School Effectiveness and School Improvement
An International Journal of Research, Policy and Practice

ISSN: 0924-3453 (Print) 1744-5124 (Online) Journal homepage: https://www.tandfonline.com/loi/nses20

Capturing the complexity of differentiated instruction

Marieke van Geel, Trynke Keuning, Jimmy Frèrejean, Diana Dolmans, Jeroen van Merriënboer & Adrie J. Visscher

To cite this article: Marieke van Geel, Trynke Keuning, Jimmy Frèrejean, Diana Dolmans, Jeroen van Merriënboer & Adrie J. Visscher (2019) Capturing the complexity of differentiated instruction, School Effectiveness and School Improvement, 30:1, 51-67, DOI: 10.1080/09243453.2018.1539013

To link to this article: https://doi.org/10.1080/09243453.2018.1539013

© 2018 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group

Published online: 08 Nov 2018.

Submit your article to this journal

Article views: 10636

View related articles

View Crossmark data

Citing articles: 4 View citing articles

Full Terms & Conditions of access and use can be found at
https://www.tandfonline.com/action/journalInformation?journalCode=nses20

SCHOOL EFFECTIVENESS AND SCHOOL IMPROVEMENT
2019, VOL. 30, NO. 1, 51–67
https://doi.org/10.1080/09243453.2018.1539013

Routledge
Taylor & Francis Group

ARTICLE

OPEN ACCESS Check for updates

Capturing the complexity of differentiated instruction

Marieke van Geel [a], Trynke Keuning [a], Jimmy Frèrejean [b], Diana Dolmans[b], Jeroen van Merriënboer[b] and Adrie J. Visscher [a]

[a]Department of Teacher Development, University of Twente, Enschede, The Netherlands; [b]School of Health Professions Education, Faculty of Health, Medicine and Life Sciences, Maastricht University, Maastricht, The Netherlands

ABSTRACT

Providing differentiated instruction (DI) is considered an important but complex teaching skill which many teachers have not mastered and feel unprepared for. In order to design professional development activities, a thorough description of DI is required. The international literature on assessing teachers' differentiation qualities describes the use of various instruments, ranging from self-reports to observation schemes and from perceived-difficulty instruments to student questionnaires. We question whether these instruments truly capture the complexity of differentiation. In order to depict this complexity, a cognitive task analysis (CTA) of the differentiation skill was performed. The resulting differentiation skill hierarchy is presented here, together with the knowledge required for differentiation, and the factors influencing its complexity. Based on the insights of this CTA, professional development trajectories can be designed and a comprehensive assessment instrument can be developed, enabling researchers and practitioners to train, assess, and monitor teaching quality with respect to providing differentiated instruction.

KEYWORDS

Differentiated instruction; cognitive task analysis; primary education; mathematics; assessment

Differentiation as part of teaching quality

Ideally, teachers should not use a one-size-fits-all basis but differentiate instruction activities deliberately so that students receive instruction that matches their needs (George, 2005). Parsons et al. (2018) even stated that adapting instruction is "a cornerstone of effective instruction" (p. 206) and "considered the gold standard teachers should strive for" (p. 206). This is not an easy task; differentiated instruction (DI) is regarded as a complex teaching skill (Deunk, Doolaard, Smale-Jacobse, & Bosker, 2015; Van de Grift, Van der Wal, & Torenbeek, 2011). Research by the Dutch Inspectorate of Education (Inspectie van het Onderwijs, 2014, 2015a, 2015b) showed that teachers insufficiently adapt their instruction to student differences. Furthermore, the majority of beginning teachers feel unprepared for this task (Inspectie van het Onderwijs, 2015a). As such, it would be desirable to design a professional development trajectory or redesign the teacher-training curriculum to enhance this skill in (beginning) teachers.

CONTACT Marieke van Geel marieke.vangeel@utwente.nl

© 2018 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group
This is an Open Access article distributed under the terms of the Creative Commons Attribution-NonCommercial-NoDerivatives License (http://creativecommons.org/licenses/by-nc-nd/4.0/), which permits non-commercial re-use, distribution, and reproduction in any medium, provided the original work is properly cited, and is not altered, transformed, or built upon in any way.

To enable the design of such an intervention, a clear definition of "quality" differentiated instruction is required. Tomlinson and Imbeau (2010) have stated that "the core of the classroom practice of differentiation is the modification of four curriculum-related elements – content, process, product, and affect – which are based on three categories of student needs and variances – readiness, interest, and learning profile" (p. 15). Bosker (2005) adopted a broader approach, defining differentiation as adapting "aspects" of education (such as student grouping, learning goals, teaching time, or instructional strategy) to "differences" between students (primarily regarding performance and readiness, but also, for example, regarding intelligence, personality, or motivation). Roy, Guay, and Valois (2013) described differentiated instruction as "an approach by which teaching is varied and adapted to match students' abilities using systematic procedures for academic progress monitoring and data-based decision-making" (p. 1187).

Each of these definitions stresses the adaptation of aspects of instruction to differences between students. However, it remains uncertain what "high-quality" adaptations are, how this is enacted in classrooms, and what is required from teachers (Deunk et al., 2015; Park & Datnow, 2017). To obtain insights into the practice and quality of differentiated instruction and to determine how providing DI could be trained and assessed in practice, the literature has been reviewed for instruments that researchers have used to measure the quality or degree of differentiation, as the construction of such instruments requires an explicit operationalization of teacher behavior.

How differentiation is measured

We searched for a variety of studies that report the use of an instrument for assessing differentiated instruction, via Scopus, ERIC, and Google Scholar, but do not claim to present an exhaustive inventory of such instruments here. In the retrieved studies, we mainly found instruments based on self-report regarding DI practice (Coubergs, Struyven, Vanthournout, & Engels, 2017; Prast, Van de Weijer-Bergsma, Kroesbergen, & Van Luit, 2015; Roy et al., 2013) and instruments for measuring the perceived difficulty of DI strategies (Gaitas & Alves Martins, 2017), teachers' attitudes towards DI (Coubergs et al., 2017), and teacher self-efficacy regarding DI (Prast et al., 2015; Wan, 2016). Furthermore, several lesson observation schemes aimed at assessing whether a teacher applies specific differentiation strategies were reviewed (Tomlinson, Brimijoin, & Narvaez, 2008; Van de Grift et al., 2011; Van Tassel-Baska, Quek, & Feng, 2006). Also, two *student* questionnaires were included. The first questionnaire was designed by Nelson, Ysseldyke, and Christ (2015), which included five items on differentiated instruction and the second by Chamberlin and Powers (2010), containing 14 items that were used to measure perceived differentiation in college mathematics. The final instrument in our selection was the Adaptive Planning and the Adaptive Implementation Competency test, in which teachers were asked to respond to a vignette and to a video (Vogt & Rogalla, 2009). The scores on these tests were determined on several DI dimensions. However, specific indicators used to compute these scores were lacking, so in our overview we included the more general DI dimensions Vogt and Rogalla (2009) provided.

Scales and factors

In order to obtain a clear picture of the concepts researchers focus on when measuring differentiation, we first studied the scales and factors (either predetermined subscales or factors based on factor analysis) as presented in the different studies. We grouped these scales and factors into six overarching categories. Three of these categories concern differentiation prior to instruction. The first is referred to as *curriculum*: to enable differentiation, teachers should be subject-matter experts with sufficient pedagogical content knowledge, and they should be able to plan a sequence of learning tasks. Furthermore, teachers are expected to *identify instructional needs* by means of analyzing assessment data and evaluating student progress, and *set challenging goals* based on the curriculum and students' needs. During the lesson, teachers should *monitor and diagnose* student progress, and *adapt instruction and activities* accordingly. The sixth and final category consists mainly of *general teaching quality dimensions* such as creating a safe classroom climate and teaching relatively specific student skills such as critical-thinking or research strategies.

A more detailed analysis of the distribution of items across these scales and factors showed that *adapting instruction* proved to be the major focus of the instruments we studied involving 124 out of 294 items. Within these items, we noticed several recurring themes. In order to gain more insight into how these instruments aim to measure *adapting instruction*, we manually coded each item according to the content that it suggests should be adapted. The resulting codes were grouping, materials, assignments and tasks, pace and provided learning time, questions, classroom activities, and instruction. In Table 1, an overview of these categories and some examples from different instruments are presented.

Reviewing literature on differentiation instruments revealed that they primarily focus on the adjustments that can be made in the classroom. However, the question remains as to whether the use of these instruments really provides insight into the nature of *differentiation*. As Deunk et al. (2015) stated: "the key of successful differentiation may not merely be placing students in groups but actually adapting the teaching to the needs of different ability groups" (p. 49). We argue that this statement holds for all aspects in which teachers can adapt instruction; the *match* between students' needs and the adaptation is crucial to the real quality of the adaptation. However, items assessing this match explicitly are lacking. Although items such as "Attended appropriately to students who struggle with learning" in Tomlinson et al.'s (2008) observation scheme or "I adapt the level of abstraction of instruction to the needs of the students" from the self-assessment instrument by Prast et al. (2015) appear to relate to this match, it is unclear how the observer or teacher would be able to indicate the appropriateness of the adaptation(s).

Corno (2008) stated that "researchers need to know more about the actual practice of adaptive teaching" (p. 161) as a basis for teacher professionalization. In accordance with Deunk et al. (2015) and Corno (2008), we can conclude that the operationalizations of differentiation in previous studies, although informative, do not provide much insight into the acting and reasoning of teachers who differentiate instruction well. Such insight is required to measure differentiation as an aspect of teaching quality. In other words, we need to know what quality differentiation looks like as a basis for improving and

Table 1. Example items per category within "adapting instruction" scales.

	Type	Item	Source
Grouping	Self-reported practice	Flexible grouping is used (e.g., heterogeneous, homogeneous, cross-age, between-class, within-class)	(Rock, Gregg, Ellis, & Gable, 2008)
	Observation scheme	Varied student groupings: individuals, pairs, small groups	(Tomlinson et al., 2008)
Materials	Perceived difficulty	How difficult is: using different materials for struggling learners	(Gaitas & Alves Martins, 2017)
	Student questionnaire	My teacher helps me with materials that are on my level.	(Nelson et al., 2015)
Tasks and Assignments	Observation scheme	The teacher adapts the assignments and processes to the relevant differences between students	(Van de Grift et al., 2011)
	Self-reported practice	During my lessons, different students work on different tasks with a different level of difficulty	(Coubergs et al., 2017)
Pace and Time	Self-reported practice	I adapt the pace of instruction to the needs of the students	(Prast et al., 2015)
	Student questionnaire	Class time is used flexibly according to students' needs – Class time is inflexible	(Chamberlin & Powers, 2010)
Questions	Student teacher beliefs upon DI	By posing different questions, I can test understanding at various levels	(Wan, 2016)
	Self-reported practice	Questioning is planned strategically and adjusted spontaneously	(Rock et al., 2008)
Activities	Perceived difficulty	How difficult is: adapting classroom activities based on students' interests	(Gaitas & Alves Martins, 2017)
	Self-reported practice	I adjust different types of practice to the needs of the students in the classroom (e.g., having a specific child complete exercises on the computer because this child learns more in this way)	(Prast et al., 2015)
Explanation/ instruction	Obervation scheme (rating effectiveness)	Teacher accommodated individual or subgroup differences	(Van Tassel-Baska et al., 2006)
	Self-reported practice	I regularly provide high-achieving students with additional instruction or guidance at their level, in a group, or individually	(Prast et al., 2015)

assessing the quality of differentiation. Our aim is to gain more insight into how primary school teachers, considered differentiation experts, adapt math instruction to differences between students. Our empirical study is guided by the following research questions: (1) Which constituent skills are required for differentiated instruction? (2) What kind of knowledge is required for differentiated instruction? (3) Which factors contribute to the complexity of differentiated instruction?

In order to answer these questions, a cognitive task analysis (CTA) was performed. The CTA focused on the actions and reasoning of teachers exposed to real-life classroom situations requiring instructional differentiation.

Method

Cognitive task analysis

Cognitive task analysis is a technique used to identify, analyze, and structure the skills and knowledge used by experts during the performance of a complex task (Clark, 2014).

This method is suitable for obtaining insight into the actions and reasoning of teachers when performing the complex task of differentiation. CTAs are conducted in many other fields, for example, to collect input for designing computer systems, developing training programs, or developing assessment instruments (Schraagen, Chipman, & Shalin, 2000). Although numerous CTAs have been conducted in a variety of contexts within different domains (Clark, Feldon, Van Merriënboer, Yates, & Early, 2008), a CTA of teacher behavior in primary education, as far as we know, is novel.

A CTA leads to an integrative, coherent description of the prerequisites for performing professional tasks adequately (Van Merriënboer, 2010). We decided to follow the five-steps CTA process, which is dominant in most of the CTA methods and identified by Clark et al. (2008). The focus here was on *how* differentiation was performed in *practice*. The following steps were performed: (1) collect preliminary knowledge, (2) identify knowledge representations, (3) apply focused knowledge elicitation methods, (4) analyze and verify data acquired, (5) format the results for the intended application.

Procedure

Table 2 presents how the steps described by Clark et al. (2008) have been conducted in the present study. Step 1, collecting preliminary knowledge required for conducting the CTA, encompassed a literature study on differentiation, and focused on inventorying real-life situations and tasks requiring teacher differentiation skills through classroom observation and interviews. In Step 2, identifying knowledge representations, the format in which knowledge (as collected in Steps 3 and 4) will be represented is determined. For that purpose, the present study followed the 4C/ID (four components instructional design) model by Van Merriënboer and Kirschner (2018). The representations refer to (a) a skill hierarchy in which all constituent skills and their mutual relationships are described, (b) an overview of the associated knowledge enabling teachers to execute these skills (cognitive strategies, mental models, and cognitive rules), and (c) factors related to complexity that are used to sequence differentiation tasks based on their complexity. For Step 3, applying elicitation methods, observations of lessons by expert teachers were used, followed by semistructured interviews with these teachers (stimulated recall), and combined with information from a joint expert meeting with them. The

Table 2. CTA steps.

Steps according to Clark et al. (2008)	In current study
Step 1: Collect preliminary knowledge	Literature study Classroom observations to identify real-life tasks and situations that require differentiation skills
Step 2: Identify knowledge representations	Based on 4C/ID Skill hierarchy Required knowledge Complexity factors
Step 3: Apply focused knowledge elicitation methods	Semistructured interviews based on classroom observations in Step 1 (stimulated recall) Expert meeting with teachers
Step 4: Analyze and verify data acquired	Iterative qualitative analysis of data from observations, interviews, expert meeting with teachers Expert meeting with subject-matter experts
Step 5: Format results for intended application	At a later stage, the results will be used to design a teacher training program

classroom observations and individual interviews at this step are the same as those in Step 1. Therefore, in practice, Steps 1 and 3 were partially performed simultaneously. For Step 4, analyzing and verifying the data acquired, we analyzed the data collected in Step 3 and subsequently verified this information in an expert meeting with other (subject-matter) experts. Step 5, finally, did not play a role yet. This step refers to using all the information collected for designing a training program for teachers.

The description of the constituent skills and their relations were, as decided upon in Step 2, represented in a skill hierarchy with "differentiation" on top. The relatively more specific constituent skills at lower levels enable the learning and performing of skills higher up in the hierarchy. For each identified constituent skill, the question is always which skills are necessary for performing that particular skill (Van Merriënboer & Tjiam, 2013). Moreover, the required constituent knowledge was identified, as well as the factors contributing to the complexity of executing the task.

Expert teachers and subject-matter experts

Two groups of experts were consulted to obtain a comprehensive image of the complex differentiation task. First, nine primary school teachers, considered to be differentiation experts, were identified through a network of school inspectors, educational consultants, school boards, and teacher training institutes. Criteria for inclusion were that they were teaching in Grades 1 to 6 in regular primary schools (precluding Montessori, Jenaplan, and Dalton schools) in which regular mathematics textbooks were used. Characteristics of these teachers are presented in Table 3. As is for the majority of primary school teachers in The Netherlands, these expert teachers taught mathematics based on instructional plans in which they describe the instructional approach they planned to follow for several ability groups (Inspectie van het Onderwijs, 2010).

In addition to the expert teachers, 10 subject-matter experts were selected from the networks of the authors. The aim was to compose a group of experts with varying perspectives on differentiation. This group of subject-matter experts included three school inspectors, four educational consultants, one teacher trainer, and two researchers. The expert group consisted of experts on the pedagogy of mathematics (educational consultants and researchers), professionals who provide training courses in differentiated instruction (teacher trainers and educational consultants), experts who study differentiation (researchers), and those who evaluate differentiation (school inspectors).

Table 3. Characteristics of expert teachers at the time of the classroom observation.

Teacher[a]	Gender	Age	Years of experience	Grade	Number of students	Fulltime	Selected via
Willem	Male	34	10	5/6	22	No	School board
Harm	Male	36	9	4	24	No	Educational consultant
Karin	Female	28	6	6	28	Yes	Inspectorate of education
Manon[b]	Female	28	6	4	17	Yes	Educational consultant
Mette	Female	24	3	1	25	Yes	Teacher trainer
Saskia	Female	25	4	1/2/3	12	No	School board
Heleen	Female	52	33	1	16	No	Inspectorate of education
Evert[b]	Male	30	7	6	19	Yes	Researcher
Janneke[c]	Female	34	9	5/6	27	Yes	Educational consultant

[a]Names are pseudonyms.
[b]Observed, but not present at the expert meeting.
[c]Present at the expert meeting, but not observed.

Data collection

As is shown in Table 2, the first step involved collecting preliminary knowledge required for conducting the CTA and making an inventory of real-life tasks and classroom situations that require differentiation skills. This was done through classroom observation during mathematics lessons, followed by semistructured interviews (Step 3 according to Clark et al., 2008), and, after all observations and interviews had been conducted, a joint expert meeting was held with these teachers (Step 4 according to Clark et al., 2008). Next, the subject-matter experts were consulted with the goal of verifying and expanding the data collected from teachers (Step 4 according to Clark et al., 2008). Data collection and analysis were conducted iteratively in which each stage of data collection was followed by a (short) analysis providing input for the next stage. After this trajectory, a comprehensive analysis was conducted, leading to the results presented in this paper.

Classroom observations and interviews

During the first step of the CTA, two subsequent mathematics lessons of eight teachers were videotaped. This allowed us to obtain more insight into their differentiation approaches and strategies, their reasoning, and the constituent skills required for differentiating. By means of stimulated recall, a retrospective approach that can be used for clarifying decision-making processes (Vallacher & Wegner, 1987), a semistructured interview was conducted after each classroom observation. In these interviews, 3 to 10 lesson fragments were reviewed and discussed. The researcher selected situations that appeared to require teacher differentiation skills. To obtain insight into the teacher activities and considerations, the researcher asked questions such as "What are you doing here? With what goal?"; "What are you doing with the information you obtain from X?"; "X happens, what did you do based on that?" (Vallacher & Wegner, 1987). In order to obtain as much information as possible, the researcher could ask the teacher to elaborate. To acquire a comprehensive conceptualization of differentiation, each teacher was asked a number of more general questions about the classroom composition, the course of events during the lesson in general, lesson preparation, how differences between students were addressed during the lesson, the evaluation of student work, and the complexity of differentiation. All interviews were recorded and transcribed.

Expert meeting with teachers

The next CTA stage was an expert meeting involving seven of the nine expert teachers. The first goal of this meeting was to make an inventory of differentiation complexity factors. For this purpose, two groups of teachers described five authentic situations calling for teacher differentiation skills, sequencing them from simple to complex. Based on the sequence, an overview was made of the factors that make differentiation easier or more complex during a plenary discussion.

The second goal of the expert meeting was to identify teachers' activities and decision-making processes during a differentiated mathematics lesson. Systematic approaches and (especially implicit) strategies that teachers apply when they differentiate were gathered by means of an activity in which teachers used post-its to first describe and later sequence their actions during a lesson.

Subject-matter expert meeting

The findings from the classroom observations, interviews, and the expert meeting with teachers were presented to 10 subject-matter experts during a second expert meeting. The goal of this meeting was twofold. The first goal was to verify the first version of the skill hierarchy and the complexity factors. The second goal was to gather input for specifying the standards for acceptable performance by prioritizing constituent differentiation skills. This was done by asking all subject-matter experts to identify those constituent skills that, in their opinion, were crucial for teachers to differentiate well. Next, the subject-matter experts formulated performance standards for these crucial constituent skills. During this meeting, other constituent skills were also discussed. The discussions in groups as well as the plenary discussions were audio-taped and transcribed.

Data analysis

The first two authors of this article analyzed the data in an iterative process, taking place parallel to data collection. After each stage of data collection, data were analyzed and outcomes were used in the subsequent stage of data collection. The researchers started by studying, summarizing, and sorting the information available from interviews and the expert meeting with teachers independently from each other. The classroom observations were used as a basis for the interviews and were therefore not analyzed. The interviews were used for finding general themes and behavioral patterns mentioned by a sample of teachers. This information was extended with the systematic approaches as described by the teachers during the expert meeting. Next, the researchers discussed their findings with each other to reach a consensus about the skill hierarchy and the required teacher knowledge.

Thereafter, the skill hierarchy and the overview of the required knowledge were presented to subject-matter experts in the second expert meeting. The transcribed conversations with subject-matter experts were read and coded by the three researchers. First, the researchers independently indicated which stage of task execution a fragment referred to (preparation of the lesson period, lesson preparation, enactment of the lesson, lesson evaluation). After this, parts of the texts from the transcribed interviews were linked to constituent skills within that stage. In the following step, this information was used to specify the descriptions of the constituent skills within the skill hierarchy. In addition, we studied how the opinions of subject-matter experts differed from teachers' opinions.

To identify the factors influencing the complexity of differentiation, the list of complexity factors developed during the first expert meeting was used as the starting point. The factors in this list were rather specific, and for this reason were coded axially (Mortelmans, 2007). The factors were grouped and reduced to five overarching complexity factors. Factors like "*teaching a multigrade class*" or "*many students with behavioral problems in class*", for example, were coded under the overarching complexity factor "group composition". To verify the results, it was assessed whether the factors mentioned by teachers in the general part of the interviews could also be grouped under these overarching factors – this proved to be the case.

Data collection and analyses were carried out systematically, by means of member checking, that is, verifying the findings by presenting them to the participants in the study (Creswell & Miller, 2003; Stalmeijer, McNaughton, & Van Mook, 2014). During the expert meetings, it was verified whether the interpretation of the data by the researchers was in line with the interpretations by the teachers and/or subject-matter experts. For example, during the expert meeting with teachers, the researchers summarized and combined insights from the collaborating groups to immediately verify whether the information gathered was interpreted correctly. Furthermore, triangulation was achieved by collecting data in various ways, consulting subject-matter experts from various backgrounds with differing perspectives, and by having the data analyzed by multiple researchers from different backgrounds.

Results

Skills

From the preliminary data exploration of the classroom observations and the interviews, it became clear that differentiation *during* the lesson cannot be isolated from the phases of lesson preparation and evaluation. Four chronological differentiation stages can be distinguished that are closely interrelated: A teacher prepares a lesson (Stage 2) based on the evaluation of the previous lesson (Stage 4) and based on his preparation of the lesson period[1] (Stage 1). This preparation enables the teacher to adequately address the differences between students during the lesson (Stage 3). Within each of these stages, several constituent differentiation skills can be distinguished, as depicted in Figure 1. Horizontally adjacent constituent skills have a temporal relationship, implying that they can be performed subsequently, simultaneously, or in a random order. Lower level skills facilitate the learning and performance of the skills higher up in the hierarchy.

For each skill, so-called "performance objectives" were formulated in consultation with external experts. These objectives specified the desired performance, including the integration and coordination of constituent skills. In these objectives, the interrelatedness of all phases and skills became apparent. For example, the performance objective for "provide instruction matching needs" (see Figure 1) is an extensive description: *For every instruction activity, the teacher deliberately provides instruction matching the students' level of achievement and instructional needs (the latter as determined when the lesson period and the lesson were designed/prepared). However, the teacher also uses the acquired insights about students' prior knowledge (e.g., during the introduction of the lesson) and the information (s)he continuously acquires by monitoring student progress (e.g., by asking questions and observing student behavior) in order to specifically match instruction with students' estimated levels of achievement, prior knowledge, and/or level of understanding. Instruction is explicitly focused on reaching the (adjusted) lesson goal with the students at whom the instruction is aimed. Furthermore, lesson content, instruction material, and the applied math strategies align with previous instruction and/or school policy. Although the teacher deliberately planned instruction, (s)he stimulates students' self-regulation towards meeting the goals and provides them with options and opportunities to choose from, but redirects when necessary*. For measuring this performance indicator, it is suggested to let the teacher explain what (s)he was doing and why, and to check school policy documents or consult the math coordinator to check whether instructional content, material, and strategies align with school policy. Furthermore, students'

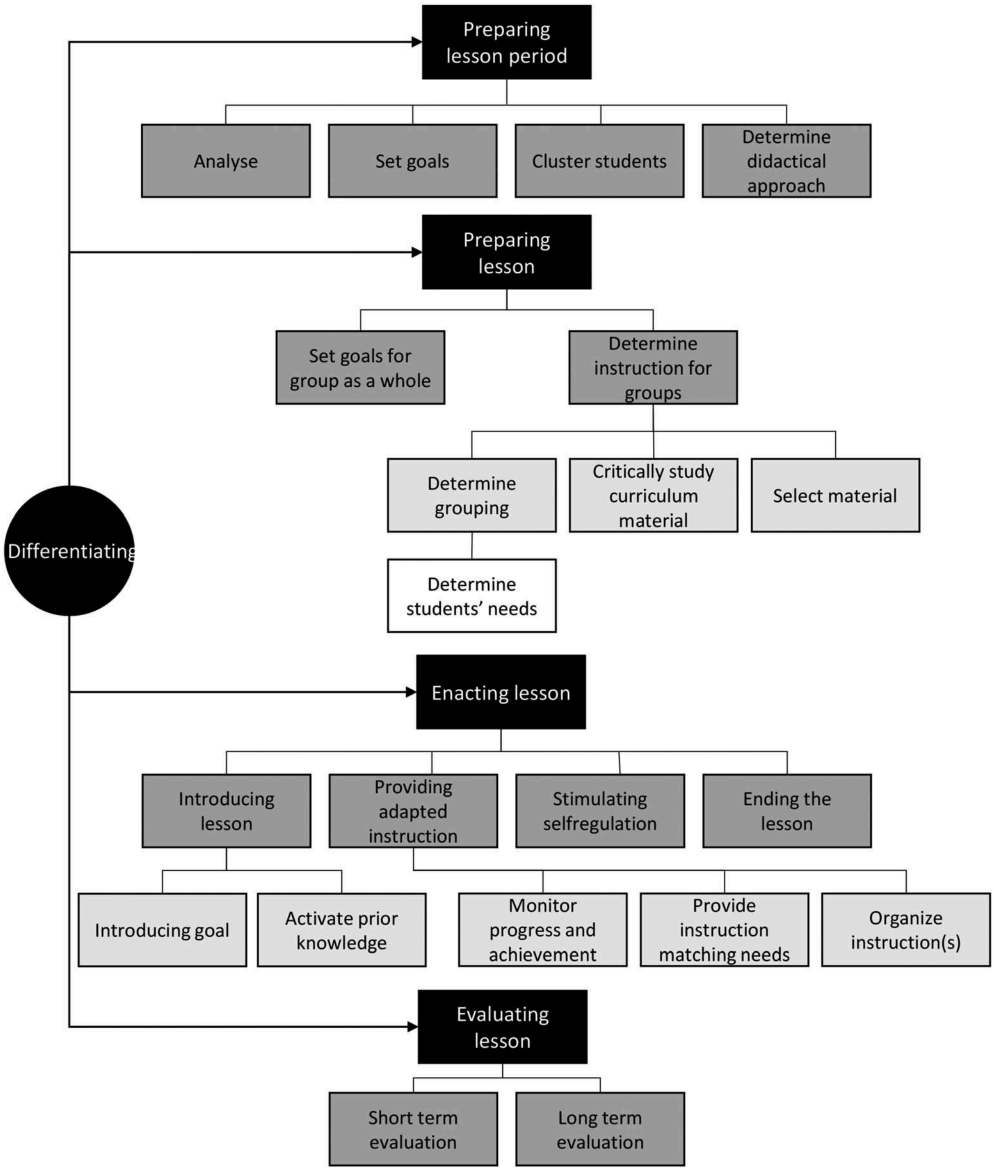

Figure 1. Differentiation skill hierarchy.

perceptions about the match between the instruction activity and their learning can provide information about the quality of the match, and students can be asked about their perceived self-regulation. A subject-matter expert can indicate whether the selected instruction, content, materials, and strategies are accurate given the teacher's goal in light of the identified student's achievement, progress, and needs.

From the performance objectives, it is clear that there is not one "successful strategy" that can be applied to differentiate properly. The core of differentiation is in teachers' deliberate and adequate choices concerning instructional approaches and materials, based on well-considered goals and thorough analyses of students' achievement, progress, and instructional needs, combined with continuous monitoring during the lesson.

Knowledge

Aside from differentiation skills, two types of knowledge are essential for being able to differentiate: knowledge about the students and subject-matter knowledge. Such knowledge supports the teacher in the performance of all differentiation constituent skills.

Knowledge about students

All experts (both teachers and subject-matter experts) stressed the importance of "knowing your students". On the one hand, this is about knowing their levels of achievement: the level at which they are and the problems they encounter when learning math. On the other hand, such knowledge is about knowing the pedagogical needs of the students, their interests, peer relations, how to motivate each of them, and the kind of problem-solving strategies they will understand. Next to analyzing student work, a teacher gains insight into these kinds of instructional needs by observing students during class and by asking them questions. Basic information about students is often represented in an overview that teachers compose at the start of a lesson period.

Subject-matter knowledge

Knowledge about the subject (mathematics, in our study) was regarded as important during all phases of differentiation: for setting proper goals, for connecting to students' prior knowledge, and for identifying students' zones of proximal development (ZPD) and adjusting instruction to fit this ZPD. Subject-matter knowledge is also essential for making decisions with regard to the use of curriculum materials and additional materials. The subject-matter knowledge base is developed first during formal teacher training and is later developed on the basis of in-service experience.

Complexity factors

As mentioned previously, differentiating is a complex skill. However, the level of complexity differs across situations. To obtain more insight into the factors contributing to this complexity, we asked expert teachers and subject-matter experts to rank situations requiring some form of differentiation ranging from relatively easy to relatively complex. On the basis of this ranking, we identified the following complexity factors: the content of the lesson (goal and topic), group composition (diversity, number of grades, and students with special education needs), school support (collaboration and facilities), curriculum material (suggestions for remediation and materials), and data regarding student achievement and progress (information richness, availability, and usefulness). In practice, numerous combinations of complexity factors are present. Furthermore, several complexity factors are strongly interrelated. This list of complexity factors provides a basis for developing a professionalization trajectory (which will be done at a later stage in our project).

Discussion and conclusion

The aim of this study was to gain further insight into how primary school teachers adapt their math instruction to student differences. The cognitive task analysis we performed resulted in a unique overview of constituent skills required for providing differentiated instruction. Furthermore, the essential knowledge and the factors influencing the complexity of differentiation were identified. In the following sections, we discuss the value of these outcomes for both practice and research.

Value for practice

Differentiation is regarded as a complex teaching task mastered by few teachers (Inspectie van het Onderwijs, 2014, 2015a, 2015b) and which beginning teachers feel unprepared for (Inspectie van het Onderwijs, 2015a). Professional development and the redesign of teacher training curricula therefore seems desirable. The outcomes of the CTA can be used to design such a training or inform curriculum adjustments.

We now know the combination of constituent skills that facilitate differentiation as a teaching task and which knowledge is essential for making instructional decisions related to differentiation. The key to successful differentiation is not the application of strategies, but the actual adaptation of teaching to the thoroughly identified needs of all students. "Meeting the needs of all learners" assumes that teachers "have an accurate view of students' levels of understanding, and that they know which instruction and learning activity is appropriate for children at different levels, given the goal they strive for" (Deunk et al., 2015, p. 52). This relationship between the goals, students' needs, and the provided instruction is reflected in the skill hierarchy. In this hierarchy, the relationship between the preparation of a lesson period, a lesson, the enactment of a lesson, and the lesson evaluation is essential for differentiating instruction during a lesson. This is in line with the work of Parsons et al. (2018), who found adaptive teaching in all phases of instruction, during planning, in the midst of teaching, and when reflecting on their instruction. Furthermore, the performance indicators showed that effective differentiation is not only complex due to the interrelatedness of these chronological phases, but also because the core of differentiation is in deliberate and accurate choices. These choices must be based on a variety of well-considered goals and the analysis of students' instructional needs, in combination with continuous monitoring of student progress and adapting on the fly.

In order to make these deliberate and accurate choices, two types of knowledge are considered essential: knowledge about the students and subject-matter knowledge. This subject-matter knowledge, as briefly described in the Results section, might be the key to success. After all, teachers need this knowledge across all stages and teachers can probably not make the right decisions when they lack proper knowledge and deep insights on the subject they teach. A more thorough follow-up study into the range, depth, and types of knowledge would be worthwhile. For example, it could be argued that knowledge about effective interventions is important as well.

Furthermore, ensuring a safe learning climate or being able to create an orderly classroom atmosphere can be regarded as prerequisites for providing differentiated instruction (e.g., Van de Grift et al., 2011). However, these types of knowledge and skills were not mentioned by either expert teachers or subject-matter experts and were therefore not included in our skill hierarchy and description of the required knowledge.

The skill hierarchy and required knowledge can be used in the development of a professional development trajectory or the redesign of teacher training curricula. We plan to design such a trajectory based on the 4C/ID model by Van Merriënboer and Kirschner (2018), in which the complexity factors can be used to sequence learning tasks. Basic pedagogical skills such as classroom management skills and ensuring a safe climate can be regarded as prerequisites for differentiation. These elements should therefore be included when designing training opportunities, especially for beginning teachers. Furthermore, the relationship between those skills and differentiation could be investigated in more detail.

Value for research

Our analysis of various instruments identified six overarching categories of skills. Three of these play a role prior to instruction: mastering the curriculum, identifying instructional needs, and setting challenging goals. Two play a role during instruction: monitoring and diagnosing student progress, and adapting instruction and activities accordingly. The sixth category consists mainly of general teaching dimensions. The reviewed instruments focus on "adapting instruction and activities", and within this category we distinguished the adaptation of the following specific aspects: grouping, materials, assignments and tasks, pace and provided learning time, questions, classroom activities, and instruction. These overarching factors and specific aspects can be recognized in the results of our CTA, both in the skill hierarchy and the description of required knowledge. For example, the constituent skill "determine student needs" is closely related to "identify instructional needs", and "monitor and diagnose student progress" is related to "monitor progress and achievement". The items we reviewed regarding the "curriculum" aspect are related to the constituent skills "critically study curriculum material" and "select material" and to required subject-matter knowledge.

Parsons et al. (2018) stated that "researchers need to work on creating measures and presenting evidence that are valid and reliable" (p. 232) to measure adaptive instruction or differentiation. We can conclude that this is not an easy task. We know that the assessment of professional competencies is very complex as a competency comprises the complex integration of knowledge, skills, and attitudes (Baartman, Bastiaens, Kirschner, & Van der Vleuten, 2006). The indicators in the reviewed instruments for measuring DI mainly consist of descriptions of differentiation strategies that may be applied, such as grouping, adapting the pace of instruction, or varying assignments. These instruments cannot be used to assess the actual quality of the applied differentiation strategies. Given the complexity of differentiating in itself and the interrelatedness of a variety of aspects involved in quality differentiation, the question remains whether and, if so, how we can assess this complexity in an efficient manner within the reality of the school context.

Baartman et al. (2006) stated that "it seems to be impossible to assess a competency using only one assessment method" (p. 154). Since differentiated instruction requires the *adaptation to student differences*, the assessor ideally should be able to evaluate whether observed adaptations *meet the needs* of different learners. The evaluation of the relationship between the instruction provided and student characteristics (what they need) is lacking in existing instruments. It is therefore uncertain whether existing instruments fully capture the complexity of differentiated instruction and whether these instruments are suitable for determining a teacher's quality in terms of providing DI. The assessment of differentiation quality seems to require a combination of insights into students' needs as well as a valid picture of the appropriateness of teachers' actions to meet these needs. Furthermore, since teachers' actions should be based on their teaching goals, which may differ across students, these goals should ideally also be taken into account. Finally, the quality of differentiation is highly dependent on the degree to which teachers make deliberate and adequate decisions when attempting to adapt to student needs. Assessing differentiation adequately will therefore require information from multiple sources, as well as much time and effort from skillful assessor(s). For example, document analysis of teachers' lesson period plans and lesson preparations could be used in combination with classroom observations and student perceptions in order to gain insight into the relation between the chronological phases of lessons (from lesson period preparation to lesson preparation and enacting the lesson-to-lesson evaluation) and the match between the teachers' choices and their students' needs. Furthermore, in order to determine the deliberateness of the choices, teachers could be interviewed and a subject-matter expert could judge whether these choices are accurate given the achievement, progress, and instructional needs of the students. Depending on the goal of the assessment, feedback based on the insights from these different sources and assessors can be shared with the teacher.

Van der Vleuten (2016) states: "any single assessment method can never be perfect on all criteria and in reality assessment always involves a compromise" (p. 885). This compromise is needed since an assessment such as the one described here would be unfeasible in terms of the required effort and costs. We therefore suggest the programmatic assessment approach (Van der Vleuten et al., 2012), which implies that expert judgement plays an important role and that multiple (low-stake) assessments can be aggregated to come to an overall decision.

By means of the CTA we performed, we gained valuable insights into the complexity of differentiation, and the differentiation performance objectives now provide a basis for a framework for developing assessment instruments to capture this complexity. For assessing the quality of differentiation, a comprehensive set of assessment instruments can be developed that account for the complexity factors based on the skill hierarchy and the performance objectives. With this set of instruments, the various constituent skills of differentiation may be assessed in different ways, and when a teacher appears to master a specific skill at a specific complexity level, this aspect might not need to be assessed again.

Finally, to our knowledge, this is the first cognitive task analysis conducted in the context of teacher skills for differentiation. This thorough analysis of the cognition and behavior of expert teachers in practice provides rich insights into the knowledge and constituent skills needed to be able to adapt instruction to student differences. By analyzing expert performance, we were able to capture the complexity of this task in practice, enabling us to design curricula and develop assessment instruments that truly relate to this practice. This study shows how a CTA can be conducted with respect to teacher skills, and how this can provide valuable information and insights for teacher professional development. We encourage educational researchers to conduct similar CTAs for other complex skills such as "ensuring a safe pedagogical climate" or "classroom management". The procedure illustrated in this study can serve as an example for other studies on various complex teacher skills and in various contexts.

Note

1. Teachers generally prepare a lesson period of 6 to 12 weeks. In this preparation, overarching goals are identified and students' achievements and instructional needs are analyzed. Teachers describe their overall instructional approach in an instructional plan for this lesson period.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by the Nederlandse Organisatie voor Wetenschappelijk Onderzoek [405-15-733].

ORCID

Marieke van Geel http://orcid.org/0000-0003-2033-6612
Trynke Keuning http://orcid.org/0000-0002-1730-3871
Jimmy Frèrejean http://orcid.org/0000-0002-3026-3624
Adrie J. Visscher http://orcid.org/0000-0001-8443-9878

References

Baartman, L. K. J., Bastiaens, T. J., Kirschner, P. A., & Van der Vleuten, C. P. M. (2006). The wheel of competency assessment: Presenting quality criteria for competency assessment programs. *Studies in Educational Evaluation*, *32*(2), 153–170. doi:10.1016/j.stueduc.2006.04.006

Bosker, R. J. (2005). *De grenzen van gedifferentieerd onderwijs* [The limits of differentiated instruction] (Oration). Retrieved from https://www.rug.nl/research/portal/files/14812458/bosker.pdf

Chamberlin, M., & Powers, R. (2010). The promise of differentiated instruction for enhancing the mathematical understandings of college students. *Teaching Mathematics and its Applications*, *29*(3), 113–139. doi:10.1093/teamat/hrq006

Clark, R. E. (2014). Cognitive task analysis for expert-based instruction in healthcare. In J. M. Spector, M. D. Merrill, J. Elen, & M. J. Bishop (Eds.), *Handbook of research on educational communications and technology* (4th ed., pp. 541–551). New York, NY: Springer. doi:10.1007/978-1-4614-3185-5_42

Clark, R. E., Feldon, D. F., Van Merriënboer, J. J. G., Yates, K. A., & Early, S. (2008). Cognitive task analysis. In J. M. Spector, M. D. Merrill, J. J. G. van Merriënboer, & M. P. Driscoll (Eds.), *Handbook of research on educational communications and technology* (3rd ed., pp. 577–593). Mahwah, NJ: Lawrence Erlbaum.

Corno, L. (2008). On teaching adaptively. *Educational Psychologist*, *43*(3), 161–173. doi:10.1080/00461520802178466

Coubergs, C., Struyven, K., Vanthournout, G., & Engels, N. (2017). Measuring teachers' perceptions about differentiated instruction: The DI-Quest instrument and model. *Studies in Educational Evaluation*, *53*, 41–54. doi:10.1016/j.stueduc.2017.02.004

Creswell, J. W., & Miller, D. L. (2003). Determining validity in qualitative inquiry. *Theory Into Practice*, *39*(3), 124–130. doi:10.1207/s15430421tip3903_2

Deunk, M., Doolaard, S., Smale-Jacobse, A., & Bosker, R. J. (2015). *Differentiation within and across classrooms: A systematic review of studies into the cognitive effects of differentiation practices*. Groningen: GION onderwijs/onderzoek.

Gaitas, S., & Alves Martins, M. (2017). Teacher perceived difficulty in implementing differentiated instructional strategies in primary school. *International Journal of Inclusive Education*, *21*(5), 544–556. doi:10.1080/13603116.2016.1223180

George, P. S. (2005). A rationale for differentiating instruction in the regular classroom. *Theory Into Practice*, *44*(3), 185–193. doi:10.1207/s15430421tip4403_2

Inspectie van het Onderwijs. (2010). *Opbrengstgericht werken in het basisonderwijs* [Data-based decision making in elementary education]. Utrecht: Author.

Inspectie van het Onderwijs. (2014). *De staat van het onderwijs: Onderwijsverslag 2012/2013* [The state of education in The Netherlands: The 2012/2013 education report]. Utrecht: Author.

Inspectie van het Onderwijs. (2015a). *Beginnende leraren kijken terug – Onderzoek onder afgestudeerden. Deel 1: De pabo* [Starting teachers looking back – A study among graduates: Part 1: Teacher training]. Utrecht: Author.

Inspectie van het Onderwijs. (2015b). *De staat van het onderwijs: Onderwijsverslag 2013/2014* [The state of education in The Netherlands: The 2013/2014 education report]. Utrecht: Author. Retrieved from https://www.rijksoverheid.nl/binaries/rijksoverheid/documenten/rapporten/2015/04/15/de-staat-van-het-onderwijs-onderwijsverslag-2013-2014/de-staat-van-het-onderwijs-onderwijsverslag-2013-2014.pdf

Mortelmans, D. (2007). *Handboek kwalitatieve onderzoeksmethoden* [Handbook for qualitative research methods]. Leuven: Acco.

Nelson, P. M., Ysseldyke, J. E., & Christ, T. J. (2015). Student perceptions of the classroom environment: Actionable feedback to guide core instruction. *Assessment for Effective Intervention*, *41*(1), 16–27. doi:10.1177/1534508415581366

Park, V., & Datnow, A. (2017). Ability grouping and differentiated instruction in an era of data-driven decision making. *American Journal of Education*, *123*(2), 281–306. doi:10.1086/689930

Parsons, S. A., Vaughn, M., Scales, R. Q., Gallagher, M. A., Parsons, A. W., Davis, S. G., … Allen, M. (2018). Teachers' instructional adaptations: A research synthesis. *Review of Educational Research*, *88*(2), 205–242. doi:10.3102/0034654317743198

Prast, E. J., Van de Weijer-Bergsma, E., Kroesbergen, E. H., & Van Luit, J. E. H. (2015). Readiness-based differentiation in primary school mathematics: Expert recommendations and teacher self-assessment. *Frontline Learning Research*, *3*(2), 90–116. doi:10.14786/flr.v3i2.163

Rock, M. L., Gregg, M., Ellis, E., & Gable, R. A. (2008). REACH: A framework for differentiating classroom instruction. *Preventing School Failure: Alternative Education for Children and Youth*, *52*(2), 31–47. doi:10.3200/PSFL.52.2.31-47

Roy, A., Guay, F., & Valois, P. (2013). Teaching to address diverse learning needs: Development and validation of a Differentiated Instruction Scale. *International Journal of Inclusive Education*, *17*(11), 1186–1204. doi:10.1080/13603116.2012.743604

Schraagen, J., Chipman, S., & Shalin, V. (2000). Introduction to cognitive task analysis. In J. M. Schraagen, S. F. Chipman, & V. L. Shalin (Eds.), *Cognitive task analysis* (pp. 3–23). Mahwah, NJ: Erlbaum.

Stalmeijer, R. E., McNaughton, N., & Van Mook, W. N. K. A. (2014). Using focus groups in medical education research: AMEE Guide No. 91. *Medical Teacher*, *36*(11), 923–939. doi:10.3109/0142159X.2014.917165

Tomlinson, C. A., Brimijoin, K., & Narvaez, L. (2008). *The differentiated school: Making revolutionary changes in teaching and learning*. Alexandria, VA: ASCD.

Tomlinson, C. A., & Imbeau, M. B. (2010). *Leading and managing a differentiated classroom*. Alexandria, VA: ASCD.

Vallacher, R. R., & Wegner, D. M. (1987). What do people think they're doing? Action identification and human behavior. *Psychological Review*, *94*(1), 3–15. doi:10.1037/0033-295X.94.1.3

Van de Grift, W. J. C. M., van der Wal, M., & Torenbeek, M. (2011). Ontwikkeling in de pedagogisch didactische vaardigheid van leraren in het basisonderwijs [The development of teachers' pedagogical-didactical skills in primary education]. *Pedagogische Studiën*, *88*, 416–432.

Van der Vleuten, C. P. M. (2016). Revisiting "Assessing professional competence: From methods to programmes." *Medical Education*, *50*(9), 885–888. doi:10.1111/medu.12632

Van der Vleuten, C. P. M., Schuwirth, L. W. T., Driessen, E. W., Dijkstra, J., Tigelaar, D., Baartman, L. K. J., & Van Tartwijk, J. (2012). A model for programmatic assessment fit for purpose. *Medical Teacher*, *34*(3), 205–214. doi:10.3109/0142159X.2012.652239

Van Merriënboer, J. J. G. (2010). *Innovatief onderwijs ontwerpen in het gezondheidsdomein* [Designing innovative instruction in the health domain] (Oration). Retrieved from https://www.ou.nl/Docs/ICO/Oratie_Van_Merrienboer.pdf

Van Merriënboer, J. J. G., & Kirschner, P. A. (2018). *Ten steps to complex learning: A systematic approach to four-component instructional design* (3rd ed.). New York, NY: Routledge.

Van Merriënboer, J. J. G., & Tjiam, I. (2013). Development and teaching of complex skills in invasive procedures. In P. Lanzer (Ed.), *Catheter-based cardiovascular interventions: A knowledge-based approach* (pp. 173–186). Berlin: Springer. doi:10.1007/978-3-642-27676-7

Van Tassel-Baska, J., Quek, C., & Feng, A. X. (2006). The development and use of a structured teacher observation scale to assess differentiated best practice. *Roeper Review*, *29*(2), 84–92. doi:10.1080/02783190709554391

Vogt, F., & Rogalla, M. (2009). Developing Adaptive Teaching Competency through coaching. *Teaching and Teacher Education*, *25*(8), 1051–1060. doi:10.1016/j.tate.2009.04.002

Wan, S. W.-Y. (2016). Differentiated instruction: Hong Kong prospective teachers' teaching efficacy and beliefs. *Teachers and Teaching*, *22*(2), 148–176. doi:10.1080/13540602.2015.1055435