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EDITED BY

Ramona Maile Cutri,
Brigham Young University, United States

REVIEWED BY

Elisa Kupers,
University of Groningen, Netherlands
Tom Porta,
Flinders University, Australia

*CORRESPONDENCE

Kyra Meutstege
✉ k.meutstege@utwente.nl

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A cognitive task analysis of the teacher skills and knowledge required for differentiated instruction in secondary education

Kyra Meutstege*, Marlijn Vrieling, Marieke van Geel and
Adrie J. Visscher

Section of Teacher Development, University of Twente, Enschede, Netherlands

Providing differentiated instruction (DI) is a complex teacher task that many secondary school teachers do not master well. In the current study, a cognitive task analysis of this teacher task was conducted by analyzing how expert teachers do this and why, resulting in an inventory of the necessary teacher skills and knowledge for providing DI, and a description of the factors that influence the complexity of DI. The results of this analysis show what providing DI in secondary education entails, which is valuable for designing teacher professional development programs for DI at that level.

KEYWORDS

teacher professional development, differentiated instruction, teacher skills and knowledge, cognitive task analysis, secondary education

Introduction

Teachers are increasingly expected to adapt their teaching to their students' needs, since this can have a positive effect on students' achievement (Deunk et al., 2018; Smale-Jacobse et al., 2019). Implementing differentiated instruction (DI), however, is something teachers struggle with (Smale-Jacobse et al., 2019). To be able to support teachers in providing DI, we need to identify the teacher knowledge and skills required for DI. Van Geel et al. (2019) conducted a cognitive task analysis of DI in primary education. Since we cannot assume that the results are fully the same for secondary education, the current study aimed to identify the knowledge and skills teachers in secondary education need in order to adapt their teaching to students' varying needs. The results can be used to improve initial as well as in-service secondary teacher professional development (TPD) for DI.

DI entails more than strategies

DI is a teaching approach “in which teachers proactively modify curricula, teaching methods, resources, learning activities, and student products to address the diverse needs of individual students and small groups of students to maximize the learning opportunity for each student in a classroom” (Tomlinson et al., 2003, p. 121). Providing DI is a complex teacher task, as teachers are required to have an accurate picture of the learning levels of all their students and then adapt their explanations and assignments to those differing levels, while keeping in mind the goal they are working toward in the lesson (Deunk et al., 2015).

Teachers use various strategies to provide DI, such as ability grouping (e.g., to create a group of low-achieving students who receive more explanations), or the use of a computerized system to support DI (Deunk et al., 2015, 2018). The effects of these various strategies on student achievement also vary (Deunk et al., 2018; Puzio et al., 2020). Examples include studies showing that between- or within-class homogeneous ability grouping can have a positive effect, no effect, or even a small negative effect, and studies showing that DI supported by computerized systems can have a small to moderate positive effect on student achievement (Deunk et al., 2015, 2018).

Smale-Jacobse et al. (2019) conducted a review of the research on within-class DI in secondary education. Although positive effects were found in general, only 12 studies were included, which led to their most important conclusion being that there are not enough good studies about the effectiveness of DI in secondary education. Although the evidence is limited, it seems that providing DI can positively influence student achievement. Next to student achievement, DI can also affect students' socio-emotional outcomes. Pozas et al. (2021) studied the perceptions of 379 students from 23 Austrian secondary school classes (both inclusive and regular classes) and found that students' ratings of their teachers' DI was positively associated with their school well-being, social inclusion, and academic self-concept.

The effectiveness of providing DI, however, mainly depends on what the teacher actually does. The quality of DI depends on the degree to which a teacher deliberately, proactively, and successfully adapts instruction to their students' needs (Tomlinson et al., 2003; van Geel et al., 2019). Differentiating teachers ensure that students do not receive assignments that are too difficult or too easy for them, as in that case, learning does not take place (Joseph et al., 2013). When assignments are neither too difficult nor too easy, students work in their zone of proximal development, where they work on a task just above their abilities while receiving coaching and support (Vygotsky, 1978). When students receive instruction suited to their learning needs, they all can perform at a high level. The goal of DI is to provide the opportunity to excel to students of all levels (Tomlinson, 2015). It thus is likely that DI could improve student performance provided that the instruction matches the learning needs of the students. Given the previous, the definition of DI used in the current study is: the deliberate adaptation of teaching and learning activities to the learning needs of the learners.

What does providing DI require from teachers in secondary education?

Van Geel et al. (2019) studied what providing DI requires from teachers in primary education. They found that the implementation of DI by teachers starts even when preparing the lesson series (phase 1) and preparing the lesson itself (phase 2). High-quality preparation facilitates providing DI during the lesson (phase 3). Finally, teachers evaluate their lessons (phase 4), and the results are used to prepare for the next lesson(s). Each of these four phases was further decomposed by Van Geel et al. (2019) into the constituent skills that are necessary to perform that phase. For these skills, teachers need knowledge about students and subject-matter knowledge. Van Geel et al. (2019) argued that providing high-quality DI means that teachers adapt their instruction to the systematically determined needs of all learners. Smale-Jacobse et al. (2019) argue that to systematically determine the

learners' needs, DI is inseparable from other teacher behaviors like continuous monitoring and (formative) assessment. This is not only done during the lesson: before the lesson teachers should have clear goals, use pre-assessment, and plan instruction before the lessons, and evaluate their students' progress toward the lesson goals after the lesson.

Research has shown that secondary school teachers find it hard to provide DI. Maulana et al. (2023) compared DI with other domains of effective teaching (learning climate, classroom management, clarity of instruction, activating teaching, and teaching learning strategies) and found that DI was often observed to be the lowest (i.e., most complex) in the case of the Netherlands, Indonesia, South Africa, and South Korea. This was only different in Pakistan (second lowest) and the United Kingdom (highest, i.e., least complex). Porta and Todd (2022) found that the secondary school teachers in their study of a school in Australia showed a willingness to provide DI in their lessons, but also mentioned challenges like having a lack of time for the implementation of DI or having too many students in one class making it harder to spend enough time with individual students. National research has found that Dutch teachers do not master all the skills needed for providing DI. As only 43% of secondary school teachers adapt their instruction (versus 65% of primary school teachers), and 41% of the teachers adapt assignments (versus 80% in primary education), this is especially true in secondary education (Inspectie van het Onderwijs, 2016).

A first explanation for why Dutch secondary school teachers provide less DI than their colleagues in primary education might be a difference in their initial teacher training. While 85% of beginning teachers in primary education indicated that they were sufficiently prepared for providing DI, this was the case for only 55% of beginning secondary school teachers (Inspectie van het Onderwijs, 2015a,b). Secondly, because secondary school teachers see many different students for only a couple of hours a week, they might find it harder than primary school teachers to know their students and their cognitive abilities and needs (van Casteren et al., 2017). And finally, the perceived need for DI may be lower for secondary school teachers, as Dutch secondary schools work with a system wherein students are tracked based on their cognitive abilities, which means that when starting secondary school (around the age of 12), students are assigned to either the pre-vocational, senior general, or pre-university track (EP-Nuffic, 2015; van Casteren et al., 2017). Students in the same track all take the same exam to graduate at the end of their secondary school period (Inspectie van het Onderwijs, 2016), which might lead to teachers believing they do not have to provide DI. This is unjustified, as identical graduation requirements within tracks does not mean that all students have to get there the same way, as tracked classes are more heterogeneous than is often assumed and students still have different achievement levels (Wilkinson and Penney, 2014). Hence, providing them all with the same learning goals, subject-matter content, and assignments may lead to students feeling not challenged, or not supported enough (Inspectie van het Onderwijs, 2019). To provide Dutch secondary school students with better learning opportunities, Dutch secondary school teachers are advised to implement high-quality DI in their lessons.

As mentioned earlier, however, providing DI is a complex teacher task. Hence, TPD to support teachers in the context of secondary education in mastering DI is necessary (Porta and Todd, 2022). To design such TPD, it is important to know what teachers should

be taught. Although research on DI in secondary education is growing, it is not yet known what teachers need to be able to do and know, to provide DI in secondary education. To gain insight into what providing high-quality DI requires from teachers, the current study aims to answer the following two research questions.

Research question 1: What skills are required from teachers in secondary education in order to provide DI?

Research question 2: What knowledge is required from teachers in secondary education in order to provide DI?

To answer research questions 1 and 2, the current study describes what expert teachers do to provide high-quality DI, what their reasoning behind their DI activities is, and what knowledge DI requires from teachers. It was chosen to study mathematics teachers specifically, so the results can be compared to the study of [van Geel et al. \(2019\)](#) which was focused on DI in mathematics lessons in primary education. In order to design professional development trajectories or to support teachers in their practice, factors related to the (perceived) complexity of providing DI will be identified. Hence, the third research question is:

Research question 3: What factors make providing DI in secondary education more or less complex?

Method

As the required skills and knowledge for teachers to provide DI in secondary education were not yet known, a cognitive task analysis (CTA) was conducted in the current study, to identify, analyze, and structure both the skills and knowledge that experts (in our case, teachers who differentiate well) use while carrying out a complex task ([Clark, 2014](#)). The teachers observed in the study do not necessarily have to differentiate perfectly during the observations. The goal of the CTA is to identify patterns across the data gathered from a group of teachers competent in providing DI. Also, the results thereafter were discussed with content experts (e.g., researchers with expertise on DI, secondary school teacher trainers), to both validate and, if needed, add to the findings of the classroom observations. A CTA as a research method was chosen because this emphasizes practice, resulting in an overview of DI that is attainable for teachers which could provide a good base for future TPD design and to be able to compare findings in secondary education to those of [van Geel et al. \(2019\)](#) in primary education.

The steps followed for conducting the CTA stem from [Clark et al. \(2008\)](#) and are shown in [Table 1](#), as first presented in [van Geel et al. \(2019\)](#). The first step was aimed at acquiring a basic understanding of DI in secondary education. For that purpose, a literature review was combined with classroom observations followed by interviews, as explained in section 2.2 describing the data collection. The second step was to identify knowledge representations, in order to decide how to present the data gathered in steps 3 and 4. A skill hierarchy was chosen to present the skills necessary for providing DI. Underlying knowledge required to execute these skills and factors that influence the complexity of

TABLE 1 CTA activities in the present study.

CTA Steps according to Clark et al. (2008)	Activity in this study	
Step 1: Gathering of information that is necessary for carrying out the CTA	a.	Literature review
	b.	Lesson observations to map out real-life tasks and class situations that require DI skills
Step 2: Identify knowledge representations	This was chosen based on 4C/ID <ul style="list-style-type: none"> - Skill hierarchy - Overview of underlying required knowledge - List of complexity-related factors 	
Step 3: Use of elicitation methods	a.	Lesson observations followed by semi-structured interviews (cued recall)
	b.	Expert meeting with teachers
Step 4: Analyze/verify data acquired	a.	Iterative qualitative analysis of data from observations, interviews and expert meetings with expert teachers
	b.	Expert meeting with content experts
Step 5: Shaping the results for the intended end product	In a later study, the results will be used to design and develop a TPD program for DI.	

providing DI were listed. Step 3 concerned the use of elicitation methods to gather information from teachers on how they provide DI. This was done through lesson observations followed by semi-structured interviews (cued recall), which are the same activities as those in step 1 (i.e., the gathering of data for steps 1 and 3 was done simultaneously, for the most part). An expert meeting with teachers both verified and expanded on the information already gathered during the observations and interviews. In step 4, the data gathered thus far were analyzed and verified by the researchers. Subsequently, during a meeting with experts in DI and/or secondary mathematics (i.e., content experts), this analysis was verified. The fifth and final CTA step concerned shaping the gathered information so it can be used for what comes next, which in this case will be the design and development of a TPD intervention for DI based on the four-component instructional design (4C/ID) model of [van Merriënboer and Kirschner \(2013\)](#).

Participants

For the lesson observations and expert meetings, 11 mathematics teachers who differentiate well and 10 content experts (mathematics or DI) were selected. In this section, the selection procedure and participants' characteristics are described.

Expert teachers

This study involves cooperation between the University of Twente and a Dutch school board that governs about 50 secondary schools. School leaders, mathematics department heads, and other colleagues within said school board were asked to identify mathematics teachers who were above average at providing DI. This resulted in a group of 11 teachers with a wide variety of years of experience, the educational levels they teach and what years they

teach. More information about the participating mathematics teachers can be found in [Table 2](#).

Content experts

After the expert meeting with teachers, an expert meeting for content experts with expertise on DI and/or secondary mathematics was organized (see step 4b in [Table 1](#)). These experts were recruited by the researchers via connections with the Teacher Development department at the University of Twente, searching on LinkedIn, and websites of educational advisory companies, in combination with the snowballing method in which participants were asked if they could suggest additional experts in DI. This resulted in a total of 10 content experts: three secondary teacher trainers, three researchers with a focus on DI, two educational consultants, one school inspector, and one secondary mathematics teacher.

Data collection

Data collection started with lesson observations followed by semi-structured interviews (as described in step 3a in [Table 1](#)). After all observations and interviews had been conducted, the expert teacher meeting took place, as shown in step 3b. In step 4b, a meeting with content experts took place, during which the data gathered up to then were extended and verified. During all of these steps, the data were analyzed and re-analyzed in an iterative process in which each step started with data from the previous step as input.

Lesson observations followed by an interview

To map out what skills are necessary to provide DI, expert teachers were observed for two consecutive lessons with the same class of students to analyze the coherence between the lessons and those lesson's goals. Permission for collecting data from both observations and interviews was granted by the ethical committee

of the University of Twente. Prior to data collection, students (or their parents, depending on the student's age) had to give active informed consent. The observed lessons were video recorded for eight of the 11 participants (three teachers did not want to be recorded for either personal or school organizational reasons, in which case the researcher took notes). Video recordings of the observed lessons were used only as input for the interviews.

Every observation was directly followed by a semi-structured interview, to gain insight into the reasoning of teachers when implementing DI. Additionally, more information was gathered about the necessary skills for providing DI, which are not visible in lesson observations. These interviews included three parts. The first part included questions about the teacher's background (e.g., years of teaching experience). In the second part, the researcher selected specific situations from the recordings or notes from the observations using an overview of classroom situations that (might) call on DI skills, based on [van Geel et al. \(2019\)](#) and [van de Grift et al. \(2011\)](#). The researcher then asked the teacher to elaborate on their in-class thoughts and reasoning during those classroom situations ([O'Brien, 1993](#)). The third and last part of the interview consisted of five lead questions followed by multiple follow-up questions. The first four lead questions concerned the four phases of DI according to [van Geel et al. \(2019\)](#). One of the phases, enacting a lesson, had mostly been discussed already during part two of the interview, and during this part, the interviewer asked (in Dutch) about any topics that were yet unclear, with questions such as "How do you adapt your instruction to the needs of the students?" or "To what extent do you give students responsibility for their learning and choices?" For the other three phases (preparing a lesson series, preparing a lesson, and evaluating a lesson), the interviewer asked what these phases entailed for them, what they did in those phases and whether each phase is important for providing DI. The fifth and final lead question related to the complexity of providing DI, including follow-up questions such as "In what kind of situations

TABLE 2 Characteristics of participating expert teachers.

Name ¹	Teaching experience (years)	Number of classes taught	Mean number of students per class	Educational level of observed class	Grade
Amy	3	5	29	Pre-vocational	7
Anna ²	3	5	30	Pre-vocational/senior general	7
David	9	8	29	Senior general	10
Emily ²	10	6	31	Pre-university	8
Jennifer ²	18	5	29	Pre-vocational	9
Kelly ²	25	2	27	Pre-university	9
Robert ²	25	5	23	Pre-university	11
Sandra	16	3	25	Pre-university	12
Sharon ²	10	9	28	Pre-university	10
Steven	3	7	29	Pre-university	7
Thomas	4	4	27	Pre-university	10

¹All names are pseudonyms to preserve anonymity.

²Also participated in the expert meeting with teachers.

is providing DI easy or difficult, and why?” and “What do you think teachers need to provide DI well?”

Meeting with expert teachers

After all classroom observations and interviews were conducted, all of the 11 expert teachers were invited to the expert teacher meeting to verify the outcomes from the observations and interviews. Six of the participating teachers (as indicated in [Table 2](#)) were able to join this meeting. The first goal of the meeting was to identify the complexity-related factors. The teachers were divided into two groups, with the assignment to describe five situations during lessons in which a teacher should use DI skills. Next, they had to order these situations from simple to more complex and discuss what makes the situations more or less complex. This resulted in a ranking of the factors that make implementing DI easier or harder, in their view. The outcomes from both groups were discussed with the entire group.

The second goal of the meeting was to map out the teacher's steps, actions, and decision points when differentiating and what knowledge it requires to do that. The teachers were asked to design a standard approach for how teachers ideally differentiate for each of the four phases (lesson series preparation, lesson preparation, teaching during the lesson, and lesson evaluation). This was followed by a plenary discussion, to synthesize all procedures into a single joint procedure. Further discussion concerned what a teacher's DI actions and decision points are, what knowledge a teacher needs for carrying out each of the steps, and when a teacher executes a step correctly. During this meeting, the research team guided the teachers by asking questions and requested examples or clarifications if necessary. The research team took notes and the meeting was recorded.

Meeting with content experts

During this meeting, the results of the lesson observations, interviews, and the expert meeting with teachers (i.e., the preliminary skill hierarchy (see section 2.3 Data Analysis), the ranking of complexity-related factors, and overview of required knowledge) were presented to the content experts. The first goal was to reach consensus on the necessary skills for providing DI by presenting the already-collected data to participants in the study (i.e., member-checking; [Stalmeijer et al., 2014](#)). The second goal was to describe how the skills in the skill hierarchy should be carried out, to be used as a basis for performance objectives. The content experts first used the skills identified in the skill hierarchy to choose the top three most important skills for providing high-quality DI. Next, participants were divided into three groups, and each group was asked to draw up the criteria for one of the skills from the top three. They had to draft criteria for inadequate, adequate, and good performance for a particular DI skill. The identified performance level descriptors do not contribute to answering the current research questions, and will therefore not be included in the results section of this paper. Notes were taken during this meeting as well, and the meeting was recorded.

Data analysis

The data for this cognitive analysis included the transcripts of the interviews (for which the recordings of the lesson

observations were used as input) and the notes and recordings from both expert meetings. First, the data from the interviews and the expert meeting with teachers were analyzed. Codes were assigned to the actions and the reasoning of teachers, the knowledge they used and the factors that make providing DI more or less complex. These codes were subsequently clustered into categories. The first four categories were the four phases of DI: the preparation of the lesson series, preparation of the lesson, teaching during the lesson and evaluation of the lesson ([van Geel et al., 2019](#)); the fifth category was the knowledge teachers required for providing DI, and the sixth category concerned the complexity-related factors. Next, the codes within each of the categories were grouped (e.g., a group called “monitoring” within the category “teaching during the lesson”). The first four categories (i.e., the four phases of DI) and the corresponding code groups were put in a draft skill hierarchy. For the fifth and sixth categories and their corresponding code groups, (i.e., “required knowledge” and “complexity-related factors”), detailed lists were created. Finally, the draft skill hierarchy and the draft lists of both the required knowledge and the complexity-related factors were discussed during the content expert meeting to both verify and expand them. In the next section, the outcomes will be presented in more detail.

Results

Skill hierarchy

Our respondents confirmed that for DI in secondary education, the four closely interrelated phases (preparing a lesson series, preparing a lesson, teaching during the lesson, and evaluating a lesson) also play an important role. All of these phases can be decomposed into constituent skills (see [Figure 1](#)). The skills that are next to each other within a phase have a temporal relationship and can be carried out consecutively, simultaneously, or in random order. For the skills that have a vertical relationship, the lower skill is required or supplementary for the higher skill. This means that the performance of a higher skill or phase is only possible when a teacher enacts the skills identified below. Although some skills or phases may seem to be independent of the skills positioned below, for providing DI these underlying skills are deemed essential.

In the rest of this section, the constituent skills will be described per phase. For each of the skills, the number of teachers who were observed doing or who mentioned the skill will be stated. While most skills were used by all teachers, at least nine of the 11 teachers performed all the skills. An exception is ‘to determine the lesson goal’ during lesson preparation, which was mentioned by seven teachers. As the content experts emphasized the importance of this skill, it was decided to include this skill as well. In the rest of the paragraphs, examples will be given of how teachers enacted the specific skill.

Preparing a lesson series

When preparing the lesson series (generally lasting 4 to 8 weeks), teachers lay the foundation for providing DI. In this phase, teachers

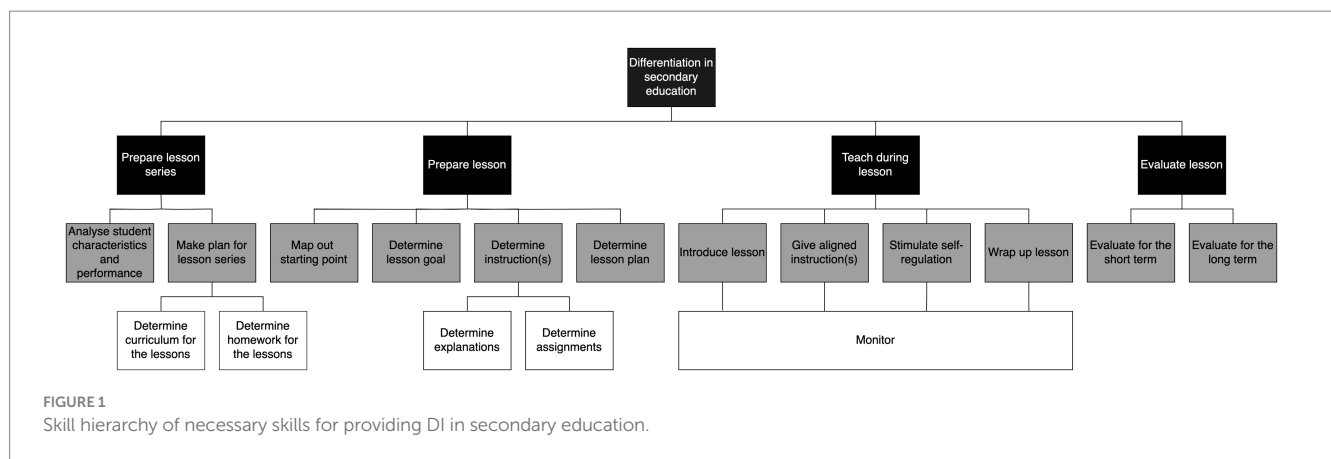


FIGURE 1 Skill hierarchy of necessary skills for providing DI in secondary education.

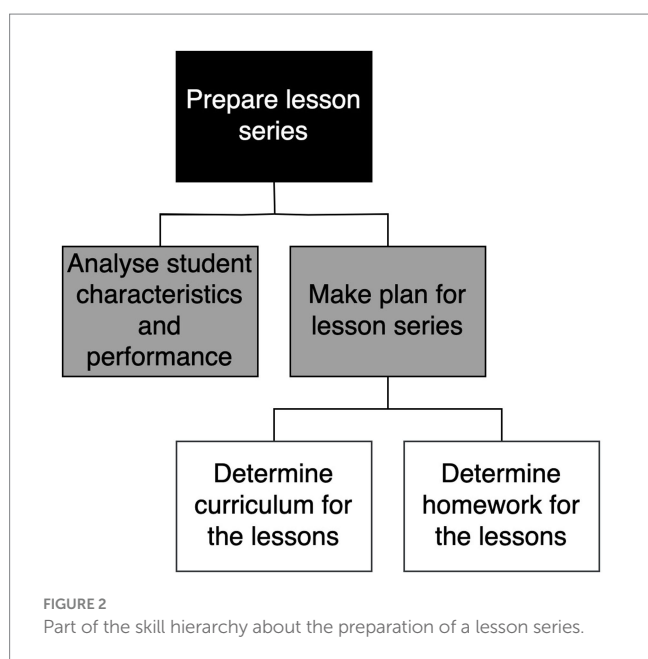


FIGURE 2 Part of the skill hierarchy about the preparation of a lesson series.

analyze student characteristics and performance and they make a plan for the lesson series, wherein they determine both the curriculum and the homework for the lessons. The relationships between the necessary skills are shown in Figure 2.

In this study, all teachers analyze student characteristics and performance when preparing a lesson series for a class. Teachers analyze their students' achievement level and preferences to see whether students have achieved earlier stated learning goals or not. They do so by combining different resources including tests, observations, and information from colleagues.

One source of information is a previous or earlier lesson series with related goals, to paint a picture of where the students stand regarding the goals of the lessons in the upcoming lesson series. Because inadequate performance can have various causes (e.g., some students may have difficulties grasping a certain topic, while other students may have made a lot of mistakes in how they wrote down the solutions), teachers try to explain those performances by talking to students and observing student behavior. Teachers

analyze how well the students, in general, did on the test they took at the end of a previous lesson series by checking both the grades and whether there were any frequently made mistakes. They also map out what topics the students still find hard and take these as points of attention for (the planning of) the upcoming lesson series. Besides that, teachers look at the results and mistakes of those students who did not achieve the goals of the earlier lesson series, or who performed below expectations. Teachers have diagnostic conversations with students to analyze why the student performed differently from what was expected and to discuss with the student how both the student and the teacher can ensure they will do better next time.

Another source of information for the teachers are colleagues: other mathematics teachers within the school or teachers who teach different subjects to the same students. Teachers indicated that it is important to know the students themselves as well, and to combine the information from colleagues with their own experiences. When starting a new school year with classes with students they have never taught before, some expert teachers find it important to look at students' results from previous school years, while others find it important to get to know the students themselves without bias. The content experts agreed with the latter, stating that looking at students' data while not yet knowing the students themselves (well) could lead to a self-fulfilling prophecy; therefore, they advised being careful with it. There are, of course, exceptions where information should be shared between colleagues, for example, when a student has a visual impairment and should sit in the front of the class to see the teacher well.

Combining the information from all of the different available resources, teachers assess students' achievement levels. Especially for low-performing students, teachers check if they have mastered the earlier goals that are necessary for new, upcoming goals. The teachers specified that they find it important to know upfront whether the students have sufficient prerequisite knowledge, because if they do not, the teachers can take this into account in their planning. Teachers deem it important to know what part/topic (of mathematics) high-performing students are good at. Teachers keep in mind that those students might not need as much instruction for that subject, and often give high-performing students more freedom in choosing what assignments to complete.

All teachers mentioned that they make a plan for a lesson series. They first need to consider the yearly timetable in which the subjects to be taught and exams and other summative tests are specified and established by all the teachers of the mathematics department. Although these timetables are drawn up for all grades, there is more room for flexibility in the lower grades, due to the absence of exams. In the plan for the lesson series, teachers develop a timetable for when to attend to what content and in how much time. A teacher might need to develop multiple timetables as they can differ for (groups of) students, depending on their individual learning needs. To develop a plan for a lesson series, teachers need to master two constituent skills: determining the subject matter for the lessons, and determining the homework for the lessons.

All teachers mentioned that they *determine the subject matter during their* lesson series preparations. Teachers start with checking what is scheduled in their planning for the whole year. They check what the subject and approach of the textbook are, what the learning goals for the students are, and, from experience and subject knowledge, what difficulties there might be. When teachers determine the subject matter for the lessons, they primarily stick to the textbook, but adapt it when they think something else would be more suitable for addressing the learning needs of the students. What is suitable for the student is determined based on experience from previous years, the analysis of student characteristics and performance, and lesson evaluations from a previous lesson series. For example, teachers might plan extra time to better explain a topic from the previous period that was still unclear or difficult for most students. This can result in different plans or activities for two classes from the same track and year, or even a different plan for a specific student.

Along with determining the subject matter, 10 teachers stated that at this point they *determine the homework* for the lessons, and the 11th teacher determines homework during lesson preparation. For homework, teachers primarily consider the assignments from the textbook. Most teachers make sure they have completed the assignments themselves first, which they might have already done in an earlier year. This, together with teaching experiences from earlier years, is used to judge what assignments the students should complete to reach the goal of every lesson. There is special attention for closing assignments at the end of a chapter in the textbook, which are used to measure whether the student understands the theory taught so far and has achieved the learning objectives of that chapter. Four of 11 of the teachers specify the homework for different levels during this phase. An example was a teacher who labels homework assignments as basic, extra practice and challenging. In this way, students are challenged at their own learning levels, and stimulated to self-regulate their learning. The subject matter and homework for each lesson that are decided upon make up the planning for the lesson series.

Preparing a lesson

When preparing a lesson, the teacher extends the foundation laid when preparing the lesson series by mapping out their students' starting point and determining the goal of the lesson, instruction and lesson plan. For teachers to determine the instruction(s), they must determine what explanations and assignments are going to be used during the lesson. The necessary skills for lesson preparation are

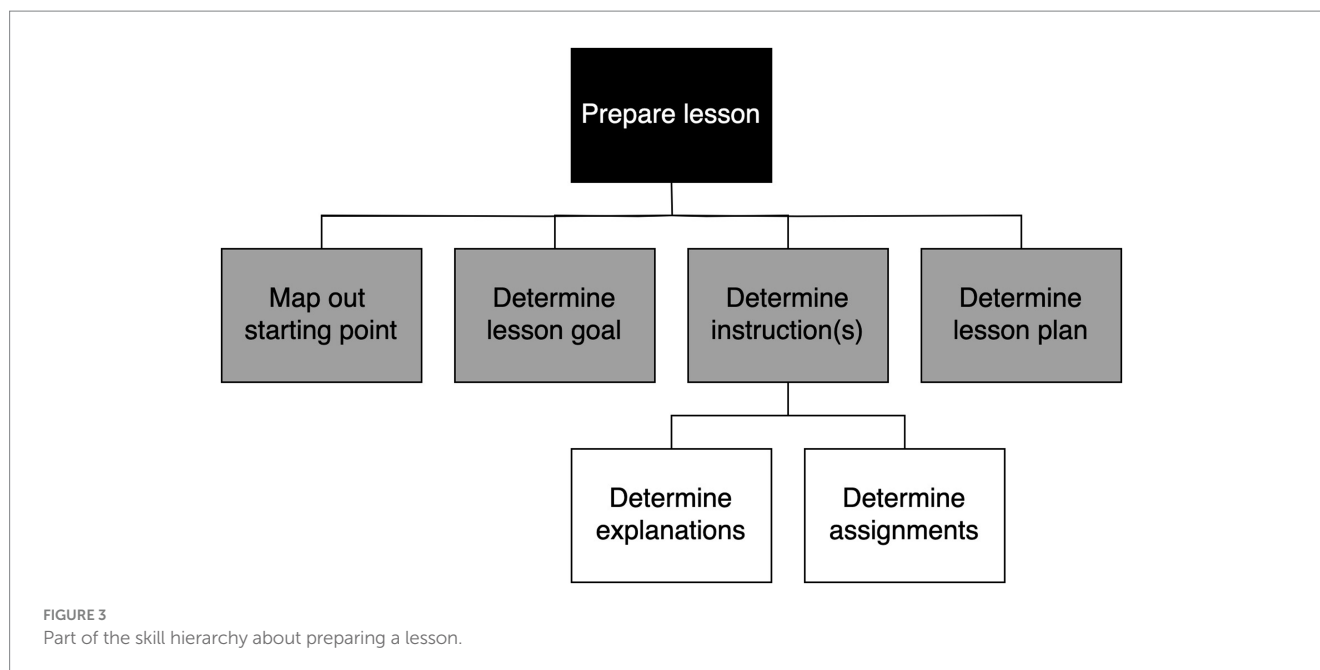
depicted in [Figure 3](#) and will be further elaborated upon in the rest of this section.

All teachers look back at the previous lessons for the class to map out the starting point. The teachers' goal is to know about the students' prior knowledge and learning needs. Teachers look back at the evaluation of the previous lesson to check whether the learning material was transmitted as planned and whether there were any problems. For example, there might still be a lot of questions, and students could experience difficulty grasping the theory. Teachers also check on for whom this was the case. They map out the starting situation so that they can take this into account during the rest of the lesson preparation.

Along with this, seven teachers determine the goal of the lesson, which is the second constituent lesson preparation skill. The content experts emphasized that it is very important to determine the goal of the lesson when providing DI, and that the goal should be connected to the bigger picture of what the class has already discussed and what are they working toward. Teachers decide what they want the students to be able to do or to understand at the end of the lesson. For example: "you can use quadratic formulas in contextual sums" or "you know the difference between a quadratic and a linear formula." To formulate the lesson's goal, teachers look at what is scheduled in the curriculum and they take into account the mapped-out starting point. In addition to determining the goal of the lesson for the group as a whole, some teachers also formulate additional goals for specific students or groups of students.

All teachers determine instruction(s) when preparing a lesson. To do this, all teachers first *determine the explanations*. Teachers think about how they will explain the theory in order to achieve the lesson's goal. They check whether the explanation in the textbook or a PowerPoint used earlier are suitable, where problems might arise (e.g., parts that might provoke a lot of questions from students) based on experience from previous years, and whether or not they want to use specific materials or software for the explanation, for example, to visualize something. However, teachers also take into account the mapped-out starting point and learning needs of this specific class of students. Based on this, teachers decide what they want to demonstrate, whether they can explain the theory differently, or whether they need to prepare extra explanations. Content experts mentioned that teachers should be able to think of alternatives for their explanation of the subject matter, in case it becomes clear during the lesson that the planned explanation does not work for everyone. When deciding on the explanations, teachers often decide what they want to explain to the whole group and how. They might decide that there are students who do not need any explanation at all (i.e., high-performing students who can immediately start completing assignments on their own), and might prepare additional explanations for students who generally find mathematics difficult or have trouble with a certain goal. Based on the analysis of student characteristics and performance during the lesson preparation and/or the evaluation of earlier lessons, the teachers identify which student(s) need these additional explanations. Finally, content experts indicated that it is important when preparing a lesson that teachers think about how they want to attend to the needs of both the low- and high-performing students.

Along with determining the explanations, all teachers *determine the assignments* for students, to practice with the new theory and



check whether or not the students understand it. These can be assignments from the textbook, from the internet, or self-made, and can be traditional paper-and-pencil written assignments, some form of a game, practicum, or another kind of assignment. To adapt these assignments to the differing learning levels of students, teachers might choose two or multiple assignments that vary in complexity and let students choose which one they will do, for example. Another way of differentiating assignments is to offer a harder, more complex assignment as an option for high-performing students, which the content experts identified as important. Textbooks often already include “learning paths” (i.e., a path from starting goals, through intermediate goals, toward the final learning goal) for students of different levels (e.g., a learning path with more complex assignments for high-performing students). Teachers said that they use the learning paths from the textbook when they think they are appropriate but also that they design learning paths and combinations of assignments themselves when they believe the ones the textbook offers are not suited to their students’ learning needs. The more challenging assignments are given instead of, and not along with, the regular assignments. Moreover, teachers sometimes decide upfront what assignment they would like to work on during extended instruction (i.e., longer instruction with more explanations and practice together with the teacher) with the students who need it. Content experts argued that it is important that the teacher deliberately chooses assignments that suit the initial situation and learning needs of the students.

The explanations and assignments together make up the instruction. The teachers decide what they want to do and how they want to do this. For the teachers, instruction thus means not only the explanation of subject matter, but also the use of learning activities and assignments during the lesson, with the aim being for the students to reach the goal of the lesson.

Finally, during lesson preparation, the teachers determine the lesson plan. This was done by nine of the teachers. Teachers decide what they are going to do, for how long, what they will do with the whole class, and what is obligatory for all, or only for a

specific group of students. This is also where teachers decide if and when they want to discuss the homework from the previous lesson. Teachers also indicated that they find it important to make time during the lesson for any individual questions students may have.

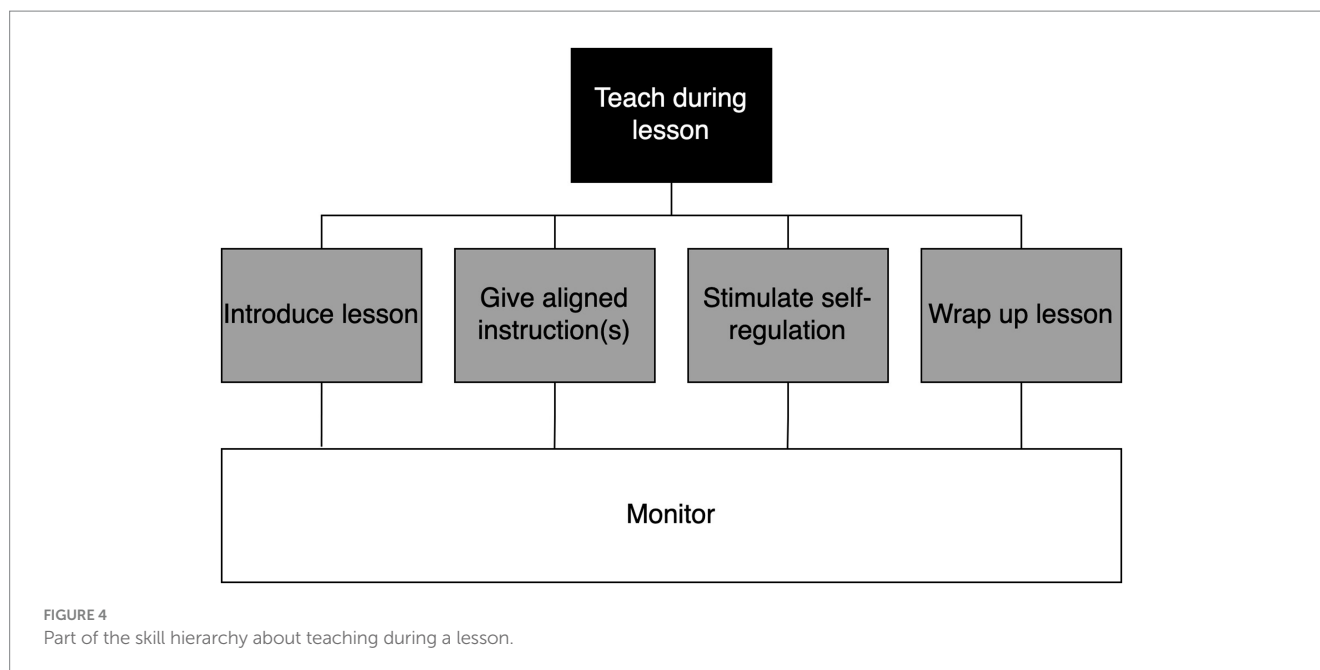
Teaching during a lesson

When teaching a lesson, teachers make use of four constituent skills. A teacher starts by introducing the lesson. Next, teachers give instruction(s) aligned to the learning needs of the students, while simultaneously stimulating the students’ self-regulation. This phase ends with teachers wrapping up the lesson. As can be seen in [Figure 4](#), these four skills have one shared constituent skill, which is monitoring. The rest of this section will further elaborate on all the necessary skills for the third phase.

Monitoring is an important underlying skill for all constituent skills in this phase. All teachers in the CTA continually monitored the progress and understanding of their students with regard to the goal of the lesson, using various strategies. What monitoring looks like for each of the skills in this phase will be detailed in the description of the skill itself.

This phase starts by introducing the lesson. All teachers explain the subject of the lesson and four teachers explicitly pay attention to the goal of the lesson. It was stressed by the content experts that introducing and explaining the goal of the lesson is very important. They encouraged teachers to explain what the students will learn, why that content is important and what it will yield for the students. Teachers also often state what the schedule for the lesson is going to be and what is compulsory for all or only for specific students.

When introducing the lesson, teachers check what the prior knowledge of the students is, for example, through discussing homework, asking and answering questions, or whole-class discussion of an assignment. In this way, the teacher not only monitors but also activates students’ prior knowledge, so that students can relate the new lesson material to what they have already learned.



All teachers provide adapted instruction(s). According to content experts, this is the most crucial constituent skill for providing DI. Instruction includes explanations, assignments, and all other instruments to help students achieve the goal of the lesson. Teachers adapt this instruction to the learning needs of their students, based on their constant monitoring. For example, when teachers notice that there are many similar questions, they might choose to give an extra explanation to a selected group of students or even the class as a whole. The content experts indicated that a teacher should give all students guidance that is adapted to their learning needs.

The observed lessons frequently followed the same pattern. After introducing the lesson, teachers started with general class instruction about that lesson's theory. Teachers specified that they try to keep the general class instruction short to ensure that it is not too long for the students who do not need it. Some teachers give high-performing students the choice of whether or not to follow this instruction or to work independently. After this general class instruction, teachers in the observed lessons often gave extended instruction to students who had not fully grasped the subject matter yet. The goal is to make sure all students reach the goal. Depending on the number of participating students, teachers choose to do this in front of the class or in a small group. Teachers often do an assignment together with the students to provide guided practice, but they can also give more elaborate explanations using simpler words or visualizations.

Three teachers mentioned that they offer a more in-depth explanation to explain underlying theories or a higher-level assignment to challenge the students. Sometimes students may choose which one they prefer to do and other times the teacher decides what is most suitable based on what they have seen in their monitoring. High-performing students can work on these instead of following the general class instruction or can start after the instruction. During the meeting with content experts, it was specified that a teacher has

provided adapted instruction well when students at all levels feel challenged.

Stimulating students' self-regulation is a skill that all teachers mentioned. Teachers involve students during the lesson by giving them responsibility for their learning process. They can do this, for example, by giving them the choice to not to follow the general class instruction and/or extended instruction, or by giving choices about what assignments to do as their homework. Teachers stimulate self-regulation by helping students to form an image of where they stand in the learning process and what they still need to do to attain the goal of the lesson. For example, teachers can indicate that if students find a certain assignment hard to do, they should do more practice using an easier version of that assignment. When stimulating students' self-regulation, teachers take on the role of a coach, continually monitoring whether the students are making the right choices by asking the students questions about their learning process.

Wrapping up the lesson was identified as constituent skill based on observations and explanations of ten teachers. The teachers in the expert meeting stated that this should be part of every lesson. In practice, teachers were sometimes still answering questions in class, which left them with no time to explicitly wrap up the lesson. When teachers do wrap up the lesson, they do so by discussing a difficult assignment, giving an extra tip, taking stock of any unanswered questions, and/or mentioning the homework, based on their monitoring during the lesson. While teachers look back at the lesson, they often summarize how the lesson went, how the work ethic of the students was, and by asking students their opinion about the lesson. Content experts found it important that teachers check during the wrap-up whether or not the goal of the lesson has been achieved. Teachers do so by asking the students questions about the lesson or by giving an assignment to check if the students can put into practice what they have learned.

Evaluating a lesson

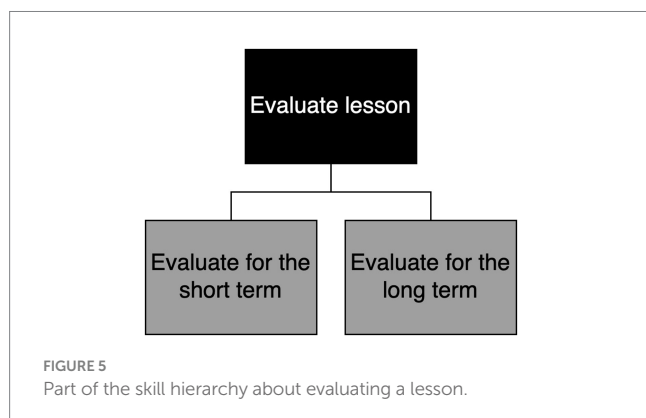
After the lesson, teachers look back at the lesson, which, as can be seen in [Figure 5](#), consists of evaluating for the short term as well as for the long term.

All teachers evaluate for the short term. Teachers reflect on how the lesson went, what kind of questions were asked, and whether or not all students achieved the goal of the lesson. First of all, the teacher evaluates the group of students who received the lesson. A teacher might find out that the explanation during the extended instruction was too hard for some of the low-performing students. Teachers think about what they can do differently in the next lesson so the students can learn the content and achieve the goal of the lesson. Some teachers make notes of this, while others think about it and take it into account when preparing the next lesson. Content experts stressed that it is important that the teacher not only looks at the class as a whole, but also zooms in on individual students. Second, teachers can evaluate a group or groups of students who are going to experience the same lesson, namely, a parallel class. If this lesson did not go the way the teacher planned, they might change some things so that the parallel class will not run into the same problems and will achieve the goal of the lesson, while the first group of students maybe did not.

Along with evaluating for the short term, all teachers also evaluate for the long term. They reflect on what they could do differently next school year. Teachers do not just look at one lesson, but evaluate multiple lessons at once, or even all lessons within a lesson series. For example, when teachers notice that they are going through the subject matter too quickly, they take this into account when preparing the lesson series in the next school year. They can make notes in their curriculum material manual and plan to take more time for this topic. Furthermore, all teachers check how well the explanation of the subject matter worked; if it did not work very well, they will consider changing things for next year. The teachers often make notes about this in their own textbook.

Required underlying knowledge

To provide DI by deploying all of the constituent skills, teachers also need specific knowledge. In this CTA, three types of knowledge emerged: knowledge about students, general didactic-pedagogical knowledge, and subject-matter knowledge.



All teachers indicated that it is important to have knowledge about the students. First, a teacher must know the level of all individual students per class. A teacher in secondary education sees a lot of different students per week, which makes it hard to always have all this knowledge about every specific student available. Getting to know the students takes time. Teachers mainly gather information by continually monitoring during the lessons. They acknowledged that it is important to know which students find mathematics hard, which students are good at math, and which students are in between those two groups. It is also important that a teacher knows how motivated and independent students are.

Next, teachers need to have general didactic-pedagogical knowledge: knowledge about how students learn and what activities can help them learn, which teachers mostly gather when monitoring during a lesson. Teachers use this knowledge, for example, to decide how they can help an insecure student or a student who is good at math.

Finally, teachers need subject-matter knowledge: pedagogical content knowledge (PCK) for math, knowledge of the curriculum, and knowledge of the learning path. PCK is important for knowing how to explain math subject-matter content. Knowledge about the learning path is important so a teacher can take a step back or a step forward. In this way, a teacher can respond to the needs of low- and high-performing students. Knowledge of the curriculum relates to knowledge of the textbook and the assignments in the textbook. With this knowledge, teachers can use and explain subject-matter content well in the class.

Complexity-related factors

In the CTA, various factors were identified that influence the complexity of providing DI in secondary education. Multiple class characteristics influence the complexity (see [Table 3](#)), for instance, having a bigger class size with more students makes it harder to know the learning needs of every individual student. School organization also matters as having little preparation time makes it hard to plan explanations for different learning levels. A higher information richness, i.e., if the teacher has access to good information about their students' achievement level makes providing DI easier. Finally, if the curriculum supports DI by offering the teachers assignments and/or explanations at different levels, providing DI is easier than if the teacher has to determine assignments/explanations on various levels by themselves. How complex it is for a teacher to provide DI depends on a combination of all of the complexity-related factors, which can be found in [Table 3](#).

Discussion and conclusion

DI refers to how teachers adapt their instruction to the continually monitored needs of all learners ([van Geel et al., 2019](#)). At the start of this study, it was unknown what teacher behaviors and knowledge are necessary for DI in secondary education and whether they are similar to what providing DI in primary education requires. This research has filled that gap by investigating the actions and reasoning of DI experts when providing DI, together with what knowledge teachers need for providing DI and what factors make providing DI more or less

TABLE 3 Factors influencing the complexity of DI.

Factor	Aspect	Explanation
Characteristics of a class	Class size	Teachers indicated that they find providing DI easier when the class size is smaller, as that makes it easier to have an overview of their students.
	Variation in student levels	The higher the difference between and variation within the groups of low- and high-performing students, the harder it is to differentiate. Teachers then must consider many and very different levels.
	Classroom ambience	When the ambience in a class is not good, that asks for a lot of the teacher's attention, which makes it harder to differentiate. When the ambience is good, students will feel more comfortable answering and asking questions, providing more information for the teacher.
	Class attitude	If (a large part of) the students do not work independently when they should, providing DI is harder.
School organization	Preparation time	Teachers mentioned often that they do not have much time to prepare a lesson. This makes it harder for them to think upfront about how they would like to differentiate during the lesson.
	Number of activities	Teachers stated that their planning of activities within a year is very tight and that they do not have much room for revisiting topics from the previous period.
	Time spent with students	The more time a teacher spends with the same students, the easier it is to get to know them and to identify their educational needs.
	Lesson duration	When lessons last longer, there is more room to provide instruction in different ways and as such to respond to the varying needs of the students.
	Physical space in classrooms	If there is more space, a teacher can use a table for instruction and sit apart with a smaller group of students. If a classroom is quite full, this is harder.
Data regarding student achievement	Information richness	Teachers gather information about students' progress by monitoring during lessons and in (summative) tests they administer. Having the right information gives more insight into the students' learning needs, which makes it easier to differentiate.
Support from the curriculum	Assignments at different levels	If the textbook has differentiated assignments according to different levels, it is easier for a teacher to align the assignments to the varying needs of the students.

complex. This has been done through a CTA, where providing DI in a real-world context was studied through lesson observations, interviews with teachers, and expert meetings.

The rest of this section is divided into two parts. The first part addresses the three research questions: (1) "What skills are required from teachers in secondary education to provide DI?," (2) "What knowledge is required from teachers in secondary education to provide DI?," and (3) "What factors make providing DI in secondary education more or less complex?." The second part of this section compares the required teacher knowledge and skills for providing DI between the contexts of primary and secondary education.

What does providing DI require from teachers in secondary education?

This study showed that four phases are important for providing DI in secondary education, in which teachers use various skills and different types of knowledge, and that a number of factors influence the complexity of DI. Furthermore, the in-depth interviews revealed that the quality of DI depends on the deliberate adaptations a teacher makes, based on their knowledge.

In the first phase, preparation of a lesson series, teachers lay the foundation for providing DI. Teachers analyze student characteristics and performance, to add to their already-existing knowledge about their students. They use their subject-matter knowledge to make a

plan for the lesson series, determining both the curriculum and the homework. Curriculum material can support teachers in preparing for DI in a lesson series; for example, it is easier to determine assignments at varying levels when the textbook material already provides assignments for different achievement levels.

In the second phase, lesson preparation, teachers map out the students' starting point. Teachers determine the goal of the lesson and the lesson plan, and prepare the required instruction(s), for which they use their didactic-pedagogical knowledge to determine both explanations and assignments so as to ensure that their students can reach the goals.

Teaching during the lesson is the third phase. Teachers introduce the lesson, provide instruction(s) aligned to the learning needs of the students and stimulate the students' self-regulation. Finally, they wrap up the lesson. During the lesson as a whole, teachers monitor the progress and understanding of their students, and continually expand and refine their knowledge about students. Providing DI during the lesson is more complex when lessons are shorter, as that leaves less time to provide a variety of types of instruction to attend to all students' learning needs. Enough physical space in classrooms enables teachers to sit apart with a smaller group of students, which is experienced as helpful for DI.

In the fourth and final phase, evaluating a lesson, teachers evaluate whether or not students have reached the goal of the lesson in the short term. Teachers also evaluate for the long term, where they consider if they could do anything differently in the next school year,

such as changing the order of topics in the curriculum/learning path, using other activities that help students to learn better, or planning more time for a certain topic.

In the theoretical framework it was mentioned that for high-quality DI teachers should adapt their instruction deliberately and proactively (Tomlinson et al., 2003; van Geel et al., 2019). It is thus not surprising that lesson (series) preparation and lesson evaluation were deemed important phases for providing DI in the current study. This is in line with the findings of Smale-Jacobse et al. (2019), who argue that providing DI during the lesson cannot be separated from lesson preparation (e.g., state clear goals and plan instructions) and lesson evaluation (e.g., evaluate students' progress toward the lesson goals). To provide DI, various strategies can be used, such as ability grouping or making use of a computerized system to support DI (Deunk et al., 2015, 2018). In the current study, teachers often chose ability grouping (as providing for example extended instruction was part of a common lesson), the use of computerized systems to support teachers in providing DI was not mentioned.

From the CTA it appeared that the core skill for providing DI is continually monitoring students' learning and progress. In all phases, teachers identify their students' learning level. This goes from analyzing performance in the preparation for the lesson series and mapping out starting points in the lesson preparation, to observing students' expressions and behavior, asking them questions and checking their work during the lesson. In their evaluation, teachers monitor to what extent each student reached the goal of the lesson. Continual monitoring contributes to teachers' knowledge about their students. Smale-Jacobse et al. (2019) too found that continuous monitoring is inseparable from DI. Students only learn if their assignments are neither too easy or too difficult for them and if they work in their zone of proximal development (Vygotsky, 1978; Joseph et al., 2013). Teachers need the knowledge they gather through continually monitoring students' progress for providing DI: teachers can only provide instruction that is suited to the learning needs of their students if they have thoroughly identified those learning needs.

How does providing DI in secondary education compare to primary education?

As not much was yet known about the teacher skills and knowledge required for providing DI, van Geel et al. (2019) conducted a CTA in primary education in mathematics classes. By conducting a CTA in secondary mathematics education, the current study enables us to compare the required knowledge and skills in these two educational sectors. In general, although the contexts are quite different (e.g., teachers in primary education have only one class of students, while the teachers in secondary education in this study had an average of 5 classes of students), we have identified many similarities in the phases and required knowledge and skills necessary for providing DI. In the subsequent paragraphs, we will elaborate on the similarities and differences between DI in primary and secondary education.

Providing DI in secondary education happens in the same four interrelated phases as were found in primary education (van Geel et al., 2019). Teachers in both primary and secondary education start with preparing a coherent set of lessons, which is called a lesson period (primary education) or lesson series (secondary education). Next,

teachers zoom in and prepare a single lesson. This is followed by teaching the lesson itself. Finally, teachers evaluate how the lesson went and if they need to adapt anything in the future. Although the constituent skills required for DI in the various phases are also rather similar, some differences can be identified, too. For example, in the preparation of the lesson period in the CTA by van Geel et al. (2019), the determination of subject matter and homework are not explicitly mentioned, but creating groups within the class and determining goals are. The last is also mentioned in the CTA for DI in secondary education, but during the preparation of the lesson, not the lesson series. Another example is monitoring, which is a constituent skill for "giving adapted instruction(s)" in the CTA by van Geel et al. (2019). While this is true for the CTA in the current study as well, 'monitoring' here is a constituent skill for the phase of teaching during a lesson as a whole. It can be concluded that although the focus is slightly different or the skill is used in a different phase, providing DI in primary and secondary education generally makes use of the same phases and skills.

What knowledge is necessary for providing DI is also mostly similar between primary and secondary education. For secondary education, three types of knowledge were found: knowledge about students, subject-matter knowledge, and didactic-pedagogical knowledge. Although the last type of knowledge was not explicitly mentioned in the study by van Geel et al. (2019), they did mention that primary school teachers need to know, for example, what kind of problem-solving strategies the students will understand, which is an example of didactic-pedagogical knowledge.

Regarding the complexity-related factors, in both primary and secondary education the composition of the group, school support, and available data on the students' progress were mentioned (van Geel et al., 2019). A difference is that van Geel et al. (2019) mentioned "the content of the lesson" explicitly as a factor influencing the complexity of providing DI.

In sum, the current study confirms the findings of van Geel et al. (2019) in an additional context, as the data gathered through CTAs in both primary and secondary education led to mostly similar results, which means that providing DI in both contexts requires approximately the same skills and knowledge and is made more or less complex by mostly the same factors.

Limitations and suggestions for future research

Although we studied teachers who are considered to be above average in terms of DI skills (within a Dutch school board) and we looked for patterns across this group (which led to a stable pattern), we cannot guarantee that the 11 participating teachers are the best in the country at providing DI in secondary education. In this study, content experts proved more normative and sometimes more ambitious than the observed teachers. However, the common patterns led to the skill hierarchy, knowledge types overview, and complexity-related factors, which we think are a good basis for the development of a professional development trajectory, as they emerge from school practice and therefore should have high feasibility. On the other side, although the current study provides rich insight into the constituent skills in the four phases, each skill in itself could be analyzed in more detail in order to obtain an even better understanding of how teachers exactly enact these skills and which underlying knowledge and skills are required.

All expert teachers worked for the same large school board, which only has schools in the Netherlands. For a future study, the results could be verified in a broader context, such as teachers of a different Dutch secondary school board or even secondary schools in other countries. As all teachers were mathematics teachers, the results of this study cannot be generalized to teachers teaching other subjects. Hence, it would be interesting to verify the results with teachers of other subject domains, such as other STEM (e.g., physics or chemistry) subjects or languages (e.g., English or French). All participating teachers taught classes that were mostly theoretical. For a future study, it would be interesting to see if teachers who teach more practical lessons (e.g., in vocational education) use the same knowledge and skills for providing DI as the teachers in the current study. Furthermore, since the factors related to complexity (as described in Table 3) cannot be influenced by individual teachers, more research is needed into how to support DI at school or even at the system level.

Practical implications

In secondary education in the Netherlands, teachers do not yet implement DI in their lessons very often and often do not feel equipped for it (Inspectie van het Onderwijs, 2015a; van Casteren et al., 2017). Providing DI is a complex skill, and pre-service as well as in-service teacher education could give teachers more support to be equipped for providing DI. This study has mapped out what skills and knowledge are required for teachers to provide DI, which can be used to design such TPD. In addition, complexity-related factors were investigated that can be used to manipulate situations to create scaffolding for the complexity. In this way, situations where providing DI is less challenging can be created wherein teachers can gradually develop the required skills. As we found several complexity-related factors at the school level, school leaders can play an important role in facilitating the complex task of DI for their teachers, for example, by providing them with more preparation time, or smaller class sizes.

As mentioned in the introduction, secondary school teachers do not yet provide much DI. Nevertheless, the current study shows that providing DI in secondary education can be achieved, as the data are based on practice. Hence, TPD based on insights from the current study could help teachers to provide (better) DI. Although providing high-quality DI is not something that happens very often yet (Inspectie van het Onderwijs, 2015a), the data obtained from experts in this research are inspiring and prove that it is possible.

Data availability statement

The datasets presented in this article are not readily available because the data include video observations and recorded interviews

that are not anonymized. Requests to access the datasets should be directed to k.meutstege@utwente.nl.

Ethics statement

The studies involving humans were approved by the Ethical committee of the University of Twente. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

MV, MG, and AV contributed to the design of the study. MV contributed to data collection. MV and KM performed the analysis of the data and wrote sections of the manuscript. All authors contributed to manuscript revision, read, and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The reviewer EK declared a past co-authorship with the authors MG to the handling Editor.

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