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Effects of in-service teacher education courses on teachers' pedagogical content knowledge in primary science education

Construction and analysis of an instrument to assess aspects of teachers' pedagogical content knowledge concerning primary science

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Theoretical background and research design

Within the domain of teachers' personal professional knowledge (Bromme, 1997; Shulman, 1987), the focus of this investigation lies on teachers' pedagogical content knowledge as it regards teaching scientific subject matters in primary school, especially the teachers' conceptions of teaching and learning. The study aims at investigating potential changes respectively enhancements of these conceptions.

The theoretical background of the study is based on a moderate constructivist view of learning and teaching, which draws on conceptual change theories, the theory of situated cognition, social-constructivist theories, self-determination theories, educational-psychological theories of interest and theories of self-directed learning (Deci & Ryan, 1993; Gerstenmaier & Mandl, 1995; Greeno, 1998; Krapp, 1998; Pintrich, Marx, & Boyle, 1993; Posner, Strike, Hewson, & Gertzog, 1982; Reinmann-Rothmeier & Mandl, 1998).

The intervention consists of a 16-day in-service education programme, which is based on the cognitive apprenticeship approach (Collins, Brown, & Newman, 1989) and stretches over a period of five months. In three matched groups (N=3×18) the degree of tutorial support and the degree of authenticity of embedded research modules, in which teachers themselves investigate students' learning processes, are being varied (Möller, Kleickmann, & Jonen, 2004).

The contents of the programme (preconceptions, learning difficulties, diagnosis of learning processes, and methods of learning as elements of the pedagogical content knowledge, content and curricular knowledge) as well as the materials used are held constant among all three groups.

The main dependent variables are the teachers' conceptions of teaching and learning in science in primary schools as well as motivational and self-related variables concerning the teaching of physical science and teacher performance. Those variables are assessed in a pre-/post-test design immediately before and about eight weeks after the intervention.

Construction and analysis of a questionnaire instrument

Teachers' conceptions of teaching and learning are assessed by a questionnaire instrument, whose construction and analysis is described in the following. Starting with an item pool, which consisted of newly constructed items and items from already existing instruments (Cobb et al., 1991; Diedrich, Thußbas, & Klieme, 2002; Huibregste, Korthagen, & Wubbels, 1994; Peterson, Fennema, Carpenter, & Loef, 1989; Staub & Stern, 2002), the instrument was pre-tested three times. In addition, items with open response were generated. For the analysis of these items content analytic categories were constructed and reviewed. After selection of items the third pre-test-version consisted of 61 items with fixed and five items with open response format. In our project we first used some selected scales for a matching-process in order to parallelise the three intervention groups. In the following we will first go into the fixed-response-items.

The following constructs concerning conceptions of learning and teaching should be represented in the items: First, following Reinmann-Rothmeier and Mandl (1998) the constructs "acquisition of knowledge as an active, constructive, self-regulated, social und situated process" should be represented. In addition, the conception of learning and teaching should include instructive elements, such as cognitive activations or structuring of discussions. As a result of factor analyses during the pre-tests, a scale "extremely 'open' conception of teaching and learning" was constructed, which is just the opposite of this idea. Moreover, the questionnaire should assess the degree of a "hands-on-conception" of learning and teaching. According to this conception children do understand natural phenomena by simply conducting hands-on-activities. Especially in the Anglo-American literature we found some evidence for the widespread existence of this conception among primary science teachers (Gustafson & Rowell, 1995; Prawat, 1992). The response format of the items is a 5-point Likert scale.

Test construction and analysis were primarily based on criteria of classical test theory. First, aspects concerning the contents: The items should represent central aspects of the aforementioned constructs and they should be formulated in a short, intelligible and clear style. As a measure of internal consistency we used Cronbach's Alpha. Values shouldn't drop below .60. Item difficulty was estimated by the mean. As a measure of variability the standard deviation was taken. Item discrimination was detected by the item-total-correlation. Items with r_{it} lower than .20 were taken out or modified for the next pre-test. If the item discrimination was low, we additionally tested, if the regression of frequency (Lienert & Raatz, 1998) was monotonically increasing.

Table 1
Scales

Scales "constructivist oriented conceptions of teaching and learning"		*N* of Items	α
Scale	*Sample item*		
"Motivation as necessary condition for understanding in science"	Children can only fully understand natural phenomena if they are motivated to understand them.	4	.69
"Students should construct their own ideas"	In primary science children only understand natural phenomena if they themselves develop explanations to interpret these phenomena.	9	.83
"Learning as conceptual change"	Children only learn scientific knowledge if new conceptions are more convincing to them than their prior ones.	6	.73
"Preconceptions"	Elementary school children can already have tenacious conceptions about natural phenomena, which make the learning process more difficult.	3	.65
"Students should discuss their ideas"	In order for children to understand natural phenomena it is crucial that they discuss their ideas of solutions among themselves.	4	.69
"Situated learning"	Children can only utilise acquired scientific knowledge in everyday situations if the topics of primary science are incorporated into real questions that arise from everyday life.	5	.73
Scales "specific conceptions of teaching and learning"			
"Hands-on-conception of teaching and learning"	The carrying out of experiments itself ensures that children understand natural phenomena.	5	.69
"Strongly directive conception of teaching and learning"	Natural phenomena need to be explained to weaker students.	7	.79
"Extremely 'open' conception of teaching and learning"; rejection of the aforementioned instructive elements	In primary science, children learn best without the teacher's interference and guidance.	5	.74

The scales were also revised by factor analyses. These analyses showed that the aforementioned constructs could partly not be confirmed by factor analysis. After the third pre-test the following scales had been constructed (see table 1).

Additionally, the scales were reviewed with regard to aspects of validity. Following Rost (1996, 1999) a test is internally valid, if the validity of an assumed test model can be shown, which means that the assumed model fits the data. We assumed that the nine scales measure quantitative latent variables. Only in this case it is legitimate to interpret the score of a scale, to make use of a quantitative analysis. Otherwise a qualitative, classifying analysis should be preferred. Therefore, we tested, whether the scales fit the one-dimensional Rasch-Model. The Mixed-Rasch-Model offers a good possibility to do this model test. We compared the model-fits (we used the BIC and C-AIC) for the 1- to the 5-class-solution of the Mixed-Rasch-Model. The model-fits supported in all nine scales the 1-class-solution, which corresponds to the one-dimensional Rasch-Model. So this is a strong hint to the validity of the Rasch-Model in the scales.In order to estimate external validity of the scales, the following external criteria are available within the project: the open-response-items, then written plannings of science-lessons from the intervention teachers and interviews with them. External validity then is defined as the correlation with an external criterion. Up to now, only results from the items with open response are available. In the following we will go into this criterion.In these items on the one hand concrete and demanding situations from science lessons were described. Teachers should then explain the actions they would prefer to take in that situation. On the other hand teachers were asked to describe their role as a teacher in science lessons and in instructional conversations.

The data were analysed by qualitative content analysis following Mayring (2003). Thereby, categories were constructed in a deductive and inductive way. The theoretical constructs were mainly parallel to the aforementioned scales. Coders were trained and inter-coder agreement was assessed. Cohens Kappa finally was higher than .75 in each category. In order to be able to correlate category frequencies with scale scores, the category frequencies were transferred into a three-step ordinal scale from none to one to multiple occurrences. The open-response-items from n=67 questionnaires were coded. As a measure of the correlation we took Kendall's Tau-b.The correlations were partly significant. For example in the case of "Students' ideas" (r=.204), "Preconceptions" (r=.332), "Conceptual Change" (r=.247) and "Discussing ideas" (r=.289). "Motivation" and "situated learning" the correlations were not significant, the latter was almost a correlation of zero. The problem was that the category "everyday phenomena", which was correlated with "Situated learning", had been coded very seldom. Thus there was no immense variability, but the danger of random errors. Concerning the scales representing specific learning-conceptions, "Strongly directive" correlates as expected significantly with the category "Explaining subject matter" (r=.266) and negatively with the category "Students ideas" (r=.220). The scales "Extremely open" (r=-.148) and "Hands-on" (r=-.155) correlate as expected negatively but weakly (not significantly) with the category "providing support". With exception of the scales "Motivation" and "Situated learning", we interpret these findings as a hint to external validity with regard to the items with open response.

Prospects for future work

A first future task is the analysis of correlations between learning conceptions and results from the interviews and written plannings in order to estimate external validity of the scales. We will also analyse correlations with the videotaped teachers' actions in order to estimate the relevance of learning-conceptions for teachers' performance. At the moment we assess the students' achievement growth in the classes of our intervention-teachers. With hierarchical linear models (HLM) we will analyse the relevance of the conceptions of learning and teaching for students' achievement growth. At the centre of our interest is the measurement of changes in the conceptions of teaching and learning. First results from an evaluation of a study-module (Kleickmann, Gais, & Möller, in press) indicate that especially the scales "Conceptual change" and "Preconceptions" are sensitive concerning changes effected by interventions.

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