Constructing Competence Scales in Graduate Tracer Studies
Working Towards Theoretical Validity and Empirical Reliability

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Mareike Landmann, M.A.

University of Cologne

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Institutional Background of the Study
The 'Cooperation Project for Graduate Tracer Studies (KOAB)'

- initiated and coordinated by the *International Centre for Higher Education Research (INCHER) Kassel*
- 40 to 70 higher education institutions involved
- *University of Cologne* involved since 2008 – survey including graduates from the study year 2007 (1st October 2006 to 30th September 2007)
- teacher questionnaire since 2009 – survey including graduates from the study year 2008 (1st October 2007 to 30th September 2008)
- teacher questionnaire now in the field with the third version of the scale on demands of the teacher profession – survey including graduates from the study year 2011 (1st October 2010 to 30th September 2011)

Theoretical Foundation - Action Fields of the Teacher Profession

Teacher Education Standards in Germany

- 2000: *Standing Conference of the Ministers of Education and Cultural Affairs* and *Teachers' Unions* agreed on new principles of the teacher profession
- 2004: *Standing Conference of the Ministers of Education and Cultural Affairs* published guidelines on teacher education standards for the educational sciences based on these principles and an expertise issued by the working group on teacher education reform around Prof. Terhart (University of Munster) in 2002
- 2008: *Standing Conference of the Ministers of Education and Cultural Affairs* published guidelines regarding teacher education standards for the subject areas

Theoretical Foundation – Action Fields of the Teacher Profession

A Model of Teacher Action Fields

1st layer	2nd layer	3rd layer	4th layer
Teacher Action	**Teacher Action Fields**	**Areas**	**items – specific teacher action**
Teacher Action	Teaching	Planning and Design of Lessons	
		Enhancement of Pupils' Motivation and Performance	
		Support for Independent Learning Strategies in Pupils	
	Moral Education	Consideration of Pupils' Social Background	
		Conveyance of Norms and Values	
		Creation of a Pleasant Social Atmosphere	
	Student Evaluation	Diagnostics and Counselling	
		Grading and Evaluation on the Basis of Objective Standards	
	School Development	Creation of a Work-Life-Balance	
		Adapting to the Regulatory Framework	
		Evaluation	
	Subject Areas	Representation of Subject Areas	
		Application of Scientific Methods from Subject Areas	
		Use of Subject-Specific Pedagogical Knowledge	

Steps to Ensure Validity and Reliability of a Scale

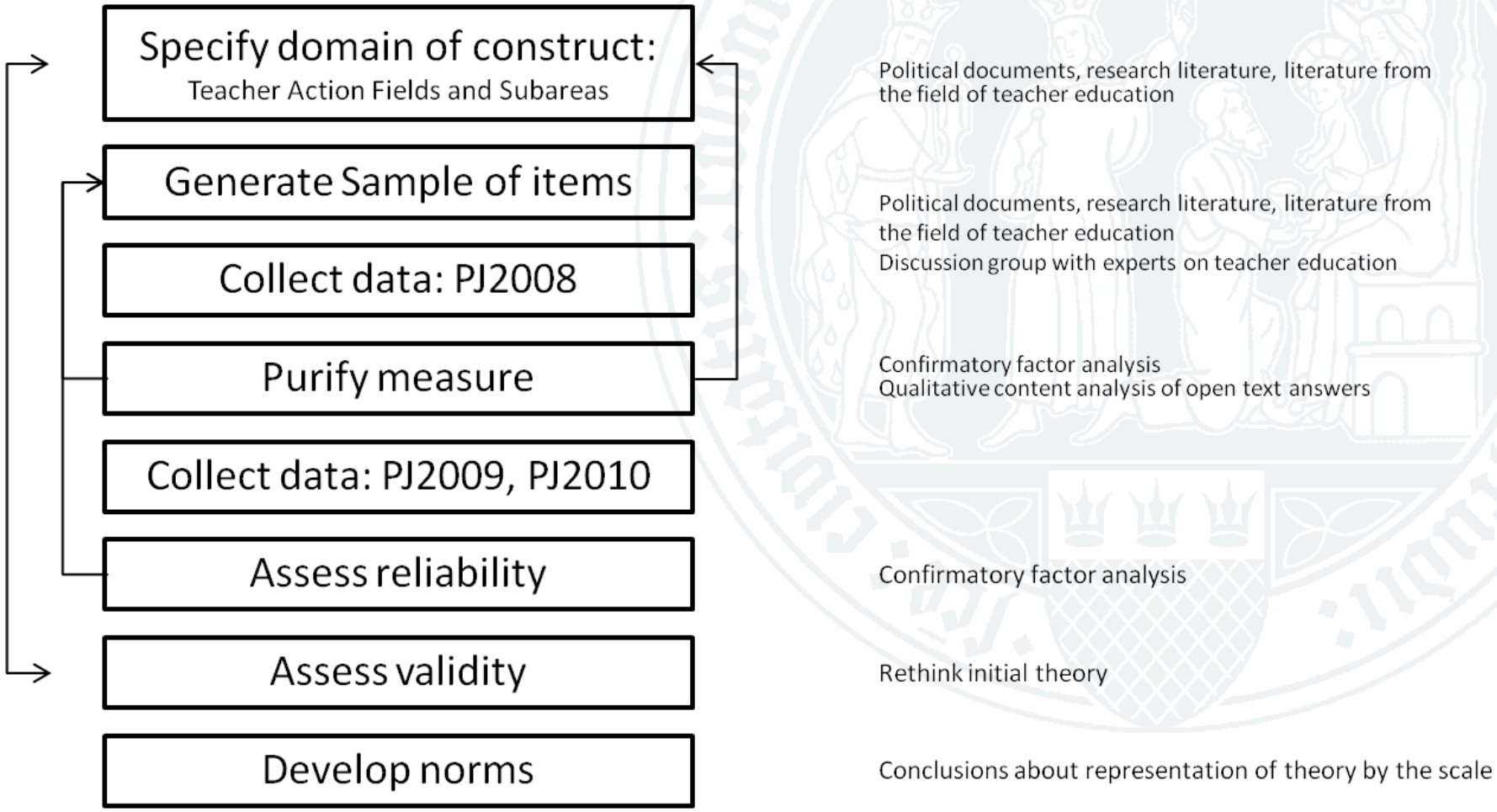

Figure based on Churchill (1979: 66) with modifications

Empirical Reliability
Confirmatory and Exploratory Factor Analysis, Cronbach's Alpha

1. CFA:
   - coherent models of interrelated factors can be tested concerning factor reliability of items and overall reliability of proposed theoretical model (Kahn 2006; Guo et al. 2009; Russel 2002; Bollen 1989)
   - model structure contains manifest variables and latent variables
   - scores for latent constructs, measurement errors and variances of latent constructs estimated on basis of empirical scores for manifest items (Gorsuch 1983; Schreiber et al. 2006; Bollen 1989)
   - fit of theoretical model estimated by contrasting empirical and estimated correlation or covariance matrix for this model
2. EFA (Principal Component Analysis):
   - may be useful when a scale lacks theoretical foundation
   - not adequate to test multi- or unidimensionality (Gerbing & Anderson 1988)
   - restricted theory based testing as theoretical model cannot be fully depicted
3. Cronbach's Alpha:
   - supposed to indicate the internal consistency of a unidimensional scale
   - criticised because of its application to test reliability in terms of unidimensionality of questionnaire scales (e.g. Sijtsma 2009; Graham 2006; Schmitt 1996)
   - rendering better results of consistency for scales including more items: assumed correlation mean of 0.5, a scale of 10 items would generate an Alpha value of 0.91, whereas a 5 item scale would generate an Alpha value of 0.83

$$\alpha = \frac{n * r}{(1 + r * (n - 1))}$$

Empirical Reliability – Multidimensionality
Example of the Subscale 'Teaching'

2nd layer	3rd layer	4th layer
Teacher Action Fields	**Areas**	**items – specific teacher action**
Teaching	Planning and Design of Lessons	
	Enhancement of Pupils' Motivation and Performance	
	Support for Independent Learning Strategies in Pupils	

2nd layer	3rd layer	4th layer
Teacher Action Fields	**Areas**	**items – specific teacher action**
Teaching	Planning and Design of Lessons	
	Enhancement of Pupils' Motivation and Performance	
	Support for Independent Learning Strategies in Pupils	

- data from the 2011 graduate survey (graduate year 2010)
- data input, where cases were deleted listwise in advance, contains 1169 cases
- data for the action field 'Teaching' with relatively high level of non-normality with univariate skew between -.732 and -3.163 and univariate kurtosis between 0.023 and 12.868

Confirmatory Factor Analysis – 'Teaching' – I

CFA Teaching: Model 1: three layers: standardised regression weights

		factor score 'Teaching'
	factor score 'Planning and Design of Lessons'	
obtaining, viewing and developing teaching materials	.500	.549
varying methods in the design of lessons	.621	
creating an obvious underlying structure for each lesson	.812	
creating a lesson according to the learning objective	.750	
	factor score 'Enhancement of Pupils' Motivation and Performance'	
including pupils' mistakes in the learning process	.718	.907
analysing pupils' mistakes	.727	
motivating pupils to learn	.590	
	factor score 'Support for Independent Learning Strategies in Pupils'	
supporting independent learning strategies in pupils	.698	.868
encouraging pupils to reflect on their individual learning process	.819	
guiding each pupil's learning progress by offering individual support	.662	
	SRMR .0508 / RMSEA .076 / TLI .920 / CFI .943	

CFA Teaching: Model 2: two layers: standardised regression weights

	factor score 'Teaching'
obtaining, viewing and developing teaching materials	.396
varying methods in the design of lessons	.544
creating an obvious underlying structure for each lesson	.517
creating a lesson according to the learning objective	.505
including pupils' mistakes in the learning process	.616
analysing pupils' mistakes	.607
motivating pupils to learn	.609
supporting independent learning strategies in pupils	.658
encouraging pupils to reflect on their individual learning process	.714
guiding each pupil's learning progress by offering individual support	.616
SRMR .0940 / RMSEA .155 / TLI .668 / CFI .742	

Confirmatory Factor Analysis – 'Teaching' – II

CFA Teaching: Model 1: three layers: standardised regression weights

		factor score 'Teaching'
	factor score 'Planning and Design of Lessons'	
obtaining, viewing and developing teaching materials	.500	.549
varying methods in the design of lessons	.621	
creating an obvious underlying structure for each lesson	.812	
creating a lesson according to the learning objective	.750	
	factor score 'Enhancement of Pupils' Motivation and Performance'	
including pupils' mistakes in the learning process	.718	.907
analysing pupils' mistakes	.727	
motivating pupils to learn	.590	
	factor score 'Support for Independent Learning Strategies in Pupils'	
supporting independent learning strategies in pupils	.698	.868
encouraging pupils to reflect on their individual learning process	.819	
guiding each pupil's learning progress by offering individual support	.662	
	SRMR .0508 / RMSEA .076 / TLI .920 / CFI .943	

CFA Teaching: Model 3: three layers, item 1 excluded: standardised regression weights

		factor score 'Teaching'
	factor score 'Planning and Design of Lessons'	
~~*obtaining, viewing and developing teaching materials*~~		.531
varying methods in the design of lessons	.598	
creating an obvious underlying structure for each lesson	.830	
creating a lesson according to the learning objective	.755	
	factor score 'Enhancement of Pupils' Motivation and Performance'	
including pupils' mistakes in the learning process	.720	.897
analysing pupils' mistakes	.728	
motivating pupils to learn	.588	
	factor score 'Support for Independent Learning Strategies in Pupils'	
supporting independent learning strategies in pupils	.698	.877
encouraging pupils to reflect on their individual learning process	.820	
guiding each pupil's learning progress by offering individual support	.662	
	SRMR .0549 / RMSEA .081 / TLI .920 / CFI .947	

Confirmatory Factor Analysis – 'Teaching' – III

CFA Teaching: Model 1: three layers: standardised regression weights

		factor score 'Teaching'
	factor score 'Planning and Design of Lessons'	
obtaining, viewing and developing teaching materials	.500	.549
varying methods in the design of lessons	.621	
creating an obvious underlying structure for each lesson	.812	
creating a lesson according to the learning objective	.750	
	factor score 'Enhancement of Pupils' Motivation and Performance'	
including pupils' mistakes in the learning process	.718	.907
analysing pupils' mistakes	.727	
motivating pupils to learn	.590	
	factor score 'Support for Independent Learning Strategies in Pupils'	
supporting independent learning strategies in pupils	.698	.868
encouraging pupils to reflect on their individual learning process	.819	
guiding each pupil's learning progress by offering individual support	.662	
	SRMR .0508 / RMSEA .076 / TLI .920 / CFI .943	

CFA Teaching: Model 4: three layers, item 7 excluded: standardised regression weights

		factor score 'Teaching'
	factor score 'Planning and Design of Lessons'	
obtaining, viewing and developing teaching materials	.497	.532
varying methods in the design of lessons	.619	
creating an obvious underlying structure for each lesson	.814	
creating a lesson according to the learning objective	.751	
	factor score 'Enhancement of Pupils' Motivation and Performance'	
including pupils' mistakes in the learning process	.780	.807
analysing pupils' mistakes	.741	
~~*motivating pupils to learn*~~		
	factor score 'Support for Independent Learning Strategies in Pupils'	
supporting independent learning strategies in pupils	.687	.886
encouraging pupils to reflect on their individual learning process	.832	
guiding each pupil's learning progress by offering individual support	.660	
	SRMR .0390 / RMSEA .058 / TLI .958 / CFI .972	

Confirmatory Factor Analysis – 'Teaching' – IV

CFA Teaching: Model 1: three layers: standardised regression weights

		factor score 'Teaching'
	factor score 'Planning and Design of Lessons'	
obtaining, viewing and developing teaching materials	.500	.549
varying methods in the design of lessons	.621	
creating an obvious underlying structure for each lesson	.812	
creating a lesson according to the learning objective	.750	
	factor score 'Enhancement of Pupils' Motivation and Performance'	
including pupils' mistakes in the learning process	.718	.907
analysing pupils' mistakes	.727	
motivating pupils to learn	.590	
	factor score 'Support for Independent Learning Strategies in Pupils'	
supporting independent learning strategies in pupils	.698	.868
encouraging pupils to reflect on their individual learning process	.819	
guiding each pupil's learning progress by offering individual support	.662	
	SRMR .0508 / RMSEA .076 / TLI .920 / CFI .943	

results from EFA, 3 factors

CFA Teaching: Model 5: three layers, item 7 in subarea 3: standardised regression weights

		factor score 'Teaching'
	factor score 'Planning and Design of Lessons'	
obtaining, viewing and developing teaching materials	.499	.547
varying methods in the design of lessons	.622	
creating an obvious underlying structure for each lesson	.811	
creating a lesson according to the learning objective	.750	
	factor score 'Enhancement of Pupils' Motivation and Performance'	
including pupils' mistakes in the learning process	.768	.787
analysing pupils' mistakes	.753	
~~*motivating pupils to learn*~~		
	factor score 'Support for Independent Learning Strategies in Pupils'	
supporting independent learning strategies in pupils	.711	.944
encouraging pupils to reflect on their individual learning process	.786	
guiding each pupil's learning progress by offering individual support	.655	
~~*motivating pupils to learn*~~	.593	
	SRMR .0455 / RMSEA .069 / TLI .934 / CFI .953	

Exploratory Factor Analysis – 'Teaching'

EFA (PCA) Teaching

	component 1	component 2
Area 'Planning and Design of Lessons'		
obtaining, viewing and developing teaching materials		.655
varying methods in the design of lessons		.678
creating an obvious underlying structure for each lesson		.834
creating a lesson according to the learning objective		.792
Area 'Enhancement of Pupils' Motivation and Performance'		
including pupils' mistakes in the learning process	.708	
analysing pupils' mistakes	.714	
motivating pupils to learn	.605	
Area 'Support for Independent Learning Strategies in Pupils'		
supporting independent learning strategies in pupils	.699	
encouraging pupils to reflect on their individual learning process	.794	
guiding each pupil's learning progress by offering individual support	.706	
Total of explained variance	31.5 %	2.41 %

EFA (PCA) Teaching: 3 factors

	component 1	component 2	component 3
Area 'Planning and Design of Lessons'			
obtaining, viewing and developing teaching materials		.661	
varying methods in the design of lessons		.670	
creating an obvious underlying structure for each lesson		.828	
creating a lesson according to the learning objective		.785	
Area 'Enhancement of Pupils' Motivation and Performance'			
including pupils' mistakes in the learning process			.781
analysing pupils' mistakes			.836
Area 'Support for Independent Learning Strategies in Pupils'			
motivating pupils to learn	.549		
supporting independent learning strategies in pupils	.810		
encouraging pupils to reflect on their individual learning process	.778		
guiding each pupil's learning progress by offering individual support	.716		
Total of explained variance	24.05 %	23.58 %	16.31 %

Cronbach's Alpha – 'Teaching'

Cronbach's Alpha : single tests for 'Teaching', subarea 1, 2 and 3

	Subarea	Teaching
Area 'Planning and Design of Lessons' *obtaining, viewing and developing teaching materials* *varying methods in the design of lessons* *creating an obvious underlying structure for each lesson* *creating a lesson according to the learning objective*	.760	.829
Area 'Enhancement of Pupils' Motivation and Performance' *including pupils' mistakes in the learning process* *analysing pupils' mistakes* *motivating pupils to learn*	.706	
Area 'Support for Independent Learning Strategies in Pupils' *supporting independent learning strategies in pupils* *encouraging pupils to reflect on their individual learning process* *guiding each pupil's learning progress by offering individual support*	.759	

Summary

1. three different methods lead to four different outcomes
   - CFA: multidimensionality in accordance to the theoretical foundation can only be tested by CFA
     - items number 1 and 7 show unsatisfactory factor loadings in the CFA of .50 and .59 in model 1
     - exclusion of item 1 leads to a worse fit of model 3
     - exclusion of item 7 in model 4 increases model fit
     - reallocation of item 7 to subarea 3 improves model fit but is below model 3
     - → three layered model with three subareas should be maintained and item number 7 excluded
   - EFA 1
     - → two layered model where methodical demands of teaching make up one subarea and social pupil centred demands another
   - EFA 2: results suggest a model which fits the empirical correlation matrix worse than a model which excludes the item
     - → forced to extract three factors, EFA produces three subareas assigning item number seven to the third subarea
   - Cronbach's Alpha: differing number of items for the subscales and the teaching scale as one will lead to better results for the 11 item scale
     - → one layered model seems suitably represented by the 11 items of the scale, the subareas seem less consistent

Discussion

Statistical Reliability vs. Content Validity

1. CFA: three layered model with three subareas should be maintained and item number 7 excluded
2. EFA: forced to extract three factors, EFA produces three subareas assigning item number 7 to the third subarea
3. Item number 1: 'obtaining, viewing and developing teaching materials' should not be discarded on theoretical grounds
   - represents major part of the construct 'Planning and Design of Lessons'
   - represents the preparation of lessons
   - remaining three items focus on the design and realisation of lessons

   → excluding this item would lead to the exclusion of a theoretical aspect of the a priori defined meaning of the construct
4. Item number 7: 'motivating pupils to learn' should not be discarded on theoretical grounds
   - represents major aspect of the 'Enhancement of Pupils' Motivation and Performance'
   - items 5 and 6 represent the inclusion of errors in learning to motivate pupils

In these cases, the decision is pretty arbitrary and could go either way, because statistical reliability contradicts theoretical reasoning.

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