your solution process!

<table>
<thead>
<tr>
<th>guiding idea</th>
<th>space and form (L2)</th>
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<tbody>
<tr>
<td>competencies</td>
<td>Solving mathematic problems (K2) using graphs (K4) communicating (K6)</td>
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<tr>
<td>range of requirements</td>
<td>AB II</td>
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</tbody>
</table>
Competence orientation in school

Competence orientation in teacher training
International state of research

- Revealing studies of student achievement in the past 10 years
- Increase of student achievement depends mainly on the teacher

- Development of teachers’ professional knowledge
  Abell Foundation, 2001a, b; Darling-Hammond & Youngs, 2002; Wilson, Floden & Ferrini-Mundy, 2001; Akiba, LeTendre & Scribner, 2007; vgl. als Überblicke Baumert & Kunter, 2006; Blömeke, 2004

- A small range of studies in the field of mathematic didactics show a positive correlation between students’ level of performance and teacher performance
International state of research

Two studies in the German field of research:
- IEA-Study „TEDS-M“ (BLÖMEKE, KAISER & LEHMANN, 2010)

Turn in teacher education
(outcome-orientation curricula based on standards and competencies;
vgl. KMK, 2004; HILLIGUS & RINKENS, 2006; DMV, GDM, MNU: Standards für die Lehrerbildung im Fach Mathematik 2008)

New orientation of research of teacher education

Research desiderata in tests:
- Standardised measuring of professional competencies of (future) teachers
  (Schaper, 2009)

Aim of current efforts is the development of instruments to
- evaluate the efficacy of the (academic) teacher training with empirical methods
  (vgl. BLÖMEKE, 2004)
- introduce and evaluate systematic measures fostering output-orientation
  (z.B. DARLING-HAMMOND & BRANSFORD, 2005)
important results concerning primary schools

**mathematic and mathematic content knowledge in Germany:**

- the *mathematic achievement* of future primary school teachers is significantly above average – but with a massive distance to the top countries

- in *mathematic content knowledge* Germany belongs together with Russia, Thailand and Malaysia to the average group

- 1/3 of German mathematic teachers reach Level III whereas this level is reached by 2/3 of the teachers belonging to the top countries

- < 50% in Germany are able to interpret students’ problem solving approaches, to identify misconceptions, to use different approaches of illustrating contents to improve or to explain learning processes
Tests focussing on the efficacy of teacher education are still at the beginning

- The outcome of systematic measures and control systems focussing on effectiveness and efficiency is not clear due to the difficulties in measuring the quality of teaching performance, of research and institutional data.

- The influence of individual and organisational parameters on the acquisition of competencies has not been determined.

(Eilerts, 2009)
Impact Model
„Which variables can predict competence acquisition?“

Relevant aspects of predictors | predictor | level | criteria | operationalisation of the criteria
--- | --- | --- | --- | ---
Socio-demographic features | beliefs |
Subject matter |
Mathematic pre-knowledge |
Interest in Teacher education |
Interest in Mathematics |
Learning strategies & ressources |
Mathematical solving problems |
Work effort |
Hi. Ed. teaching competence | Personal conditions |
Pre-knowledge |
interests |
Learning- & Working strategies |
Judgement of the professor |
Lesson |
Student |
Gained competence |
Exam |
Self-assessment |
guided-Interview (professor)

$r = .52, p<.001$
Interdisciplinary cooperation of researchers:

Guest-Prof. Dr. Katja Eilerts (Mathematic-Didactic)

Prof. Dr. Bernd Wollring (Mathematic-Didactic)

Prof. Dr. Niclas Schaper (Pedagogical Psychology)
Dr. Andreas Seifert (Pedagogical Psychology)

Research aim:

Development of a model comprising competence structure and levels of competence acquisition and a test to measure professional knowledge and performance of primary school teachers in the field of „space and form“
Outline of the project

our focus: „primary school teachers“

Primary teachers generally

- Work worldwide as class teachers and are trained to perform this function
- teach all subjects
- Need to integrate their subjects in a main pedagogical concept
- Prepare and guarantee easy transfer of kindergarten children to primary school and from primary school pupils to secondary school
Outline of the project

Our focus: „space and form (Geometry)“


Research focus of the project: content „space and form“
(elementare Figuren, elementare Abbildungen, Kongruenz- und Ähnlichkeitsabbildungen)

1. **Educational Standards**
   „space and form“ as equally important contents

2. „Import“ of Geometry in the field of Arithmetic
   geometric illustrations are most common (Wollring, im Druck)

3. **No Systematisation of Standards**
   emphasis on the systematisation of strategic approaches

4. **Support concerning the imagination of space**
   the aim is to foster mental operations independant from material representations
Project - abstract

Cooperation partner & projects:

- Prof. Dr. Niclas Schaper
- Dr. Andreas Seifert
- Prof. Dr. Hans-Dieter Rinkens
- Prof. Dr. Bernd Wollring
- Prof. Dr. Gabriele Kaiser
- Prof. Dr. Andrea Peter-Koop
- Prof. Dr. Christine Bescherer
- Prof. Dr. Dominik Leiß
- Gast-Prof. Dr. Katja Eilerts
- MINT-Doktorandenkongress 29.09.2011

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Prof. Dr. Bernd Wollring
Research questions

1. Which competencies characterise a professional primary school mathematics teacher concerning „space and form“?

2. Which dimensions and aspects have to be covered by a competence structure model?

3. Which competence acquisition levels have to be distinguished with regard to the dimensions of competence?

4. What sort of tests and instruments are apt to operationalise the model and its aspects?
Research questions

5. How can the assumed competence dimensions (3 domains: content knowledge, pedagogical content knowledge and pedagogical knowledge) be put into a valid item format to allow valid operationalisation and testing?

6. Are the items valid with regard to the competence structure model?

7. Are the instruments fit to represent competence development processes (longitudinal measuring) in a valid way?

8. Which parameters (e.g. differences in university curricula, opportunities to learn) have a positive effect on competence development?
Innovations

Innovative approach within the project:

1. Interdisciplinary cooperation

2. Curricular setup of content knowledge, pedagogical content knowledge and pedagogical knowledge for the topic „space and form“

3. Development of a competence model for teachers’ professional knowledge with the focus on the two interfaces

4. Construction of scenario-based items testing the three domains: content knowledge, pedagogical content knowledge and pedagogical knowledge
5. National representative study to test the validity of the competence structure model and its test instruments and to prepare a transfer to all national institutions involved.

6. Transfer possibilities
   a) other contents of mathematics
   b) other teachers’ studies
   c) other subjects

7. Transparency concerning the representation of individual courses of competence development

8. Which parameters have a positive effect on competence development?
Which competencies characterise a professional mathematics teacher?

Teachers’ Professional Knowledge

- Cognitive skills: Professional knowledge
  - Content knowledge
  - Pedagogical knowledge
- Pedagogical content knowledge
- Beliefs
- Motivational orientation
- Self-efficacy

Definition: professional competence
Weinert (1999, 2001) and Bromme (1992)

Confirmed by national and international research
TEDS-M, COACTIV
The competence model pursues two intentions:

- Arranges teachers’ professional knowledge
- Gives an empirical based idea of levels and ranks of teachers’ competencies
Competence structure model

Competencies can´t be described by individual, isolated achievements. They need to be tested in a frame of specific situations in which competencies are demanded.

Test items to test teachers´ professional knowledge demanding content knowledge, pedagogical content knowledge and pedagogical knowledge:

**Situational Judgement Tests**

(different aspects in one item)
Domain-integrated Item-Packages
Scenario-based Items

[cf. Situational Judgement Tests (WEEKLEY & PLOYHART, 2006) or Unterrichtsvignetten (OSER, HEINZER & SALZMANN 2010) or Bridging-Itmes (MARX & RINKENS, 2008)].

Specific situations or hypothetical scenarios in which the test persons are required:
  o to analyse and
  o to generate
  (teaching-)situations.

The competencies are deduced from the described situation analyses, intended actions and hypothetical actions.
I 1. basic knowledge
In a maths-lesson the students were asked to find as many nets of a cube as possible, cut them out and arrange them on a poster. Kevin created the following poster (Grade 3). The numbers were added later.

A. Are all images nets of a cube? ........

mark all numbers not being nets of a cube:

<table>
<thead>
<tr>
<th>No.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
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</tbody>
</table>

no net of a cube: ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
B. How do you create a learning-environment that gives students the possibility to decide whether a given representation is a net of a cube or not? 
(open response format)

C. Are there nets of a cube which are double? 
If Yes: Please name the two numbers of the nets of a cube? 
(closed response format)

D. When do you decide if two nets of a cube are identical? 
(open response format)

E. Are there missing nets of a cube? 
If Yes: draw the nets of a cube onto the paper. (open response format)
I 2. Reaction towards students’ action
In a maths lesson the students are asked to find as many nets of a cube as possible, cut them out and arrange them on a poster. Dorothea created the following poster (Grade 3). The numbers are Dorothea’s.

A. What do you realise? (open response format)
B. Three children are discussing, how many different nets of a cube there are on Dorothea’s poster:

- Dorothea’s poster shows 9 nets.
- No, Dorothea’s poster shows 10 nets.
- Well, I see 12 nets on Dorothea’s poster.

How would you react?
1. I interrupt to avoid misconceptions. .................. o
2. I don’t interrupt this discussion because I think it’s valuable. … o

If 2.: After a while the three are asking for your opinion who’s right? How would you react?

(open response format)
I 3. content knowledge regarding the topic „nets of a cube“

A. Teachers in a further training are asked to create a poster with many different nets of cubes. Here you see such an incomplete poster which was marked with names. How would you complete it?

(Please complete this poster by adding the net(s).)

C. You’ll be asked in a maths-test how many different nets of a cube there are? What would you answer? (open response format)
I 4. pedagogical content knowledge regarding the topic „nets of a cube“

A. How far is spatial visualization capacity needed? (open response format)

B. In a maths lesson the students are asked to find all nets of a cube and to glue them on a poster. Where would you position this task within the educational standards of primary schools? (Make a cross – Multi replies possible.)
Milestones of the project

**Milestone I.**
Theory-based design of a competence structure model
(based on important concepts of content-dimensional and development-related structuring of teaching skills).

**Milestone II.**
Analysis of documents of different locations
(study regulations, seminar schedules, textbooks).

**Milestone III.**
Expert-interviews to specify the competence model and to secure its curricular validity.

**Milestone IV.**
Development of scenario-based tests for a paper-pencil-test.
Milestones of the project

**Milestone V.**
Pilot study and optimisation of the test with student teachers at the beginning, in the middle and at the end of their study program (cross-sectional study).

**Milestone VI.**
Validation of the test with a longitudinal study in about ten locations (incl. Opportunities to learn); Feedback of the results with responsible co-workers.

**Milestone VII.**
Dissemination as a result of the project: Processing of the test and the reference values of the main study for scientific and application-oriented purposes (e.g. self-evaluation of a university). Usage for centres for teacher education and similar university institutions.
Expected results & perspectives

the results of the project are meant to:

- Foster competence orientation within mathematics teacher education for future primary school teachers with regard to pre-calculus

- Provide information for a sustainable optimisation of the structural, organisational and individual level

- Provide a competence level model to improve teaching accompanied by the development and implementation of innovative teaching and learning formats to improve individual competence development
Thank you very much for your attention!

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