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Journal for educational research online 11 (2019) 2, S. 169-191

Quellenangabe/ Reference:
Hardy, Ilonca; Decristan, Jasmin; Klieme, Eckhard: Adaptive teaching in research on learning and instruction - In: Journal for educational research online 11 (2019) 2, S. 169-191 - URN: urn:nbn:de:0111-pedocs-180040 - DOI: 10.25656/01:18004

https://nbn-resolving.org/urn:nbn:de:0111-pedocs-180040
https://doi.org/10.25656/01:18004

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Journal for Educational Research Online
Journal für Bildungsforschung Online
Volume 11 (2019), No. 2, 169–191
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Adaptive teaching in research on learning and instruction

Abstract

In education, adaptive teaching is commonly viewed as adjusting instruction to students' individual differences in abilities, motivation, and linguistic background. According to Corno (2008), adaptive teaching involves the adaptation of instruction on a macro level and a micro level, using methods of differentiating instruction. Despite of these broad defining properties, there is no consensus on how to assess the fit to individual learners' needs and the effects of successful adaptive teaching, as they largely depend on the specific theoretical and methodological considerations involved. In this paper, we systematize different approaches to adaptive teaching on a conceptual level. Further, we summarize the main approaches to investigating the effects of adaptive teaching and discuss the respective results. We distinguish between studies on overall effects of adaptive teaching, on ATI effects and differential effects, and studies on effects of within-class variation on student achievement. Exemplary results are highlighted to illustrate the different methodological approaches. The paper ends with implications for theoretical clarification and empirical investigation.

Keywords

Adaptive teaching; Scaffolding; Classroom process quality; Teacher expertise

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Adaptiver Unterricht in der Lehr-Lernforschung

Zusammenfassung

Im erziehungswissenschaftlichen Kontext wird adaptiver Unterricht als Anpassung von Lehrkräftehandeln an die individuellen kognitiven, motivationalen und sprachlichen Voraussetzungen von Schülerinnen und Schülern verstanden. Nach Corno (2008) beinhaltet dies Anpassungen an die Voraussetzungen der Lernenden auf der Makroebene und der Mikroebene des Unterrichts, sodass der Einsatz von differenzierenden methodischen Arrangements erforderlich ist. Jenseits dieser breiten Unterscheidungen gibt es jedoch keinen Konsens hinsichtlich der Erfassung einer gelungenen Passung und deren Wirkungen, da diese auf entsprechenden theoretischen und methodologischen Annahmen basieren. In diesem Beitrag fassen wir die unterschiedlichen Konzeptualisierungen des adaptiven Unterrichts sowie die wesentlichen methodischen Herangehensweisen bei der Untersuchung von Adaptivität zusammen. Wir unterscheiden dabei zwischen Studien zu Gesamteffekten, ATI-Studien bzw. Studien mit einer differenziellen Perspektive und Studien zur Variabilität von Schülerleistungen. Beispielhaft werden Ergebnisse vorgestellt, welche die unterschiedlichen methodischen Herangehensweisen verdeutlichen. Der Beitrag endet mit Implikationen für die Konzeptualisierung und empirische Erfassung von Adaptivität im Unterricht.

Schlagworte

Adaptivität; Scaffolding; Unterrichtsqualität; Lehrerexpertise

1. Introduction

Educational contexts typically involve students from a variety of social and linguistic background with differing cognitive, motivational, and self-regulatory resources. Recently, the consideration of individual student needs has reemerged as a major issue in theoretical, empirical, and practice-oriented work, especially in contexts with increased student heterogeneity such as inclusive educational settings. In educational research, teachers' adjustments to students' individual developmental states have been repeatedly considered a core element of effective teaching (for an overview see Parsons et al., 2018). As Corno (2008) stated, these adaptions may refer either to the macro level of instruction, as in planned programs for groups of similar students, differentiated learning material and tasks, or they may refer to the micro level of instruction, as in contingent support, on-going diagnosis and didactical moves. Interestingly, although intuitively appealing, the theoretical considerations as well as the methodological approaches regarding the construct of adaptive teaching are by no means unitary. For example, Parsons (2008) refers to adaptive teaching as "teacher action that (a) is non-routine, proactive, thoughtful, and improvisational; (b) includes a change in professional knowledge or practice;

and (c) is done to meet the needs of a student or an instructional situation" (p. 20). According to this definition, beyond a teacher's acknowledgement of individual student needs, teachers' professional knowledge, beliefs, and skills are considered prerequisites of adaptive teaching. Furthermore, the notion of adaptive teaching as non-routine and flexible is in line with Glaser's (1972) early view of adaptive teaching as "a wide range and variety of instructional methods and opportunities for success" (p. 6). The definition of adaptive teaching put forward by Corno (2008), in contrast, refers to pedagogical choices in terms of the degree of instructional support given with respect to different levels of student ability, thus focusing on teachers' considerations in instructional design and its implementation (macro-adaptivity) and in teacher-student interaction (micro-adaptivity). Weinert and Helmke (1997) conceptualize adaptive teaching as a meta-category of effective teaching and instructional quality, referring to active and proactive teacher behavior in terms of meeting individual student needs. Similarly, Walberg and Paik (2000) list "adaptive education" as one of ten categories of effective educational practices.

Besides these definitions of adaptive teaching, in a recent review of empirical literature published between 1975 and 2014 Parsons et al. (2018) identified different terminologies and theoretical foundations of adaptive teaching. They showed that in the early literature, teachers' decision making was focused on, while literature between 1995 and 2004 often referred to scaffolding and teacher reflection. The term of adaptive teaching was not used until 2008. When applying these conceptualizations in research and practice, major questions arise: How may we assess adaptive teaching on different levels of analysis? How may we judge the degree of success of adaptive teaching for individual students? What are the relations between adaptive teaching and teachers' professional competence? Which methodological approaches are useful for investigating outcomes of adaptive teaching? In this paper, we will review the core literature on adaptive teaching, point to aspects in need of theoretical clarification, and highlight promising analytical approaches.

2. Adaptive teaching: A priori considerations

According to Parsons et al. (2018), adaptive teaching is considered to be "socially constructed as teachers metacognitively reflect on students' needs before, during, and after instruction" (p. 209). Adaptive teaching thus may be regarded a type of social practice of reflective teachers in classroom settings that enables adaptations to students' individual differences and learning needs. In their review, they identified teacher factors relevant for adaptive teaching such as beliefs, experiences, knowledge, and thinking. They also identified affordances for adaptive teaching in educational settings such as the instructional approaches used and the assessment practices involved. Socio-constructivist views presume an intricate relation between the affordances for co-construction of knowledge in social or cultural contexts and individual cognitive development (Brown, Collins, & Duguid, 1989; Greeno, 1998;

Lave & Wenger, 1991; Rogoff, Baker-Sennett, Lacasa, & Goldsmith, 1995; Vygotsky, 1986). In educational settings, affordances include the physical and social resources within a learning environment, thus leaving teachers with a variety of options in instructional design to provide learning opportunities, and leaving learners with a variety of options for their enactment.

Against this theoretical background and based on the categories identified by Parsons et al. (2018), we put forward some preliminary considerations on adaptive teaching before reviewing the literature and correspondent methodological approaches for assessing adaptive teaching. We suggest to differentiate between *intended* adaptive teaching and *implemented* adaptive teaching, presuming that teachers vary in the degree to which their instructional design and planned learning activities allow for adaptations to student needs in the first place. Intended adaptive teaching thus refers to teachers' pedagogical intentions in instructional design and is primarily based on their use of diagnostic tools and their a priori considerations of students' learning prerequisites. Implemented adaptive teaching refers to adaptive teaching episodes during classroom instruction in which teacher-intended activities are actually taken up by the students; in this sense, there is an alignment of intention and situational enactment. Successful adaptive episodes will in the long run support self-regulated learning of students within educational settings (Corno, 2008). In-situ use of diagnostic tools and strategies of questioning and feedback support teachers in their implementation of adaptive teaching on a micro-level. These considerations of adaptive teaching also encompass a causal impact of adaptive teaching episodes on related student outcomes.

Consideration 1: Teacher decisions in instructional design, including the assembly of tasks, materials, and instructional methods, are conceptualized as *intended* adaptive teaching if they refer to teacher actions or instructional choices that are based on (formally or informally) diagnosed individual student needs and learning states (cf. Parsons, 2008). These teacher actions may involve decisions with respect to individualized student support with respective material and verbal supports, methods of differentiated instruction for groups of students, or long-term supports within a classroom community. Along these lines, Randi and Corno (1997) describe adaptive teaching as efficient for group instruction and, at the same time, respectful to individual learning profiles and patterns. As students are to achieve increasing autonomy by taking on responsibility of their learning, intended adaptive teaching will also incorporate goals of self-regulated learning (Corno, 2008). This implies that teachers teach students strategies for self-regulated learning and choose tasks in a way to enable increasing student autonomy, for example by fading scaffolds over time. Intended adaptive teaching also means that teachers are able to verbalize and explain their instructional decisions either in lesson planning or in post-hoc reflections, linking decisions to diagnostic information and student learning progressions.

Consideration 2: As students are active learners, features of teacher-designed learning environments may be perceived by students and taken up as intended, but they may also be transformed and re-interpreted by students. This corresponds

to the notion of individual learners' perception of social and physical affordances within learning environments and their respective acting on those. *Implemented* adaptive teaching means that an alignment of the intended adaptive design, respective in-situ didactical moves on the part of the teacher and an uptake of this learning environment on the part of students are observed. With respect to the level of analysis, implemented adaptive teaching may be segmented into adaptive teaching episodes of different grain sizes. Adaptive teaching episodes will involve evidence of teachers' on-going diagnosis and respective moves such as questioning, prompting, explaining or giving feedback. Similarly, Parsons, Dodman, and Burrowbridge (2013) propose that for differentiating instruction to be implemented successfully, student individual learning paths on a micro level need to be considered.

Consideration 3: If students' interpretations and actions match with a teacher's proposed learning needs on a macro level and a micro level of instruction, this alignment should eventually be evident in successful student learning trajectories, i.e., individual learning outcomes, developmental patterns, or in-situ evidence of learning.

Consideration 4: Given these constraints, we may then ask for facets of teacher professional competence associated with the frequency of adaptive teaching episodes such as teacher knowledge of individual differences, diagnostic competencies, frequency of reflection and meta-cognition, self-efficacy, and epistemological beliefs (Beck et al., 2008; Parsons et al., 2018).

In the following sections, we elaborate on elements of adaptive teaching that refer to the four considerations listed above. We consider the diagnosis of students' individual learning prerequisites and developmental states as a prerequisite of adaptive teaching under consideration 1. Similarly, we consider research approaches on adaptive teaching on a macro level and a micro level of instruction as relevant to the distinction between intended and implemented adaptive teaching (cf. considerations 1 and 2), although this distinction is rarely pursued explicitly. After summarizing research on teacher professional competence related to adaptive teaching (cf. consideration 4), we suggest methodological approaches to assessing successfully implemented adaptive teaching episodes (cf. consideration 3).

3. Review of research on aspects of adaptive teaching

3.1 Taking individual differences into account

A prerequisite for adaptive teaching episodes is teachers' consideration of relevant individual student characteristics prior to and/or during instruction. To describe interindividual learner variation, different categorizations of learner characteristics have been suggested. For instance, Heinzel (2008) defines five dimensions of student heterogeneity: socio-economic status, ethnicity or cultural background, abilities, gender, and generation/age – all of which have been related to students'

long-term academic success in empirical research. In addition, Hamre and Pianta (2005) distinguish between two central risk categories: demographic risks and functional risks of school failure. Demographic risks involve dimensions related to family background (i.e., socio-economic status, ethnicity or cultural background). Functional risks refer to individual student characteristics such as executive functioning, cognitive, behavioral, or domain-specific disorders, as well as students' varying ability to perform the adaptations required for social learning processes in the classroom (see also Hasselhorn, Andresen, Becker, Betz, Leuzinger-Bohleber, & Schmid, 2015). Beyond these categories frequently related to academic careers in large-scale studies and comparative group designs, instructional design is based on learner characteristics on an affective, motivational, cognitive, and social level. Along these lines, Tomlinson et al. (2003) list student readiness, interest and motivation, and learning profiles (including intelligence, gender, and culture) as relevant student characteristics for differentiating instruction.

To what extent do teachers perceive of and act on the heterogeneous student population within their classes? In order to enable the type of intended adaptive teaching described in the last section, teachers need to apply methods of diagnosing students' current understanding and preconditions for further learning. These methods include diagnostic instruments such as standardized achievement tests, language proficiency tests, and screenings as well as the ongoing diagnosis of student understanding using formative assessment tools. Formative assessment refers to the repeated use of assessment-based information to recognize and respond to student learning for the purpose of fostering development (Bell & Cowie, 2001; Black & William, 1998; Kingston & Nash, 2011), thus aligning assessment, instruction, and learning goals (Wilson & Sloane, 2000). It has been successfully used in secondary science and math education (Furtak, Morrison, & Kroog, 2014; Rakoczy, Harks, Klieme, Blum, & Hochweber, 2013) and recently in elementary science education to further students' conceptual understanding (Decristan, Hondrich et al., 2015). According to van de Pol, Volman, and Beishuizen (2012), the diagnosis of students' understanding is a prerequisite for tailored support – the type of support that has also been described within the context of formative assessment practices. Formative assessment has in fact been conceived of as a cycle starting with diagnostic strategies for assessing students' current understanding, followed by the validation of this estimate, and the use of this information for instructional task design and intervention (Ruiz-Primo & Furtak, 2007). Beyond assessment practices to gauge students' individual preconditions and current levels of understanding, teachers' overall judgment of within-class variability in student achievement may affect the way in which teachers respond to individual learners' needs in instruction. It is in this sense that adaptive teaching has been characterized as "deeply psychological" (Corno, 2008, p. 163). Corno suggests that teachers vary in the degree to which they view learner variation as "obstacles to be overcome" rather than as "opportunities for learning". Similarly, Prengel (2006) argues that within educational settings, differences between students are to be acknowledged without accompanying value judgments, evident in patterns of supportive teacher-student

interactions. Corno proposes that teachers who view learner variation as obstacles tend to deal with students' achievement heterogeneity by using homogenous grouping or individualized instruction. Teachers who view learner variations as opportunities for learning tend to provide challenging and supportive learning environments that enable all students to profit from each other. Thus, while adaptive teaching is regarded as a way to recognize and (proactively) act on student individual differences in instruction, it needs to be kept in mind that instruction is a dynamic process, and adaptation is by no means a fixed parameter referring to single students. In this sense, the long-term goals of instructional adaptations include the creation of learning spaces for individual learners within a "community of learners", capitalizing on the strengths of heterogeneous groups, and thereby supporting the self-regulated learning of all students (Behrensen, Gläser, & Solzbacher, 2015; Corno, 2008).

3.2 Adaptive teaching on a macro level

Instructional adaptations include practices on a macro level and on a micro level of adaptation. While micro adaptations are those decisions that teachers make on a moment-to-moment basis in classroom instruction, Corno and Snow (1986) describe macro adaptations as rather large-scale adjustments in instruction, informed by formal assessments. Similarly, Corno (2008) and Klieme and Warwas (2011) refer to macro adaptations as structured programs that have been designed for students with similar individual capabilities such as in gifted education or in instruction for students with limited language proficiency, pursuing the goal of individual enhancement and prevention of further risks for educational careers. There is a large body of empirical evidence on the effectiveness of early intervention programs such as instruction of literacy and numeracy if these programs are implemented with high quality over an extended amount of time (e.g., Hasselhorn & Kuger, 2014; Weiland & Yoshikawa, 2013). Likewise, practices of pull-out or partial pull-out programs are found in many countries as a means to meet individual learner needs within homogeneous grouping approaches (for a comparison of program effects for students with cognitive disabilities see Marston, 1996). Beyond these programs, teachers' instructional decision-making concerns formats of differentiating instruction within classroom communities. According to Tomlinson et al. (2003), differentiating instruction includes teaching in a proactive way, where teachers modify curricula, teaching methods, or resources to create optimal learning environments for all students. Overall, three aspects of differentiating instruction may be distinguished. On an organizational level, students may be assigned to subgroups according to different methods, media, content, or forms of social interaction. On a didactical level, students may be provided with different learning material and tasks according to individual interest, motivation, level of competency, or cognitive ability. On a level of instructional design, students may take part in

long-term activities of self-regulated learning such as individualized schedules or methods of cooperative learning (overview in Haag & Streber, 2014). For example, task differentiation may involve the assignment of groups of students with different prior knowledge and/or self-regulatory capabilities to tasks with different levels of content-related learning goals (difference of learning goals) and a more or less structured sequence of solution steps toward the same learning goal (indifference of learning goals). Yet, teachers report that they employ formats of differentiating instruction only rarely, both in elementary and in secondary education (see Tomlinson et al, 2003). In Germany, differentiation via additional time rather than via variation in task difficulty seems to be most prominent (Bos, Hornberg, Bonsen, & Buddeberg, 2008).

Following Corno (2008), teacher practices of differentiation are successful if they capitalize on the variability of student learning prerequisites (cf. Parsons et al., 2018). That is, instructional contexts that take into account learners as part of a community of learners, intending to move them towards a common core (or "the center") rather than to compensate for individual weaknesses will eventually serve a pedagogical goal of adaptivity. Therefore, one challenge to teachers is the coordination of individual and social activities that effectively consider individual students' needs. According to the socio-constructivist view, the co-construction of knowledge in discourse is pivotal for individual cognitive development. Arrangements such as structured cooperative learning activities may then serve a two-fold goal of individual participation and productive use of heterogeneity in student achievement. For example, peer tutoring has proven to be an effective method especially with heterogeneous ability grouping of students, leading to persistent effects in social, motivational, and achievement measures (Ginsburg-Block, Rohrbeck, & Fantuzzo, 2006; Rohrbeck, Ginsburg-Block, Fantuzzo, & Miller, 2003). It has been defined as "a class of practices and strategies that employ peers as one-to-one teachers to provide individualized instruction, practice, repetition, and clarification of concepts" (Utley & Mortweet, 1997, p. 9). Presumably, the processes of co-construction of knowledge, the fulfilment of basic needs of autonomy, competency, and social inclusion, and the corresponding social attractiveness of peers lead to positive effects (e.g., Fuchs, Fuchs, Mathes, & Martinez, 2002; Jordan & Métais, 1997). This line of research also points to the necessity to regard adaptive teaching as a long-term process in which students are slowly enculturated into practices of increasing autonomy before positive effects on student outcomes emerge. For example, Adl-Amini (2018) found that only after an extended phase of implementation of peer tutoring in elementary science education, student conceptual understanding increased. Furthermore, only in classes with high levels of cognitive ability was peer learning implemented with a high degree of adherence to the program goals. Apparently, teachers of students with low cognitive ability preferred controlled environments with low degrees of student autonomy so that they were not inclined to implement peer-learning activities. Along these lines, Corno (2008) proposes two continua, the support continuum and the learners' abilities continuum, which are co-considered when deciding on appropriate methods of in-

struction. Yet, the degree to which methods of differentiation employed on a macro level actually corresponds to students' individual preconditions is rarely investigated in detail; rather it is the outcomes of students' assignment to grouped formats of differentiation that is of interest.

3.3 Adaptive teaching on a micro level

The micro level focuses on teachers' processes of adaptive support on a moment-to-moment basis. One may distinguish between a contingency perspective, which is based on the construct of scaffolding, and a perspective of instructional quality, emphasizing relevant instructional processes on a classroom level. Reiser (2004) points to the difficulty of achieving an optimal level of instructional support for all learners. To realize these supports, teachers need to track individual students' content understanding and proactively structure learning activities in instructional task design. Here, learning may be conceptualized in terms of "multiple zones of proximal development" (cf. Palincsar, 1998), including supports by verbal interaction with the teacher and peers, by models, artifacts, and other symbolic or computerized support systems.

3.3.1 Scaffolding and contingent support

The construct of scaffolding was introduced by Wood, Bruner, and Ross (1976) to describe those forms of adaptive support enabling learners to successfully work through tasks which they otherwise would not be able to perform. Whereas early work on scaffolding concentrated on tutorial situations with a tutor – usually the teacher – and a student, the construct has also been transferred to classroom teaching in theoretical considerations (e.g., Clark & Graves 2005; Hogan & Pressley, 1997; Stone 1998a, 1998b) and recent empirical work (e.g., Nathan & Kim, 2009; Smit, van Eerde, & Bakker, 2013; van de Pol, Volman, Oort, & Beishuizen, 2015). The main characteristics of scaffolding in tutorial situations have been put forward by Puntambekar and Hübscher (2005) and more recently by van de Pol, Volman, and Beishuizen (2010). They include the characteristics of contingent support, transfer of responsibility (fading), and use of diagnostic strategies. In addition, Puntambekar and Hübscher (2005) refer to the construction of shared understanding between tutor and tutee as a prerequisite for contingent support. Different means of scaffolding are distinguished. Among these are: feeding back, explaining, modeling, questioning (van de Pol, Volman, & Beishuizen, 2011), cueing specific or general elements, cueing specific strategies (Beed, Hawkins, & Roller 1991), verifying and clarifying understanding (Roehler & Cantlon, 1997), framing the goal, refocusing the discussion, attending to conflicts and differences, prompts for refinement of language (Hogan & Pressley, 1997), and reacting to errors as opportunities for learning (Wischgoll, Pauli, & Reusser, 2015). Parsons

et al. (2018) refer to questioning, encouraging, managing, giving feedback, making connections, assessing, modeling, explaining, and challenging as the most frequent types of teacher adaptions in the research they reviewed. On a higher-order level of classification, Pea (2004) employs the functions of focusing and modeling. Focusing points to teachers' structuring of content with the intention of focusing learners' attention to essential aspects of a task by prompts or by reducing degrees of freedom during task solution. Modeling means teachers' intentions to gradually enculturate learners into relevant domain-specific practices, including strategies such as the use of representational means, explication of solutions, and content-directed prompts. Reiser (2004) refers to structuring content and problematizing (of concepts, preconditions, models) as functions of scaffolding, whereas Krammer (2010) distinguishes between scaffolding strategies on a level of emotions (initiate and keep up student motivation to solve a task and to manage frustration), of procedures (structuring and managing student solution processes), and of content (providing prompts for relevant task features and solution models). These functions emphasize that scaffolding employs adaptations in a multidimensional way, including cognition, affect, and self-regulation, with the goal of continuous task-engagement and transfer of responsibility (cf. van de Pol et al., 2010).

When principles of scaffolding are transferred from individualized tutoring to classrooms, additional aspects are relevant. In this regard, the "2 sigma problem" raised by Bloom (1984) points to the empirically greater efficacy of one-to-one tutoring in comparison to learning situations in a classroom context – an issue rendering questionable the direct transfer of tutorial support principles to the classroom. It suggests that teachers will have to employ different methods in larger groups than in one-to-one tutoring in order to achieve positive outcomes for all students. Accordingly, when transferring scaffolding to the classroom, Hogan and Pressley (1997) refer to the consideration of multiple zones of development with large groups of students, their diverse communication styles, curriculum and time constraints, the need for student assessment, the ownership of ideas, and the uncertainty of endpoints in classroom discussions. Smit et al. (2013) add that the layered, distributed, and cumulative nature of scaffolded discourse in the classroom constitute the most distinctive elements. A prominent application of scaffolding to classroom contexts has been pursued by Hammond and Gibbons (2005) who use strategies of scaffolding to support students of English as a second language. In their approach, micro scaffolding refers to means of enriching classroom discourse to meet individual second language learners' needs. Macro scaffolding, in contrast, is concerned with teachers' planning of classroom activities based on the diagnosis of individual language competence and the formulation of language and content learning goals.

Apart from the means and functions of scaffolding (van de Pol et al., 2010), an important consideration concerns finding the appropriate level of support. According to Wood, Wood, and Middleton (1978), the *Contingent Shift Principle* shall determine whether a specific teacher action is contingent on student behavior: If a student does not solve a task, an increase of (teacher) control follows, with

control defined as the degree of explicit information and instruction provided. If a student does solve a task successfully, a decrease of (teacher) control follows (van de Pol et al., 2012). In the *Optimal Scaffolding Distance Parameter* (van Geert & Steenbeek, 2005) contingency is defined as support in relation to a student's current level of understanding. The optimal distance of support may be computed according to a rule assuming that learning effects tend toward zero if support is given at a distance too close or too distant from a student's current level of understanding. Beyond these theoretical distinctions, in a number of studies teachers' uses of scaffolding in instructional settings were analyzed (van de Pol et al., 2010). In regular classrooms, teachers' use of diagnostic strategies in discourse is generally low, therefore an adequate basis for the provision of contingent support may be lacking (Lockhorst, Wubbels, & van Oers, 2010; van de Pol et al., 2012). In other studies, teachers' adaptations in instructional classroom discourse and accompanying parameters of contingent support were investigated in detail. For example, Nathan and Kim (2009) found that teachers related their prompts and questions to prior assessment of students' mathematical understanding during class discussions. Van de Pol et al. (2015) found that in group work, teacher contingent support was most effective in instructional settings with a high degree of student independent work if the variable of student task effort was considered in the analyses. Van de Pol, Mercer, and Volman (2018) used a mixed methods design to investigate the extent to which students pick up teacher support in small group work and their effects on learning outcomes. Using a large sample of 35 lessons, their study employed both mediation analyses and exemplary in-depth description to pinpoint the role of contingency and fading of instructional support, revealing that uptake of students occurred especially with timely fading of support in contingent interactions. This study points to the necessity of further empirical evidence for the theoretically proposed mechanisms of a link between contingent support and learning within the scaffolding literature.

3.3.2 Processes of classroom instructional quality

Besides the tradition of scaffolding research, adaptive teaching may be considered a meta-category (Weinert & Helmke, 1997) or a specific component of effective, high quality instructional practice (Walberg & Paik, 2000). Thus, there is a partial convergence of adaptive teaching with constructs of teaching quality such as instructional support or supportive climate. Instructional support typically refers to the degree to which teachers aim to promote students' conceptual understanding, e.g., by employing teacher prompts to explore students' prior knowledge, using higher-order thinking tasks, and stimulating cognitive conflicts (Baumert et al., 2010; Lipowsky et al., 2009). When comparing classrooms with different degrees of instructional support using high inference ratings, one finds that these types of support are predictive of student cognitive learning outcomes (e.g., Fauth, Decristan, Rieser, Klieme, & Büttner, 2014; Kunter et al., 2013; Pianta & Hamre,

2009). These findings hold across different subjects (mainly mathematics, science) and age groups (secondary school, elementary school). Likewise, the construct of emotional support describes teacher behavior that takes student concerns seriously, provides constructive feedback, and takes student errors and misconceptions as learning opportunities, among others (e.g., Brophy, 2000; Hamre & Pianta, 2005; Klieme, Pauli, & Reusser, 2009). Empirical findings show an impact of emotional support on students' feelings of relatedness and their peer relationship, which in turn affects their interest in academic activities, engagement, and academic achievement (e.g., DeRosier, Kupersmith, & Patterson, 1994; Wentzel, Battle, Russell, & Looney, 2010). In contrast to definitions of scaffolding and the conditions for adaptive teaching episodes outlined above, the diagnosis of student preconditions in teacher action is taken up only implicitly in instruments of instructional quality. Accordingly, indicators of instructional quality aim at judging teachers' successful consideration of students' conceptual, linguistic, and motivational preconditions in classroom activities by high-inference ratings (cf. indicators used in the CLASS system; Hamre & Pianta, 2005).

The strong empirical findings within this perspective and the conceptual overlap with teacher scaffolding such as prompting, questioning, and explaining allude to a potential benefit of merging these process-oriented perspectives. For example, approaches to investigating adaptive teaching at the macro level such as forms of differentiating instruction or cooperative learning may be specified further by relating their implementation to a micro level of cognitive and emotional support. Decristan, Klieme, et al. (2015) showed an interaction between the use of formative assessment practices at the macro level and dimensions of classroom process quality with regard to student achievement. Students benefited most from teaching that combined formative assessment strategies with high levels of classroom process quality. A further combination of approaches is proposed by Howe (2013) in a framework for investigating peer learning activities with an emphasis on scaffolding on a micro-level, focusing on its potential to resolve cognitive conflicts between peers as a relevant condition for conceptual change. These types of analyses thus may provide insights into the quality of processes on a micro level necessary to successfully implement formats of adaptive teaching on a macro level.

4. Relation of adaptive teaching and teacher professional competence

As outlined above, the degree to which adaptive teaching is implemented in classrooms is likely associated with teacher professional competence. At least two lines of research are relevant: One prominent theoretical approach is based on Shulman's distinction of different aspects of professional knowledge associated with successful teaching. With regard to adaptive teaching, diagnostic knowledge and knowledge of assessment routines, pedagogical knowledge, epistemological be-

liefs of learning and teaching, beliefs on differentiating instruction, and beliefs of learner characteristics are likely relevant teacher characteristics (e.g., Beck et al., 2008; Dubberke, Kunter, McElvany, Brunner, & Baumert, 2008; Jordan, Glenn, & McGhie-Richmond, 2010; Jussim & Harber, 2005). There is empirical evidence of systematic relations between teacher beliefs, instructional arrangements employed, and student motivational and cognitive outcomes, accompanied by theoretical models of moderator variables on these relationships (Fives & Gill, 2014).

Another prominent approach conceives of teaching competence as flexible teaching (see also Beck et al., 2008; Glaser, 1972; Parson, 2008). Here, it is the degree to which teachers are able to deal with unplanned situations in the classroom that is conceptualized as a variable distinguishing between teachers, related to effectiveness of instruction (Fairbanks et al., 2010; Parsons, 2008, 2012). For example, Darling-Hammond and Bransford (2005) view adaptive expertise as teachers' ability to effectively establish routines and procedures in the classroom while also being able to deal with the complexity of classroom instruction. Parsons (2012) investigated teachers' adaptations in literacy instruction and compared two teachers' profiles selected from a larger sample of teachers. Based on observations, teachers' lesson plans, and interviews after each observed lesson, he found adaptations on the following levels of instruction: Modification of lesson objective, means by which objectives are met, inventing an example or analogy, inserting a mini-lesson, suggesting different solution procedures, omitting planned activities or assignments, inserting unplanned activities or assignments, changing the planned order of instruction. However, Parsons, Davis, Scales, Williams, and Kear (2010) showed that teachers' adaptions might not be as thoughtful as researchers have previously proposed.

5. Investigating the outcomes of adaptive teaching

5.1 Comparison of overall learning gains

An obvious approach to assessing adaptive teaching is to estimate its contribution to successful student learning outcomes. In fact, Oh (2005) suggests that with the construct of scaffolding, the success of the employed scaffold is already required *per definitionem*. It is especially in studies with experimental designs that these causal relations are investigated, ranging from laboratory experiments to quasi-experimental studies realized in actual school contexts. For example, Murphy and Messer (2000) investigated the effects of scaffolding activities with a balance beam by with five to seven-year-olds in a controlled laboratory setting. Individual pre- and posttests assessed children's development of conceptual knowledge in two conditions, varying in degree of explanations and prompts given in comparison to a control condition with individual work. They showed that scaffolding was superior in all of the investigated student outcomes except for an abstract nonverbal

task. In a teaching experiment with six intervened classrooms and three baseline classrooms, Hardy, Jonen, Möller, and Stern (2006) investigated the effects of instructional support (high/low) on third-graders' conceptual understanding. It was shown that instructional support in terms of structured instructional discourse and a sequenced curriculum was associated with long-term gains in conceptual knowledge. Similarly, in a sequence of experimental and quasi-experimental studies, Rakoczy et al. (2013) examined teachers' adoptions of different forms of formative assessment practices in secondary mathematics instruction.

In the recent cluster-randomized IGEL (Individual Support and Adaptive Learning Environments in Primary School) study with a total of 54 teachers and 1,070 third-grade students from 39 German primary schools three instructional conditions varying adaptive teaching methods were investigated. After intensive teacher professional development, the participating teachers employed the methods of scaffolding instructional discourse (SID), peer tutoring (PT), or formative assessment (FA) in their classes. In the SID classes, teachers guided students' learning by eliciting their preconceptions, by drawing attention to essential concepts, and by providing prompts within instructional discourse. In the PT classes, a reciprocal student tutoring approach was used, thus students switched the roles of the tutor (who explained the learning content) and tutee (who was assumed to learn from the tutor) according to given rules. This interaction was supported by material that included change-of-role-signs on the worksheets (for details see Adl-Amini, Decristan, Hondrich, & Hardy, 2014). In the FA groups, teachers used students' answers to diagnostic tasks to provide each student with an individual, written, and informative feedback on his or her current level of understanding and on his or her subsequent learning task on an appropriate level of difficulty (for details see Hondrich, Hertel, Adl-Amini, & Klieme, 2016). Results of this study showed that teachers in the FA classes were most successful in providing support for their students' conceptual development (Decristan, Hondrich, et al., 2015). However, it remains to be shown in detail how the intended adaptive teaching in the instructional design was actually implemented by the participating teachers to match students' learning needs. Among others, video data, transcribed verbal interactions, as well as statistical models with mediating and moderating variables may be employed in multi-method approaches to shed light on the proposed causal mechanisms implicit in the experimental design.

5.2 Methodological approaches within ATI research

Outcomes of adaptive teaching may be well investigated by methodological innovations within the aptitude-treatment-interaction (ATI) paradigm (see Cronbach & Snow, 1977). Within this paradigm it is assumed that learner characteristics and learning environments are differentially related to student learning outcomes. For example, Corno (1979) investigated the interaction of student cognitive and affective predispositions and teacher classroom behavior with respect to achieve-

ment. In retrospect, the early studies on ATI showed that only few interactions held across several contexts. Among the persisting results is the one that teaching approaches with high levels of structure and explicit instruction are beneficial for students with low abilities and from families with low socio-economic status (see Weinert & Helmke, 1997). Methodologically, these studies have several shortcomings. Most importantly, they did not consider appropriately that students are nested within classes. Furthermore, the ecological validity of many studies is low since treatments (teaching conditions) included highly artificial laboratory conditions. Recently, researchers renewed this strand of research. For example, in the IGEL study, Decristan, Hondrich, et al. (2015) analyzed the differential effects for students at risk within specific treatments: Using hierarchical linear modelling and the specification of cross-level-interactions (individual level: students' risk variable; classroom level: treatment), students with low language proficiency were shown to particularly benefit from teacher-scaffolded discourse (SID) as well as from FA. Treatments focusing on the diagnosis of student prior knowledge, on individualized feedback, and on structuring content knowledge thus provided extra support for conceptual growth of students at risk. Studies investigating differential instructional effects consistently show that at-risk students perform better in classrooms of high-quality instructional support than in classrooms of low instructional quality (e.g., Curby, Rimm-Kaufman, & Ponitz, 2009; Hamre & Pianta, 2005). Also, Decristan, Kunter, Fauth, Büttner, Hardy, and Hertel (2016) examined whether students with demographic risks (i.e., immigrant background) and functional risks (i.e., low cognitive abilities) benefit from high extents of process quality (i.e., classroom management and classroom climate/emotional support). The authors showed that in classes with high instructional quality, students from immigrant families scored higher than their peers. In addition, students with low cognitive abilities particularly benefited from an effective classroom management.

5.3 Estimating effects on variability in student characteristics

Instructions with individualized support presumably provide equal learning opportunities for students of different abilities. Yet, it is both a normative and an empirical question if adaptive teaching will go along with decreased variability of student achievement within classes. If individual students' learning needs are met, adaptive teaching might also result in increased intra-class variability in student achievement. Technically, heterogeneity refers to the extent to which students within a given group (e.g., classes, schools) differ with respect to a certain dimension (e.g., abilities). Hence, heterogeneity is considered a group-level variable rather than an individual characteristic. Kluczniok, Große, and Roßbach (2011) differentiate between three approaches: Heterogeneity as a measure describing an entire sample, heterogeneity describing variance within groups, and heterogeneity describing variance between groups. For example, in addition to class-level mean abilities, within-class variation in abilities has been used as an indicator of class composition

when studying differences within and between classes. Studies using within-class variation in student ability as a predictor typically failed to show systematic relationships to student learning (e.g., Gröhlich, Scharenberg, & Bos, 2009; Künsting, Post, Greb, Faust, & Lipowsky, 2010). However, recently, Decristan et al. (2017) examined the interplay between dimensions of instructional quality and intra-class variability in students' abilities. They showed that students in classes of heterogeneous ability particularly benefitted from high cognitive activation and a supportive climate. In addition, research on optimal learning outcomes, labeled "optimal classes" (for a summary see Schwippert & Walker, 2003), points to the role of instructional quality for learning outcomes. In optimal classes, two instructional goals are reached simultaneously: raising achievement for all students and increasing alignment of achievement between high-achieving and low-achieving students. Thus, above-average improvement in mean achievement is combined with a reduction of intra-class variability in student achievement. Helmke (1988) showed that the profiles of optimal classes display efficient classroom management, a focus on the learning content, higher-level tasks, diagnostic competence, a positive teacher-student relationship, and adaptive teaching. Using univariate analysis of variance it was shown that teachers in optimal classes showed a significantly higher focus on the learning content and on adaptive teaching than those of comparative classes (Helmke, 1988, p. 62f).

6. Discussion: Adaptive teaching as a messy construct?

In this paper, we focused on the construct of adaptive teaching on a macro level and a micro level of instruction and related it to methodological approaches for investigating outcomes of adaptive teaching. The research on adaptive teaching presented here shows that greater precision and alignment in conceptual and methodological approaches are needed: For example, while methodologically, research with a focus on outcomes of adaptive teaching and its differential effects on students seems to be promising, the respective theoretical models specifying macro- and micro-adaptations are still vague. Also, empirically validated models of adaptive teaching as an aspect of teacher professional competence are lacking (cf. Beck et al., 2008; Kunter et al., 2013). This may be due in large part to the lack of instruments allowing the reliable and valid assessment of adaptive teaching behavior, such as teachers' reflection on action and reflection in action (see Parsons et al., 2018). Here, analyses employed within the studies of adaptive expertise by Parsons (2012) need to be highlighted. He investigated teachers' choices and adaptations by comparing them to preplanned lessons within an innovative methodological approach. Small-scale observations of classroom instruction may therefore be combined with teachers' reflection on their action to arrive at an empirical indicator of adaptive teaching. Taking indicators of teacher expertise as reflection on action may also allow researchers to relate teacher competence to instructional be-

havior on a micro level and a macro level empirically, thereby considering adaptive teaching as an individual difference variable. Finally, the consideration of student perceptions of adaptive teaching can be employed in studies of triangulation, combining student-perceived teaching quality, observer ratings of adaptive teaching, and measures of teacher competence in multimethods designs. If one recurs to the four considerations on adaptive teaching outlined in section 1, it is especially the measures of intended adaptive teaching within units of contingent teacher-student behavior that present challenges. Choices on the level and detail of analysis (as in codings of utterances, time-based codings, qualitative analyses of episodes, or high inference ratings) typically are embedded within different theoretical models of contingency. For example, Wood, Bruner, & Ross (1976) and van de Pol et al. (2010) propose to take student understanding as the basis for subsequent contingent teacher reaction. In our model, in contrast, teacher-intended adaptive design (and the respective deviations from it) would have to be considered as well.

Conceptually, the relation between adaptive teaching and ongoing diagnosis needs to be addressed in more detail. Teachers' use of appropriate formative, summative, and standardized diagnostic instruments to assess students' preconditions and content comprehension during instruction have been put forward in models of formative assessment practices (Ruiz-Primo, 2011), scaffolding (van de Pol et al., 2010), and teacher diagnostic competence (Schrader, 2013). To meet students' needs, various strands of assessment practices typically are interwoven with instructional decisions on a macro level and a micro level. While the quality of teachers' formative assessment practices shows an impact on student cognitive and motivational outcomes (Briggs, Ruiz-Primo, Furtak, Shepard, & Yin, 2012; Hondrich et al., 2016), useful connections between formats of differentiating instruction and teachers' associated formative assessment practices still need to be pinpointed. Most of the proposed lines of research imply that a combination of methodological approaches is needed especially in the stages of research where analytical categories are still being refined. In sum, the concept of adaptive teaching is still, or again, a promising field of research that needs to be addressed in more detail with regard to relations between teacher competence, teacher expertise, diagnostics, and instructional behavior.

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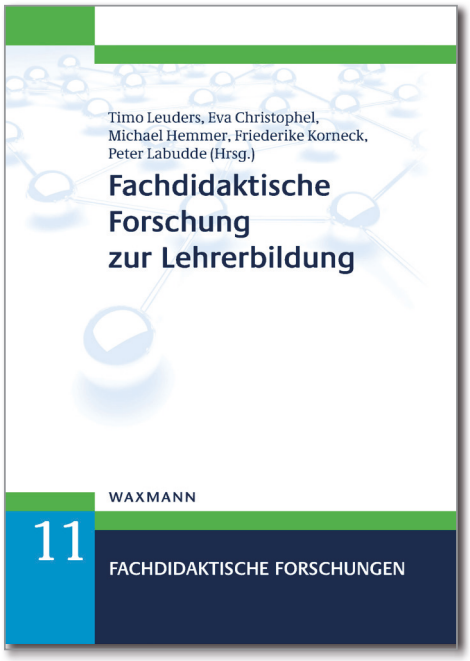

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