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Adaptive teaching competency: Effects on quality of instruction and learning outcomes

Abstract

In view of student heterogeneity, teachers need to adjust their teaching to the diverse learning needs of the students and thus require adaptive teaching competency. While adaptive teaching competency is often seen as a prerequisite of quality of instruction, the ways in which adaptive teaching competency is conceptualized and measured are diverse. This paper proposes a model of adaptive teaching competency and describes a multi-method approach, including text vignettes, a standardized video test and student questionnaires. The study explores whether students who are taught by a teacher achieving higher scores in measurements of adaptive teaching competency rate classroom processes more positively, as well as whether the measured adaptive teaching competency has a positive effect on student learning outcome and furthermore how such an effect can be explained. The sample consists of 49 primary and secondary teachers and their classes, including 898 students. Student achievement was measured with pre- and post-tests on a set science topic which teachers were asked to teach in eight lessons according to specified curricular goals. The results indicate a statistically significant positive effect of adaptive teaching competency on students' achievement. The results of a Multilevel Structural Equation Model (MSEM) analysis lead to the conclusion that adaptive teaching competency is not affecting learning outcomes directly but mediated through a high quality of classroom processes.

Keywords

Adaptive teaching competency (ATC); Teacher effectiveness; Teaching quality; Academic outcome; Diverse learning needs

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Effekte adaptiver Lehrkompetenz auf Unterrichtsqualität und schulische Leistungen

Zusammenfassung

In Anbetracht der heterogenen Zusammensetzung von Schulklassen besteht die Notwendigkeit, dass Lehrpersonen ihr unterrichtliches Handeln auf die unterschiedlichen Lernbedürfnisse der Schülerinnen und Schüler ausrichten. Während adaptive Lehrkompetenz als Voraussetzung für eine hohe Unterrichtsqualität angesehen wird, gibt es verschiedene Ansätze, wie adaptive Lehrkompetenz konzipiert und operationalisiert werden kann. Das in dieser Studie vorgeschlagene Modell der adaptiven Lehrkompetenz wird im Rahmen eines Multi-Method-Ansatzes mittels Textvignetten, standardisiertem Videotest und Schülerbefragung untersucht. Die Studie geht den Fragen nach, ob Schülerinnen und Schüler, die von adaptiveren Lehrpersonen unterrichtet werden, die Unterrichtsqualität als besser beurteilen, ob sich adaptive Lehrkompetenz positiv auf den Leistungszuwachs auswirkt und durch welche Unterrichtsprozesse sich ein solcher Effekt erklären lässt. Die Stichprobe umfasst 49 Primar- und Sekundarlehrpersonen und deren Klassen mit insgesamt 898 Schülerinnen und Schülern. Der Lernerfolg der Schülerinnen und Schüler wurde in einer Unterrichtsreihe im Fachbereich Naturwissenschaften erfasst, wobei die Lernziele und acht Lektionen als Zeitrahmen einheitlich vorgegeben waren. Die Ergebnisse zeigen einen statistisch signifikanten Effekt der adaptiven Lehrkompetenz auf den Leistungszuwachs der Schülerinnen und Schüler. Die Resultate eines mehrebenenanalytischen Strukturgleichungsmodells stützen die Annahme, dass adaptive Lehrkompetenz nicht direkt auf den Lernerfolg der Schülerinnen und Schüler wirkt, sondern über eine hohe Unterrichtsqualität vermittelt wird.

Schlagworte

Adaptive Lehrkompetenz; Lehrerwirksamkeit; Unterrichtsqualität; Schülerleistung; Unterschiedliche Lernbedürfnisse

1. Introduction

How are teachers' professional competencies affecting student learning? This fundamental question lies at the heart of schools as places of teaching and learning. Answering this question based on empirical research, however, proves to be challenging due to the multi- layered and complex nature of teaching and learning processes in school. A myriad of aspects at various levels interact with one another, individual student achievement is determined by multiple factors (Helmke, 2015; Helmke & Weinert, 1997). Consequently, learning processes do not develop in a streamlined fashion, but are different for each person, depending on his or her cognitive, motivational and affective learning preconditions. Furthermore, the intended learning goals are multi-dimensional. They not only include knowledge in a certain subject, but also interdisciplinary goals such as learning strategies, motivation and social behaviour.

A central aspect of teaching is its sheer unpredictable nature (Doyle, 1986, 2006) and the dynamic demands of perception, interpretation and decision-making (Blömeke, Gustafsson, & Shavelson, 2015; Santagata & Yeh, 2016). Teachers are constantly challenged to deal with unexpected and unforeseen situations in an appropriate way. Based on a constructivist understanding of teaching and learning (Brophy, 2002; Reusser, 2006; Parsons et al., 2018) teachers are required not only to transmit knowledge but also to adapt their teaching to the diverse learning needs of their students. Weinert (1997) calls such a proactive teaching behaviour adaptive teaching. Teachers need to embrace heterogeneity as both inevitable and positive and strive to meet the learning needs of each student in providing differentiated instruction (Tomlinson, 2014, 2015). Differentiation in teaching using different approaches is considered the highest and most demanding stage of teacher competency (Antoniou & Kyriakides, 2013).

The teachers' cognitions guiding their actions provide the basis of adaptive teaching. These cognitions are encapsulated in the concept of Adaptive Teaching Competency (ATC) (Beck et al., 2008). The concept of adaptive teaching competency integrates the principles of adaptive teaching. However, it does not focus on the teaching processes but rather on the teacher competencies required for adaptive teaching. This article presents and discusses an empirical examination of the effects of ATC on the teaching processes and the student learning outcomes while taking context effects and individual learning preconditions into account.

2. Theoretical background

2.1 Factors influencing teaching and learning

Successful learning processes, and therefore school effectiveness, depend on multiple factors, ranging from the individual characteristics of students and teachers to school related factors as well as the impact of out of school factors. Based on an extensive meta-analysis, Hattie (2009) estimated the influence of student characteristics on learning outcome to be approximately 50 %, the influence of the teacher to be 30 %. Students' pre-knowledge varies largely and affects the students' opportunities to learn a specific curricular content. Within science education, students' pre-instruction concepts are particularly relevant (Duit & Treagust, 2003).

As an early example of a research-based and successful model, the Adaptive Learning Environments Model (ALEM) highlighted the importance of teaching adaptively to students' diverse needs (Wang, 1980; Wang, Rubenstein, & Reynolds, 1985). Wang (1980) emphasized the need and the potential of teachers providing a differentiated instruction. Adaptation of learning tasks and learning contexts (i.e., the time allocated for a learning task) to the individual prerequisites of the student is crucial.

Helmke and Weinert (1997) coined the expression of the multiple determination of learning. Whereas multilevel supply-use models often distinguish between four hierarchical levels, the education systems, the school, the class and the individual student (e.g., Baumert, Blum, & Neubrand, 2004; Doll & Prenzel, 2004; Fend, 1998; Helmke, 2015), the multilevel model for this study focusses on the two lower levels, the class and the student. These two are the most influential for successful learning processes (Hattie, 2009). The learning arrangement provided by the teacher is conceptualized as 'supply', which in turn depends on the teacher's competencies. The individual pre-conditions for learning of the pupils are captured as 'utilization'. Individual learning outcomes are the results of individually diverse utilizations of the learning arrangement provided by the teacher (Reusser, 2006). This study seeks to explore and statistically test the relations between teacher competencies, classroom processes, individual learning prerequisites and learning outcomes by taking the context of the class into account. Specific aspects of instructional quality in the perception of the students are particularly relevant, such as student participation and less pressurized teaching (Eder & Mayr, 2000). These are indicators of a better adjustment to students' individual learning pre-conditions.

It is expected that teachers' professional competency does not directly affect learning outcomes but is mediated by classroom processes. The findings of the COACTIV study indicate that teachers' professional competency does not directly affect learning outcomes but is mediated through teaching and learning processes such as individual support, cognitive activation and curricular level of tasks (Baumert et al., 2013). Lenske et al. (2016) found that teachers' pedagogical and psychological professional knowledge influences student learning outcome positively mediated through classroom processes, particularly teachers' classroom management.

2.2 Adaptive teaching competency (ATC)

Teaching competencies enable meeting the specific demands of a situation (Klieme & Leutner, 2006). Competencies encompass cognitive dispositions and include motivational and action related aspects (Weinert, 2001). As Parsons et al. (2018) demonstrate in their meta-analysis, Adaptive Teaching Competency (ATC) is seen as a crucial concept for teaching and learning and discussed widely, yet there is no consensus regarding terminology. Firstly, the model of ATC employed in this research project is theoretically described. It is characterized by a special focus on the interplay between diagnostic competency and didactic competency, and between planning and performance. Secondly, the model is also discussed in relation to other models of professional competency.

This model of ATC has been developed based on the concept of adaptive instruction (Wang, 1980). In contrast to Wang (1980) it does not highlight certain adaptive ways of teaching but rather seeks to conceptualize the competencies required for adaptive teaching (Brühwiler, 2017). ATC is based on four dimensions suggested by Helmke and Weinert (1997), namely content knowledge, diagnosis, didactics and classroom management.

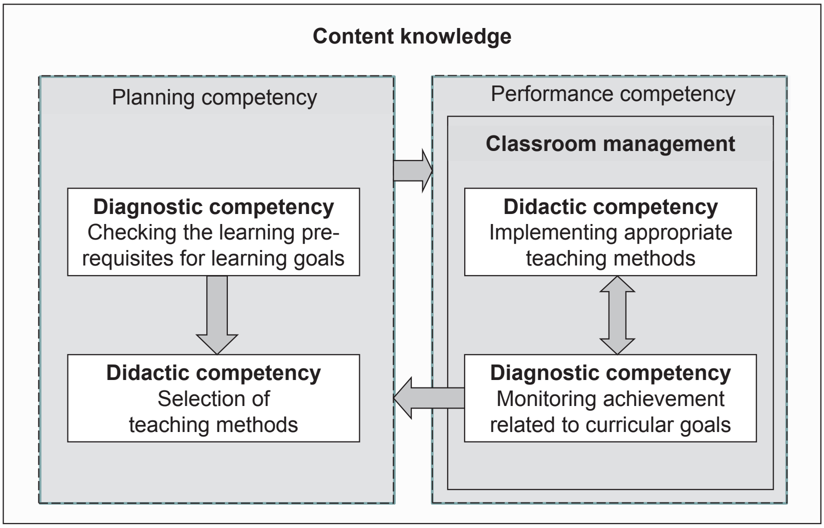
The core of ATC is to be found in the close interaction between diagnosis and didactics (Brühwiler, 2014, 2017), whereas content knowledge and classroom management provide good conditions for learning (Figure 1).

Conceptualizing diagnosis and didactics as being closely linked is a consequence of findings on the effects of diagnostic competency. Schrader (2008) found that diagnostic competency only leads to high learning outcomes when teachers are implementing didactic measures which support and structure students' learning. Lindmeier (2010) highlights the need for both reflective and action-related competencies. Whereas diagnostic competency includes a variety of aspects (Schrader, 2013), the close relation between diagnostic and didactics is at the fore of situation-related diagnostic competency (Hoth, 2016). It is not so much a single didactic approach nor a certain setting which can be considered to be adaptive but rather the interplay between diagnosis and didactic in order to determine individual pre-requisites for learning and the selection of appropriate didactic arrangements (Beck et al., 2008).

For ATC it is proposed that planning and performing can be distinguished (Beck et al., 2008). The quality of planning differs, for example, whether or not the learning processes of the students are taken into account in addition to the content to be presented (Fernandez & Cannon, 2005). The demand of differentiated instruction requires the planning of challenging tasks as well as appropriate support (Tomlinson, 2015). While performing, teachers must constantly adjust their teaching behaviour to unforeseen needs and pre-conditions of individual students as well as classroom situations (Doyle, 1986). Even chaos theory can be applied to planning and performing when the transition from a more ordered situation of planning to the uncertainty, unpredictability and complexity of delivering the lesson is considered (Cvetek, 2008). Within planning, self-regulation is an important resource of the teacher (Bodensteiner, 2016). Planning and performing require different competencies at different moments in time. They are also interdependent and might even be compensatory as indicated by the arrows in Figure 1, which lead from planning to performing and back. The learning achievements diagnosed at the end of the lesson provide the learning preconditions for the next unit, thus diagnosis feeds into further planning, as indicated by the arrow pointing from teaching back to planning. Teachers with high planning competency might consider individual learning needs more thoroughly and anticipate a larger variety of situations and consequently will need to make fewer adjustments during teaching.

The dimensions of classroom management and of content knowledge provide the context for adaptive teaching as conceptualized in Figure 1. Classroom management provides the foundation for less disruption during lessons and leads to more active learning time, which is highly relevant for effective teaching. A limited number of clear rules and procedures should be developed with the class at the

Figure 1: Model of adaptive teaching competency



beginning of the school year (Mujis et al., 2014). Classroom management includes competencies regarding typical situations such as managing transition and student behaviour as well as knowledge-based processing of perception and interpretation of classroom situations (König, 2015). Classroom management is not re-defined anew in the planning of each lesson. However, good didactic planning prohibits disruption in class (e.g., Evertson & Emmer, 2013). Content knowledge encompasses planning and performing: profound content knowledge is highly relevant while planning (i.e., the selection of curricular content and tasks) as well as during the interactive phase of teaching (i.e., in responding to student questions).

This model of ATC can be compared to other models of teacher professional competency. Relating the four dimensions to the distinction between content knowledge, pedagogical content knowledge and pedagogical knowledge suggested by Shulman (1986), didactic and diagnostic competencies can be seen as dimensions of pedagogical content knowledge, while classroom management refers to more general pedagogical knowledge. Baumert and Kunter (2013) provided a model of teachers' professional knowledge which distinguished the domains of content knowledge, pedagogical content knowledge and pedagogical knowledge, as well as organizational knowledge and counselling knowledge, whereby the first three domains are further differentiated with facets. Diagnostic competencies relate to pedagogical content knowledge as a facet of knowledge about students' thinking but also to pedagogical knowledge with the facet of knowledge about assessment. Didactic competency relates to pedagogical content knowledge with the facet of knowledge about tasks, as well as to pedagogical knowledge, with the facet of knowledge about learning processes. Comparing the model of ATC with the model by Lindmeier (2010), planning competencies relate to the reflective competency component, whereas performance competencies focus on the action-related competency component. The model of ATC does not capture teachers' beliefs nor aspects such as teacher motivation and self-regulation, though these aspects do, of course, also shape teacher professional competency (Krauss et al., 2004; Kunter & Klusmann, 2010; Santagata & Yeh, 2016).

As highlighted in teacher effectiveness research, ATC is part of a complex structure of conditions influencing learning at school (Brühwiler, 2014; Brühwiler & Blatchford, 2011). It is suggested that ATC – beside other characteristics of the teacher and the context of the class – influences instructional quality, which support student's individual cognitive processes and thus lead to better learning outcomes.

3. Research questions

The main aim of this paper is the examination of the effects of adaptive teaching competency (ATC) on teaching and on student learning outcomes. Based on theoretical considerations, ATC is expected to influence classroom processes, together with other teacher characteristics and, depending on aspects of the class and of the individual cognitive characteristics of the students, these classroom processes then lead to higher learning outcomes.

The following research questions are examined:

1) Are classroom processes rated more positively by students when taught by teachers with high adaptive teaching competency?
   As ATC is conceptualized as an action-related cognition, its effects should be noticeable in the lessons with regards to instructional quality. Therefore, it is assumed that higher adaptive teaching competency will be related to higher instructional quality (Hypothesis 1). In particular, those aspects of instructional quality should be high, which relate to a better adjustment to students' individual learning pre-conditions, such as higher student participation and less pressurized teaching.
2) What effects of ATC can be found on students' academic learning outcomes?
   As teachers with high ATC would be able to better meet individual learning needs and to offer a better learning context in class, a positive effect of ATC on student learning outcomes is envisaged (Hypothesis 2).
3) What classroom processes explain the effect of ATC on students' academic learning outcome?
   Applying a more complex model, it will be tested whether classroom processes can explain the effect of ATC on students' learning outcome. Based on the theoretical model it is expected that teachers' competencies affect student learning mediated through the classroom processes (Hypothesis 3).

4. Methods

The analysis carried out for this article is based on the data gathered for the research project "Adaptive Teaching Competency" (Beck et al., 2008; Rogalla & Vogt, 2008; Vogt & Rogalla, 2009; Brühwiler, 2014).

4.1 Sample

The sample comprised 49 teachers and their students (*N* = 898), 26 teachers at primary school (Grades 4 and 5) and 23 at secondary (Grades 7 and 8). All teachers worked at Swiss state schools and were qualified for teaching science in primary or secondary school respectively. 61% of the teachers were men, thus slightly overrepresented. The mean age of the students at primary was 11.6 years (*SD* = 0.82), and of the students at secondary 14.5 years (*SD* = 0.80). The study took place in the German speaking region of Switzerland in 2004. 81% of the students gave German as the main language spoken at home. The teachers were recruited through an advert in a teachers' bulletin and volunteered their participation in the study. The teachers had between 2 and 34 years of teaching experience (*MD* = 15).

4.2 Measures

4.2.1 Adaptive Teaching Competency (ATC) tests

A multi-method approach was employed to measure teachers' ATC. New instruments were especially developed for this research project, as research instruments measuring ATC were not available (Parsons et al., 2018). Teachers' adaptive planning competency was measured using a vignette test, while teachers' adaptive performance competency was measured with a video test (Beck et al., 2008; Bischoff, Brühwiler, & Baer, 2005).

Vignette test: To capture teachers' adaptive planning competency a written vignette eliciting written responses was developed, thus allowing respondents to formulate their thoughts and practices in their own words, but also to give the same stimulus to all respondents. The vignette asks participants to describe to another teacher, how they go about planning in natural science, to include all necessary planning steps and to make their reflections transparent.

Indicators for three of the four dimensions of ATC for planning, diagnosis, didactics and content knowledge, were developed theoretically and clarified inductively (Vogt & Rogalla, 2009). The analysis was carried out in two stages: First, teachers' written statements were categorized in a content analysis according to the criteria and indicators (Mayring, 2008) and second, two researchers independently rated teachers' responses and then agreed after discussion on a definite rating for each of the criteria. Diagnosis included three criteria (e.g., checking students' learning prerequisites) didactics two (e.g., enabling application and deepening the acquired knowledge) and one for content knowledge (ensuring one's own content knowledge). The teachers' statements were rated along these criteria ranging from 0 (no indicator mentioned), 1 (at least one indicator mentioned) to 2 (at least one indicator mentioned and addressing of the criterion in an adaptive way). For a response, thus categorized as an adaptive response, at least one of the following characteristics needed to be fulfilled: (a) orientation towards learning for understanding, (b) orientation towards individually diverse learning processes of each student, (c) depth of reflection, and (d) implementation of highly differentiated quality.

Video test: To assess teachers' adaptive performance competency a video test was constructed to allow for a standardized input. Actual teaching was not examined. The video sequence for the video test was scripted by the research team and included suboptimal teaching. It was performed by a mixed years 5 and 6 class, the students were 12 to 13 years old, so aged in between the participating classes. In a one-to-one situation with a research assistant, participants were shown the video and asked to stop the video when they noticed a non-adaptive situation, to express their thoughts and to suggest a more adaptive alternative to the teacher's action. The differentiation between noticing a problem in the teaching, as shown in the video, and suggesting a more adaptive alternative action is comparable to the differentiation between *noticing* (identifying relevant situations during a lesson) and knowledge-based *reasoning* (knowledge and reasoning applied to the identified situations) employed by van Es and Sherin (2008; see also Schäfer & Seidel, 2015). As the video test required quick decision-making, whilst the lesson on the video unfolds, immediate cognitions when observing classroom teaching were captured.

The responses were transcribed, rated independently by two researchers and agreed upon after discussion, should the ratings differ. Based on the script, as well as on the participants' responses, criteria and indicators for three of the four dimensions of ATC (diagnosis, teaching methods, and classroom management) were formulated. The measurement of diagnosis was based on two criteria (e.g., checking students' understanding during the lesson), teaching methods on five criteria (e.g., acquisition of new knowledge), and classroom management on two criteria (e.g., ensuring the attention of the class). The responses were rated as follows: not identifying a non-adaptive action was rated with 0, recognizing a non-adaptive action was rated with 1, providing adaptive alternatives was rated with an extra point for each indicator met (up to five indicators for each criterion were defined).

Construct validity of ATC: In order to verify the construct validity of ATC, Confirmatory Factor Analysis (CFA) was employed. Two models were tested and provided satisfactory fits: (a) ATC as a second-order factor model, with adaptive planning competency and adaptive performance competency as first-order factors and (b) ATC as first-order factor model with both measurements of the vignette test and of the video test loading on one factor. As this first-order factor model is more economical, this model specifying ATC as a general factor was taken for further analyses (model fit: $\chi^2(9, N = 47) = 7.30$, $p = .606$, CFI = 1.000, SRMR = .057, RMSEA = .000).

4.2.2 Quality of instruction

In order to capture the quality of instruction, six scales of classroom processes were obtained through a student questionnaire adapted from Eder and Mayr (2000). The questionnaire was completed directly after the unit "germination of seeds" (see section 4.2.3). Answers were given on a 5-point Likert-type scale from 1 (disagree) to 5 (agree). Each scale consisted of 3 or 4 items, except for the *pupil interest in instruction* scale which was a single-item indicator (see Table 1).

Table 1: Description of the scales of quality of instruction (original in German, Eder, & Mayr, 2000)

Scales (number of items)	Item examples	*M*	*SD*
Quality of teaching methods			
Pressurised teaching (3)	The teacher often explains so fast that one can hardly follow.	2.33	0.95
Student participation (3)	Again and again in class there are opportunities to realise one's own ideas.	3.48	0.68
Explaining quality (3)	Our teacher explains everything so well that we can also understand difficult material.	3.77	0.81
Student interest in instruction (1)	The teacher has taught the topic *germination of seeds* interestingly and variedly.	3.85	1.00
Classroom management			
Disturbance and noise (3)	It is not easy for the teacher to get our class to be quiet.	2.93	0.97
Orientation towards rules (4)	In class there are clear rules how students are supposed to behave.	3.75	0.70

Note. N = 898 students.

Four scales reported students' perceptions of classroom processes that were related to teaching methods (pressurized teaching; student participation; explaining quality; student interest in instruction), and two scales described aspects of classroom management (disturbance and noise; orientation towards rules). As the shared assessment of the quality of instruction was required, the student's individual responses were aggregated on the level of the class.

To examine the reliability of the aggregated measures the inter-class-correlations were calculated, with ICC_1 (variance between classes/groups) and ICC_2 (reliability of the aggregated constructs; Lüdtke, Robitzsch, Trautwein, & Kunter, 2009). ICC_1 ranged from .16 and .34, therefore suggesting relevant variance between classes. ICC_2 was between .80 and .91, indicating a high reliability of the measurements of instructional quality at class level.

4.2.3 Assessment of student learning outcome

Teachers' effectiveness was measured through student learning outcomes, focussing on a specific unit. Teachers were given curricular learning goals on a specific topic (germination of seeds) and asked to teach these within a set time frame (4 x 90 minutes). In contrast to the test on a specific topic developed in this study, other studies often use general academic tests (e.g., end-of-year tests). However, general academic science tests fall short as teachers are free in their choice of topics: depending on the curriculum chosen by the teacher, students would differ in their knowledge. Measuring student learning outcomes on a set topic within a set time allows relating the learning progress more directly to the teacher and classroom processes.

To determine the learning outcome, the students took tests in the given topic "germination of seeds" before and after the unit taught by their teacher. Students were given different test booklets for pre-tests and post-tests based on multi-matrix sampling (Adams & Wu, 2002). To calculate test scores, item response theory (IRT; Fischer & Molenaar, 1995; Rost, 2004) was applied. For primary and secondary separate item parameters and skill scores were calculated. Pre-tests and post-tests were scaled simultaneously. The EAP/PV reliability consists of .61 for primary and .81 for secondary. The pre-test scores were standardized on a mean of 50 and a standard deviation of 10 in order to render the results for both primary and secondary comparable. The mean achievement gain between pre-test and post-test was 15.2 points.

4.2.4 Control variables[1]

In order to appraise the relevance of the effect of adaptive teaching competency, other variables impacting on student academic learning outcomes are controlled for such as class variables (i.e., size of class, mean achievement of the class) and individual characteristics (i.e., socioeconomic status, languages spoken at home).

General science achievement: In order to control for the general ability of the students in science, a general science achievement test was applied. The tasks were taken from TIMSS and PISA (publicized and pilot tasks). Two tests were constructed: the general science achievement test for primary, which entailed 19 tasks, Cronbach's alpha = .60; for secondary 26 tasks and Cronbach's alpha = .76. In order to render the results comparable, scores were z-standardized.

Socioeconomic status: As a measurement for socio-economic status of the family background a scale was formed using the indicators 'parents' level of education' (International Standard Classification of Education, ISCED) and 'home learning environment' (number of books at home).

1 A detailed description of the operationalization can be found in Beck et al. (2008).

4.3 Data analysis

The postulated conceptual framework and research questions required the use of advanced statistical methods. The units of analyses included teachers and students nested within classrooms as well as contextual factors and students' individual prerequisites impacting teaching and learning. This multilevel structure of the data led to the application of hierarchical linear models; MLwiN (Rasbash, Steele, Browne, & Prosser, 2005) was used. This procedure enabled to simultaneously investigate student and teacher variables and to control for contextual effects of classes. To analyze direct and mediating effects of latent and observed variables Multilevel Structural Equation Modelling (MSEM) using M*plus* (Muthén & Muthén, 1998–2006) was employed (for an overview see Preacher, Zyphur, & Zhang, 2010). The data from two participating classes was incomplete and they were excluded from the sample. The analyses in this paper were conducted with both, primary and secondary school classes combined; this is justified, as no significant interaction effect between ATC and stage (primary or secondary) was found.

5. Results

5.1 Adaptive teaching competency (ATC) and classroom processes

The first research question addresses in what ways ATC is related to classroom processes, especially with those aspects that are linked to meeting diverse individual learning prerequisites. The assessment of teacher's instructional quality is based on the student questionnaire on learning processes, aggregated per class.

In Table 2 the results of regression analyses for each of the dimensions of ATC and the scales of instructional quality are provided. The students taught by teachers with high ATC assessed the *quality of teaching methods* generally more positively. In particular, they reported a significantly higher *student participation* (β = .31), *explaining quality* (β = .32) and *student interest in instruction* (β = .26).

Table 2: Adaptive teaching competencies (ATC) as predictors of classroom processes (student perceptions)

	Quality of teaching methods				Classroom management	
	Pressurised teaching	Student participation	Explaining quality	Student interest in instruction	Disturbance and noise	Orientation towards rules
	β	β	β	β	β	β
ATC planning	-.26*	.28*	.29*	.24*	-.14	.06
ATC performance	-.08	.26*	.26*	.22	.19	.15
ATC	-.21	.31*	.32*	.26*	.01	.11

Note. Students' data aggregated on class level; β = standardized regression coefficients; *SE* = standard errors; $N = 49$.
*$p < .05$ (one-tailed).

Whereas ATC is a predictor for the quality of teaching methods, it is not related to classroom management (disturbance and noise; orientation towards rules). These results support the assumption that ATC, as measured in this study, reflects teachers' classroom teaching.

5.2 Effect of adaptive teaching competency on student learning outcomes

In order to examine the influence of ATC on student learning outcomes, three multilevel models were specified (see Table 3). Student learning outcomes in the unit on "germination of seeds" was defined as the outcome variable to assess the effectiveness of adaptive teaching competency. To control for the specific pre-knowledge on the topic of germination of seeds, the first model included the individual achievement in the pre-test as a predictor of the regression model. Subtracting the mean score of the pre-test ($M = 50$), from the intercept, the score of 15.43 could be interpreted as the average knowledge growth. The achievement in the pre-test predicted the post-test result to a very large extent, as it showed the regression coefficient B = 3.59. If the pre-test score was one standard deviation higher than the mean score, i.e. 10 points, the post-test is expected to be 3.59 points higher than the mean. Differences between classes explained 19 % of variance.

Model 2 proves that ATC has a statistically significant effect on student learning outcomes. Students who are taught by a teacher with higher ATC (one standard deviation above the mean ATC) were predicted to achieve a 1.75 points higher learning outcome. The variance explained in addition to Model 1 is 2.8 % at individual student level and 14.9 % at class level.

Table 3: Effects of adaptive teaching competency (ATC) on the learning outcome controlled for individual and class context variables (multilevel analyses)

	Model 1		Model 2		Model 3	
	B	(SE)	B	(SE)	B	(SE)
Post-test "germination" (intercept)	65.43	(.73)	65.39	(.68)	66.61	(.68)
Individual level						
Pre-test "germination"	3.59	(.35)***	3.59	(.35)***	2.15	(.39)***
Science achievement					2.18	(.40)***
Gender (male)					-1.16	(.67)(*)
Socioeconomic status					.71	(.38)(*)
Language spoken at home (others)					-2.33	(1.00)*
Class level						
Adaptive teaching competency (ATC)			1.75	(.69)*	1.27	(.57)*
Class size					-1.71	(.59)**
Pre-test result "germination" of the class					2.26	(.61)***
Proportion of students with first language German (L1)					-1.49	(.64)*
Intra-class correlation (ICC_1)	.190		.166		.103	
Additional explained variance (R^2)	-		0.284		0.140	
Additional explained variance on class level	-		0.149		0.532	
-2(log-likelihood)	6132.85		6126.71		5630.98	

Note. N = 772 within 47 classes. Random-intercept-models. Continuous predictors were z-standardized. Dummy variables: gender (0 = female; 1 = male), language (0 = German, L1; 1 = others).
$^{(*)}p < .10$. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

In order to test the strength of the effect of ATC on student learning outcomes several relevant individual characteristics as well as context factors were included as control variables, based on the research literature. At the individual student level, in addition to the pre-knowledge measured with the pre-test "germination" student general knowledge in science was tested using a general science test, thus introducing *science achievement* as a cognitive control variable. Furthermore, at an individual level, *gender*, *socioeconomic background* and *language spoken at home* were introduced as predictors in the model. At the level of class, *class size*, the class achievement level measured as the average of the *class' pre-test result on "germination"* and the *proportion of students with German as first language* compared with students with another L1 were introduced as predictors in the multilevel model.[2]

2 In addition, multilevel models were tested which included the mean general science knowledge of class and the mean socioeconomic status of the class as predictors. However, these two context variables did not show significant effects and are therefore not presented in Table 3.

The results of the analysis of model 3 demonstrate that ATC remains an independent predictor after controlling for relevant individual characteristics as well as characteristics of the class as context factors. The effect of ATC was not confounded with other predictors of variance in learning outcomes. The regression coefficient was slightly reduced, from B = 1.75 to B = 1.27, but remained statistically significant.

At student level the cognitive abilities contributed the most to the learning outcome. Students specific pre-knowledge on the topic of "germination" (B = 2.15) as well as their general science knowledge (B = 2.18) were both highly and equally relevant for predicting learning outcomes after the unit. Gender and socioeconomic background were significant only on the 10-percent-level significance level. Statistically significant was the language spoken at home: students with German as a first language gained more from the unit than students with other first languages (B = -2.33).

The opposite is true at the level of class. The learning outcomes were higher in classes with a larger proportion of students with first languages other than German, when language spoken at home is included as predictor at individual level.

Pre-knowledge as well as class size were factors relevant for individual student learning outcomes. The mean of the pre-test results on germination explained learning outcomes (B = 2.26), a high level of pre-knowledge of the class was beneficial for the individual learning outcome. As for class size, learning outcomes were statistically significantly higher in smaller classes (B = -1.71).

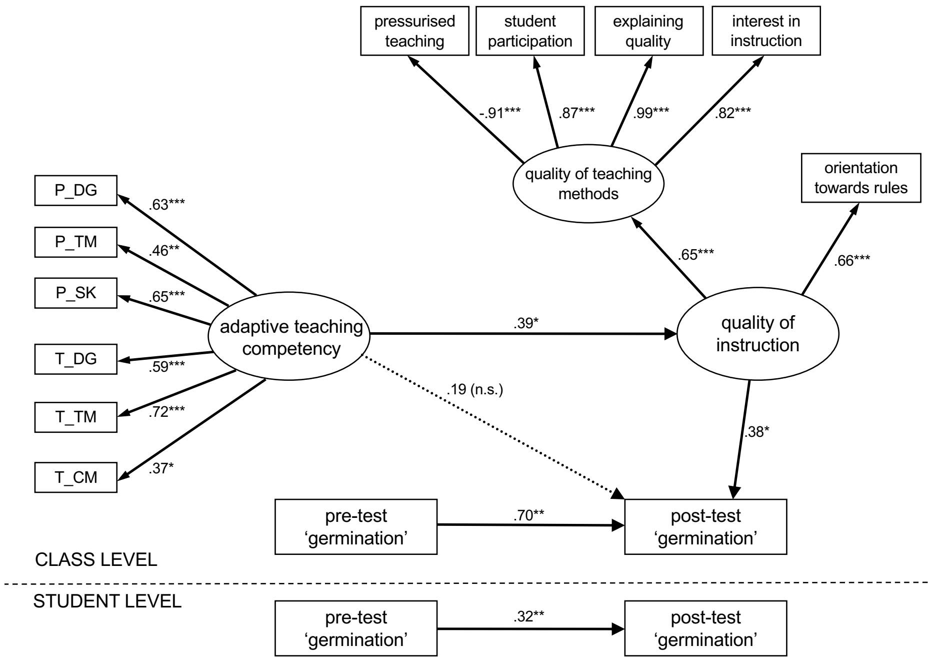
In comparison to the basic Model 1, Model 3 explains 14 % more variance. At class level, the additionally explained variance is 53.2 %. The variance between classes accounts for 10.3 % in Model 3.

5.3 Adaptive teaching competency, quality of instruction and student learning outcomes

The aforementioned results demonstrated that ATC had a positive influence on student learning outcomes. It is thus relevant to examine how this influence can be explained and which mediating factors might explain the trajectory from teachers' ATC to student learning outcomes. In order to test the theoretically derived hypothesises on the relation between teachers' ATC, the quality of instruction and student learning outcomes, a multilevel structural equation model was specified.

The model (Figure 2) includes two latent variables at class level: *ATC* as measured with the vignette and the video test and *instructional quality* based on the aggregated student questionnaire on instructional quality. Instructional quality was modelled as a second order factor consisting of quality of teaching methods including the four scales *pressurised teaching, student participation, explaining quali-*

Figure 2: Effects of ATC on student learning outcome mediated by quality of instruction



Note. N = 832 within 47 classes. Multilevel Structural Equation Model with standardised parameter estimations. Error terms and correlations on individual level are not displayed. P_DG = diagnosis (planning competency); P_TM = teaching methods (planning competency); P_SK = relevance of content knowledge (planning competency); T_DG = diagnosis (teaching performance competency); T_TM = teaching methods (teaching performance competency); T_CM = classroom management (teaching performance competency).
$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$ (one-tailed). Model fit: χ^2 (9, N = 47) = 7.30, p = .606, CFI = 1.000, SRMR = .057, RMSEA = .000; R^2 (class level) = 0.729.

ty, student interest in instruction and of the manifest variable *orientation towards rules*.[3]

Students' pre-test and post-test results on "germination" were included at class level as well as individual student level. Students' rating of instructional quality is supposedly not independent from their achievement (e.g., Wagner, 2008), correlations were specified at student level between instructional quality and test results (not included in Figure 2)[4].

Fit-indices are within the supposed cut-off criteria (e.g., Hu & Bentler, 1999) and therefore indicate a good model fit. ATC indicators' factor loadings are statistically significant and range between ß = .37 and ß = .72. Indicators for *quality of teaching methods* possess very high factor loadings, ranging from ß = .82 to ß = .99. High factors loadings can also be reported for *instructional quality* on *orientation towards rules* (ß = .66) and *quality of teaching methods* (ß = .65).

3 The scales measuring instructional quality were used as manifest indicators.
4 Residuals (errors terms) and correlations at individual level (students) were not included in the figure in order to enhance clarity of representation.

The direct path between ATC and student learning outcomes (ß = .19) was not significant when instructional quality was included as a mediator.[5] Therefore, it can be concluded that the effect of ATC is mediated to a large extent through instructional quality. Both paths are statistically significant: the path from ATC to quality of instruction (ß = .39), as well as the path from instructional quality to learning outcomes (ß = .38). The higher learning outcomes of students taught by teachers with higher ATC are due to the higher quality of teaching methods and to higher orientation towards rules.

As an estimation of the total effect of ATC on student learning outcomes the indirect regression weights can be multiplied and added to the direct effect (Geiser, 2010). The total effect of ATC on student learning outcomes was ß = .34, 0.15 mediated through instructional quality.

6. Discussion

6.1 Summary

6.1.1 Effects of adaptive teaching competency (ATC) on instruction quality and student learning outcomes

The main focus of this study is the exploration of the effects and relations between adaptive teaching competency, instructional quality and student learning outcome. The multilevel analysis reveals the significant effect of ATC on student learning outcome. The effect remains when other alternative variables at the level of the individual as well as the level of class are taken into account. The models included the following individual characteristics: *cognitive pre-requisites, socio-economic background* and *language spoken at home,* as well as context factors at class level, *class achievement level (pre-test result of class) class size and proportion of L1 German speaker*. Therefore, the effect is not due to confounding variables granting specific learning conditions but to adaptive teaching competency.

These results are in line with the findings of a meta-analysis on the effects of adaptive teaching on student learning outcome (Waxman, Wang, Anderson, & Walberg, 1985) as well as more recent effectiveness research also pointing at the considerable influence of the teacher on the learning outcomes of students (Lipowsky, 2006; Rivkin, Hanushek, & Kain, 2001; Seidel & Shavelson, 2007; Wayne & Youngs, 2003). Most studies, however, with few exceptions like the COACTIV-study (Kunter et al., 2011) or Lenske et al. (2016), did not systematically analyse the mediating factors. Furthermore, only little is known as to which classroom processes are transmitting the effect of professional competencies (Klieme, 2006).

5 Without the inclusion of instructional quality as a mediator, the direct effect of ATC on students' learning was statistically significant (ß = .42).

For this study a multilevel structural equation model was specified in order to test the theoretical model statistically. The results support the hypothesis, that ATC is influencing student learning outcome mediated through instructional quality. The advantage in learning outcome for classes with more adaptive teachers can largely be identified as the result of the *quality of teaching methods* and *orientation towards rules*.

6.1.2 Adaptive teachers' teaching

The statistical examination of the model supported the finding that ATC is noticeable in teachers' teaching. The results demonstrate that the quality of instruction, as perceived by the students, is higher with more adaptive teachers than for less adaptive teachers. This is especially true for those aspects of quality of instruction which are linked to meeting diverse individual learning prerequisites. The relevant aspects are *high student participation*, *explaining quality* and *less pressurised teaching*.

Some results are not in line with theoretical expectations, in particular those in relation to classroom management. There are no significant correlations between aspects of instructional quality such as *disturbance and noise* and *orientation towards rules* and adaptive teaching competency. However, other studies have also not found correlations between classroom management and professional competency. For example, in the COACTIV study, no effects of professional knowledge (content knowledge and pedagogical content knowledge) on classroom management were found (Baumert et al., 2013). The lack of correlation between measurements of the video test for classroom management and the perceived lack of discipline during a class could also be explained with the finding of Pekrun et al. (2006) that teachers with problems with discipline focus more intensely on aspects of classroom management when tested.

6.1.3 Replication of findings from teaching and learning research

In order to clarify the findings on the effects of adaptive teacher competency, various student characteristics, as well as context factors, were included as control variables. This allowed us to replicate other research findings (e.g., Helmke, 2015). That these results are in line with other research findings indicate that the data collected here provide high validity. For example, it could be found that higher achievement is linked to higher cognitive pre-requisites and with higher socioeconomic and German speaking (L1) family background. At the level of the classroom, not only adaptive teaching competency, but also a high level of class achievement and smaller class size contribute. Above average learning outcomes were achieved in classes with a higher percentage of children whose first language is other than

German: but this is a result of the controlled effect. Within the classes, students with German as a first language achieve a higher learning outcome than students with languages other than German at home.

6.2 Relevance for education

The encouraging results of the impact of ATC on teaching and student learning are relevant not only for research, but also for day-to-day teaching practice in the context of classes with heterogeneous learning needs. The results demonstrate that it is beneficial to adjust teaching to the individual learning pre-requisites of the students as more adaptive teachers achieve higher learning outcomes. Key to a successful handling of the heterogeneity of the class is the close relation between diagnosis and teaching methods (e.g., Kaiser, Praetorius, Südkamp, & Ufer, 2017; Schrader, 2017). Teachers are required to use all information on students' learning that is available, be it before, during or after lessons, in order to diagnose in formal or informal ways and to select teaching methods to address the issues identified.

For initial teacher training as well as for continuous teacher education it is particularly important to understand whether ATC can be fostered, and if so, in what ways. The results of the quasi-experimental intervention study with an intervention group and a control group integrated in the research project described in this paper showed that ATC can be fostered in terms of planning, but not in terms of teaching performance (Rogalla & Vogt, 2008; Vogt & Rogalla, 2009). Already the significant increase of adaptive planning competencies is remarkable and highly relevant for teacher training.

6.3 Methodological considerations and further research

Although advanced statistical methods were employed, the results should not be generalized. The results, however, point to further areas for research.

One of the main limitations is the topic set for the learning of the students in this study 'germination'. Effects were measured with the unit of eight lessons on the set topic. Indeed it is more useful to measure learning outcome based on a test which corresponds with the curriculum than was achieved in this study. The focus on a given unit for measuring the effects of teaching on learning is crucial, as this measurement proves to be of higher validity than a general knowledge test (Hill & Rowe, 1996; Seidel & Shavelson, 2007). However, this procedure has also a disadvantage, in that generalization of other areas of science or of other subjects is not possible. Similar effects in other areas can only be expected, arguing that ATC is a concept, which encompasses all subjects and themes. But this could best be tested empirically in the future.

The duration of the effects is also unknown. Long-term effects after the unit were not measured; it is unknown, whether the effects are sustained.

Finally, it needs to be mentioned once more that the teachers participated voluntarily. This might result in a group of participating teachers who are more engaged and committed to teaching than the average teaching population. Multilevel models calculated with data from 40 to 50 classes provide results considered to be precise enough (Hox, 2002; Lüdtke et al., 2009), which corresponds to the number of participants in this study. The findings on the effects of ATC remain stable, when additional variables were included.

Based on the findings of this research several areas can be highlighted for further research. Firstly, a more systematic measurement of classroom processes in situ could contribute to the understanding of the influence of ATC on teaching. Measuring ATC through vignettes and video tests is not as valid as the assessment of teaching itself. The relevance of instruction quality, as perceived by the students, can be an indication that ATC results in teaching in class which meets diverse learning needs. It would therefore be highly relevant to gather data on diagnostic procedures during class. Further research should seek to replicate the findings with video analysis of the teaching performed in the class for real.

Secondly, the concept of ATC could be further investigated in relation to other aspects. The relation between teachers' pedagogical knowledge and ATC could be very relevant (e.g., Voss, Kunter, Seiz, Hoehne, & Baumert, 2014). Teachers' beliefs, for example on learning and achievement, should be included.

Thirdly, an application of the concept of ATC to a large-scale study would be useful, so that more aspects could be related to ATC and more complex modelling could be used. Unfortunately, the instruments used in this study are not feasible for large-scale samples; an online version would need to be developed.

Fourthly, as mentioned above, a follow-up test is required in order to assess the sustained effects of ATC on achievement.

The need for further research indicates, that adaptive teaching competency is, as yet, only partly understood. However, in the light of heterogeneity of students, adaptive teaching competency will continue to be a concept of significant potential for teachers to meet the diverse learning needs of each individual student and to perform teaching accordingly.

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