The skills and knowledge a teacher needs to have, to be able to differentiate in personalised math education at a primary school

Master Thesis

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Abstract

Differentiation is considered to be an important teacher skill since schools increasingly acknowledge differences between children. Until recently it was only investigated what skills and knowledge a teacher needs to have, to be able to differentiate in traditional math education at a primary school by Keuning et al. (2017). There is a new trend in education called personalised learning (Elferink, 2017) which is applied in personalised education. Differentiation is an essential teacher skill in personalised education. However, it is not known whether the skills and knowledge a teacher needs to have, to be able to differentiate in traditional math education can be generalized to the context of personalised math education, because personalised education differs from traditional education in some aspects.

Therefore, the necessary skills and knowledge to differentiate in personalised math education at a primary school were investigated by conducting a cognitive task analysis (CTA). The conducted CTA about differentiation in personalised math education resulted in a skill hierarchy in which the necessary skills are presented and a description of the required knowledge which enables a teacher to perform these skills.

Additionally, it is has been investigated to what extent the necessary skills and knowledge to differentiate in personalised math education at a primary school differ from the necessary skills and knowledge to differentiate in traditional math education at a primary school. The necessary skills and knowledge found in the CTA about differentiation in personalised math education conducted in this study were compared with the necessary skills and knowledge found in the CTA about differentiation in traditional math education conducted by Keuning et al. (2017). Based on this comparison it is concluded that the necessary skills and knowledge to differentiate in personalised math education generally correspond to the necessary skills and knowledge to differentiate in traditional math education, but there are some differences. Most of these differences are nuance differences, because the emphasis is place on other things in personalised education since it differs in some aspects from traditional education.

The insights provided in this study are a valuable addition to what is known about the teacher skill differentiation and the practices of a teacher in personalised education. Furthermore, these insights can be used in the development of a professional development trajectory, or in the redesign of teacher training curricula aimed to prepare pre-service and in-service teachers for teaching at a school that offers personalised education.

Keywords: differentiation, personalised math education, traditional math education, primary schools, cognitive task analysis.

1. Introduction

1.1 Problem statement

Children differ from each other in several aspects. They differ in what they find fun and interesting, in the way they prefer to play, work and learn, in the level of education they can handle, and so on (Bosker & Doolaard, 2009). However, most children have in common that they will become a pupil and will go to school. Therefore, schools increasingly acknowledge differences between children (Van Loon, Van der Neut, De Ries, & Kral, 2016). This means that dealing with differences between pupils, differentiation, is an important teacher skill. However, insight into the practice of differentiation; the skills and knowledge a teacher needs to have to be able to differentiate, was scarce until recently (Keuning et al., 2017; Vandewaetere, Desmet, & Clarebout, 2011). Keuning et al. (2017) provided in their study insight into the necessary skills and knowledge for a teacher to be able to differentiate in traditional primary education where Information- and Communication Technology (ICT) is not used on a structural basis. They focused on the subject mathematics in their study.

There is a new trend in education called personalised learning (Elferink, 2017). Personalised learning is tailored learning for each individual pupil, directed by the teacher and the pupils themselves by using ICT as a tool. This has become a new trend in education because: (1) the current structure of education does not always fit the diversity in our society (Elferink, 2017), (2) ICT provides opportunities to respond to the needs of individual pupils (Ministerie van OCW, 2013; Studulski, 2015) and (3) personalised learning is seen as a solution to the challenge of motivating pupils (Onderwijsraad, 2014; Paludan, 2006). When personalised learning is applied in education, the term personalised education is used (Van Domselaar, 2014). The exact practices of a teacher in personalised education has not fully been specified yet (Prain et al., 2012), but it is known that differentiation is an essential teacher skill in personalised education (Ministerie van OCW, 2014; Prain et al., 2012). However, it is not known whether the skills and knowledge a teacher needs to have to differentiate in traditional education can be generalized to the context of personalised education, because it differs from traditional education in some aspects. Personalised education focuses on providing tailor-made learning for every individual pupil, while traditional education focuses on providing tailor-made learning for groups of pupils or individual pupils who need a lot of extra support. In addition, the teacher often gives direction to the pupil's learning process in traditional education, while in personalised education the pupil himself/herself also gives direction to his or her learning process. Furthermore, in traditional education a curriculum is mainly used as a guideline for what to do during a lesson, while in personalised education a curriculum is mainly used as a source which can be consulted for potential instruction strategies or assignments to use during a lesson. Finally, there is a difference in the usage of ICT. In personalised education ICT is used on a structural basis, while ICT is not used on a structural basis in traditional education.

Therefore, the present study will provide insight into the skills and knowledge a teacher needs to possess, to be able to differentiate in personalised education and will conclude whether this corresponds to the findings from Keuning et al. (2017). This will expand the current knowledge about the teacher skill differentiation and provides further insight into the practices of a teacher in personalised education. Similar to the study of Keuning et al. (2017) the focus in the present study is on the subject mathematics in primary schools. This study will answer the following research questions:

1. *What skills and knowledge does a teacher need to be able to differentiate in personalised math education at a primary school?*
2. *To what extent do the skills and knowledge a teacher needs to be able to differentiate in personalised math education at a primary school differ from the skills and knowledge a teacher needs to be able to differentiate in traditional math education at a primary school?*

The skills and knowledge a teacher needs to have to differentiate in personalised math education at a primary school will be investigated by conducting a cognitive task analysis (CTA). A CTA is a technique for identifying, analysing and structuring skills and knowledge that experts use to perform a complex task (Clark, 2014). This is an appropriate method for this investigation because differentiating is seen as a complex task (Inspectie van het Onderwijs, 2017; Keuning et al., 2017) and because the usage of a CTA ensures the possibility to compare the present study with the study from Keuning et al. (2017).

1.2 Overview

In the next chapter, the conceptual framework of this study will be presented in which the teacher skill differentiation and the new trend personalised learning will be conceptualized. Thereafter, the procedure of conducting the CTA about differentiation in personalised math education is described in the third chapter. Subsequently, the results of the CTA are presented and the results of comparing the constituent skills and required knowledge found in this CTA with the constituent skills and required knowledge found in the CTA about differentiation in traditional math education, conducted by Keuning et al. (2017), are presented in the fourth chapter. Finally, conclusions are drawn and the findings are discussed in the fifth chapter.

2. Conceptual framework

In this framework the teacher skill differentiation will be conceptualized which includes a description of differentiation in traditional education. Subsequently, there is described what is required from a teacher to be able to differentiate in traditional math education, according to Keuning et al. (2017). Thereafter the new trend in education, personalised learning is conceptualized, followed by a description of differentiation in personalised education and a description of what is required from a teacher in personalised education with regard to differentiation, according to the literature.

2.1 What is differentiation?

Differentiation is defined in various ways in the literature, varying from more extended definitions to more restricted definitions. According to De Koning (1973) in Bosker (2005) differentiation is creating differences between parts (e.g. schools, departments, classes, subgroups, individual pupils) of an educational system (e.g. national school, school community, department, class) regarding one or more aspects (e.g. objectives, learning time, instructional methods). The Dutch Inspectorate of Education described differentiation as dealing with differences (Inspectie van het Onderwijs, 2017, 2018). Coubergs, Struyven, Gheyssens, and Engels (2015) have defined differentiation more specifically: as proactively, positively, and systematically dealing with differences between pupils aimed to achieve the best possible learning results for each pupil. In addition, Tomlinson et al. (2003) defined differentiation as a strategy in which teachers provide different avenues to pupils' learning in response to the differences in readiness, interests and learning profiles. These definitions vary from each other but based on recurring aspects in all the aforementioned definitions, in the present study differentiation is defined as dealing with differences between pupils. This is a general definition because it may differ per educational context how a teacher has to deal with differences between pupils and with which differences he or she has to deal.

Besides, two forms of differentiation are distinguished in practice and literature: divergent and convergent differentiation (De Kool & Nijeveld, 2014). In divergent differentiation pupils are allowed to go through the subject-matter at their own pace and at their own level (De Kool & Nijeveld, 2014; Kester et al., 2018). This can result in more variety of learning performances within a class (Bosker, 2005; Reezigt, 1999). In convergent differentiation, the teacher assumes that every pupil should achieve a minimum objective (De Kool & Nijeveld, 2014; Kester et al., 2018). As a result, attention is mainly paid to pupils who perform poorly and the learning performances within a class will remain closer to each other (Bosker, 2005; Reezigt, 1999).

In traditional education, most teachers will combine convergent and divergent differentiation (Deunk, Doolaard, Smale-Jacobse, & Bosker, 2015). They will try to reach a minimum performance level for low ability pupils and offer high ability pupils the opportunity to extend their knowledge without proceeding too much ahead of their peers in the classroom.

So, based on recurring aspects in all the aforementioned definitions differentiation is defined in a general way in this study, as dealing with differences between pupils. Differentiation can be distinguished in two forms of differentiation, convergent and divergent differentiation, which are often combined in traditional education.

2.2 What is required from a teacher to be able to differentiate in traditional education?

Insight into the practice of differentiation; the skills and knowledge a teacher needs to possess, to be able to differentiate, was scarce until recently (Keuning et al., 2017; Vandewaetere et al., 2011). Keuning et al. (2017) investigated the skills and knowledge teachers need to have to differentiate in traditional math education in primary schools by conducting a CTA. They found that differentiation consists of four phases: preparing a lesson period, preparing a lesson, enacting a lesson and evaluating a lesson. Based on their findings they developed a skill hierarchy (figure 1). In this skill hierarchy the constituent skills of differentiating are placed in different levels. The constituent skills placed in the lower levels of the hierarchy are conditional for or supportive of the higher placed constituent skill. The constituent skills of differentiation are separated for each phase of differentiation (Keuning et al., 2017).

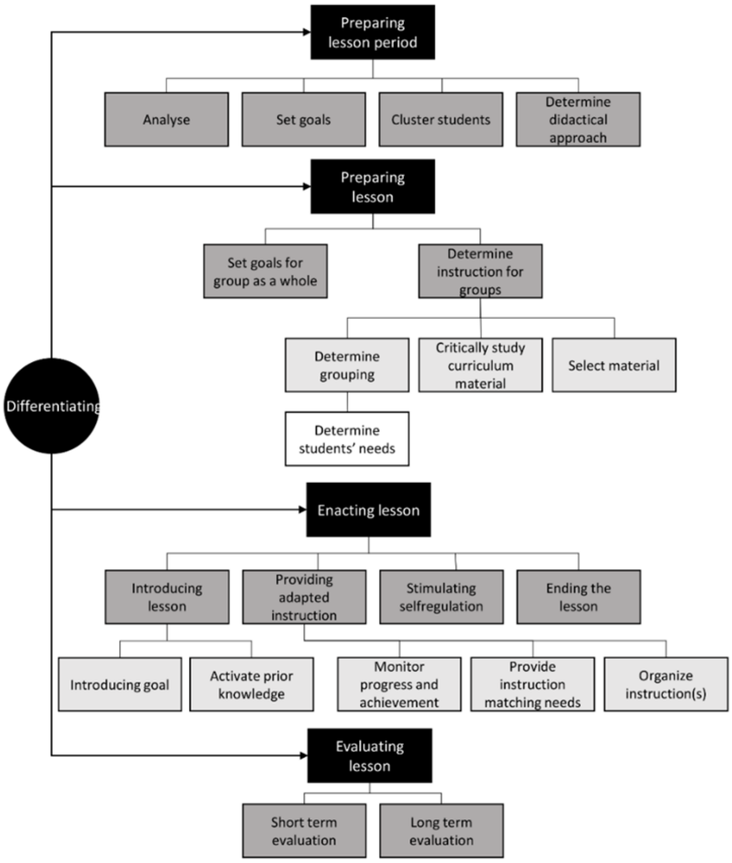

Figure 1. Skill hierarchy of differentiating in traditional math education (Keuning et al., 2017).

The preparation of a lesson period consists of four constituent skills: analysing, setting goals, clustering pupils and determining the didactical approach. The lesson preparation phase consists of two constituent skills: setting up goals for the group as a whole and determining the instruction for groups. Determining grouping, critically studying curriculum material and selecting materials are the constituent skills of determining the instruction for groups. The third phase, 'enacting a lesson', consists of four constituent skills: introducing the lesson, providing adapted instruction, stimulating self-regulation and ending the lesson. Introducing the goal and activating prior knowledge are the constituent skills of introducing a lesson. Monitoring progress and achievement, providing instruction matching needs and organizing instruction(s) are the constituent skills of providing an adapted instruction. The final phase, 'evaluating a lesson', consists of two constituent skills: short-term evaluation and long-term evaluation.

Differentiation also requires a knowledge base according to Keuning et al. (2017). Two types of knowledge are particularly important: knowledge about the pupils and subject-matter knowledge (Keuning et al., 2017). Knowledge about the pupils includes knowledge about the performance level of the pupils and knowledge about the pedagogical-didactic needs of the pupils. The subject-matter knowledge includes mathematics didactical knowledge and knowledge about the learning progression. This knowledge supports the teacher during differentiating in the four phases of differentiation.

Most research about differentiation focuses on traditional forms of education, but differentiation is hardly or not investigated in other contexts like personalised education. Therefore, it is impossible to say whether these findings can be generalized to the context of personalised education (Keuning et al., 2017), because personalised education differs from traditional education in some aspects. Therefore, personalised learning, a new trend which is applied in personalised education (Elferink, 2017) will be conceptualized in the next section.

2.3 What is personalised learning?

Personalised learning is a relatively new concept in the literature (De Kool & Nijeveld, 2014). This resulted in vagueness about the meaning of personalised learning (Prain et al., 2012; Willacy, West, Murphy, & Calder, 2017); no unambiguous authoritative definition of personalised learning exists in the literature yet (De Kool & Nijeveld, 2014). However, personalised learning is usually linked to some distinctive characteristics in the literature: *it provides tailored learning for each individual pupil, it is directed by both the teacher and the pupils* and *ICT is used as a tool.*

The main characteristic of personalised learning is that *it provides tailored learning for each individual pupil* (Bray & McClaskey, 2013; Campbell, Robinson, Neelands, Hewston, and Mazzoli, 2007; De Kool & Nijeveld,2014; DfES, 2006; Hargreaves, 2006; Heller, Steiner, Hockemeyer, & Albert, 2006; Leadbeater, 2005; Studulski, 2015; Willacy et al., 2017). For example, the British Department for Education and Skills (DfES, 2006) gave the following explanation for personalised learning: “It means a tailored education for every child and young person, that gives them strength in the basics, stretches their aspirations and builds their life chances. It will create opportunity for every child, regardless of their background” (p. 13). Personalised learning provides tailored learning for each pupil because instruction is adapted to his or her individual educational needs and pace (De Kool & Nijeveld 2014; Heller et al., 2006; Willacy et al., 2017). However, to what extent this is adapted towards each pupil depends on how personalised education is organised. This can range from offering adapted exercises for every pupil to adapting what, how, when and at what pace the pupil is learning.

Another characteristic of personalised learning is that *it is directed by both the teacher and the pupils* (Bray & McClaskey, 2013; Campbell et al., 2007; Hargreaves, 2006; Leadbeater, 2005; Studulski, 2015). This means that the teacher and the pupil both have influence on and are responsible for the learning process when it comes to what, when, where, how, why, with whom and at what pace the pupil learns. For example, Hargreaves (2006) stated that the pupil is not simply receiving instruction from the teacher but is constructing, producing or even designing the learning with the teacher in personalised learning. The degree of influence and responsibility the pupil has in personalised education differs. This can range from teacher-driven learning in which the pupil has a choice and a voice in learning, to pupil-driven learning where the teacher is a partner in learning (Bray & McClaskey, 2013; Studuski, 2015). An example of teacher-driven learning is that the teacher determines what exercises the pupil has to make, but the pupil has a choice in when and where he or she will work on these exercises. An example of pupil-driven learning is that the pupil decides what he or she wants to learn in a week and how he or she will do this, and discusses this with his or her teacher.

The last characteristic of personalised learning is that *ICT is used as a tool.* (De Kool & Nijeveld, 2014; Jones & McLean, 2012; Kester et al., 2018; Marquenie, Opsteen, Ten Brummelhuis, & Van der Waals, 2014). For example, Kester et al. (2018) mentioned that ICT is used to efficiently and effectively meet the individual differences between pupils in personalised learning. Jones & McLean stated that personalised learning requires using ICT. In personalised learning, ICT can have three functions. The first function is that ICT takes care of standardized customization and ensures coordination with responses of the pupil in a computer-controlled environment (Marquenie et al., 2014). So, ICT makes it possible that each pupil can follow a personalised learning route (Van Loon et al., 2016; Marquenie et al., 2014). The second function is that ICT supports the pupil in giving direction to their own learning process more independently (Marquenie et al. 2014). For example, by giving information about pupils’ progress by means of dashboards and planning tools (Marquenie et al., 2014; Van Rens & Van Aanholt, 2017). Based on this information, pupils can make decisions about the content, approach and planning of subsequent learning activities (Marquenie et al., 2014). The third function is that ICT supports the teacher in giving direction to pupils' learning processes by giving insight into the educational needs of the pupils (Van Loon et al., 2016). For example, a teacher can use ICT to gather data about a pupil's learning process and analyse this data for offering adaptive instruction, offering assignments and giving feedback to a pupil (Kester et al., 2018). Since these are the potential functions of ICT in personalised education, the usage of ICT will make differentiation easier to handle for a teacher in personalised education (Kester et al., 2018).

Based on these characteristics in the present study personalised learning is defined as tailored learning for each individual pupil, directed by the teacher and the pupils by using ICT as a tool. However, this does not mean that these characteristics of personalised learning do not occur in traditional education, but that less emphasis is placed on these characteristics in traditional education. For example, ICT is also used in traditional education, but more in an incidental way, while in personalised education ICT is used structurally for offering a personalised learning route. In addition, pupils will also give direction to their own learning process in traditional education, but in that case less emphasis is placed on it. Therefore, the pupils possibly get fewer opportunities to give direction to their own learning process in traditional education compared to personalised education.

2.4 Differentiation in personalised education

As mentioned before, most teachers in traditional education will combine convergent and divergent differentiation (Deunk et al., 2015). However, this will be different for differentiation in personalised education. Personalised education is more focused on divergent differentiation because this leads to tailor-made learning for each individual pupil (Deunk et al., 2015). In personalised education divergent differentiation still needs to be combined with convergent differentiation. Divergent differentiation alone would not be achievable in the current educational structure (Dean, 2006), because when all pupils go through the subject-matter at their own pace and at their own level, they will not be able to work together or learn from each other.

Since personalised education focuses more on divergent differentiation, a teacher will have to differentiate more because he or she has to deal with more differences between pupils compared to traditional education. However, literature is reviewed to provide insight into what is required from a teacher in personalised education with regard to differentiation. This will be described in the next section.

2.5 What is required from a teacher in personalised education with regard to differentiation?

A teacher in personalised education has to provide a flexible curriculum that is adequately structured in content, learnings tasks and adaptable classroom practices, to engage all pupils and address the contrasting needs of the pupils in personalised education (Prain et al., 2012; Studulski, 2015). However, a blueprint for how a teacher should do this does not exist (Studulski, 2015). Therefore, a teacher in personalised education needs to have an inquisitive attitude, the ability to cooperate, the willingness to solve problems together and the ability to be critical on their own teaching practice (Studulski, 2015). Furthermore, teachers have to monitor each pupil continuously (Prain et al., 2012) and they need to have the diagnostic skills to collect relevant information about the pupils' strengths and weaknesses (Keefe & Jenkins, 2002; Kester et al., 2018), because they have to address the different needs of pupils in personalised learning.

Since, in addition to the teacher the pupil himself/herself also gives direction to his or her learning process in personalised education, pupils need to learn to self-regulate their learning (Prain et al., 2012). This means that the pupils need to learn to motivate, monitor and manage their own learning (Prain et al., 2012). A teacher has to release his or her pupils and encourage them to make decisions about their own learning, to increase their ability to self-regulate their learning (Dean, 2006; Van der Vegt, 2016) and should be alert to pupils' reactions to the freedom offered (Boekaerts & Corno, 2005). A teacher needs to be able to adapt the degree of freedom and responsibility he or she gives to a pupil to into what extent a pupil is able to regulate his or her learning (Van der Vegt, 2016).

In addition, a teacher needs to have sufficient digital skills to be able to use the data about a pupil that can be gathered with the software, since ICT is used as a tool in personalised education (Kester et al., 2018). According to Steyaert (2000) digital skills can be divided into three clusters. The first cluster concerns the instrumental skills, which are the operational actions related to dealing with the technology itself. Button knowledge is a part of this skill. The second cluster concerns the structural skills, which includes being able to deal with the structure in which the information is displayed. The third cluster concerns the strategic skills. These skills are about the effective use and the application of information.

To conclude, further insight into what is required from a teacher in personalised education with regard to differentiation has been obtained by reviewing the literature. However, this did not result in an appropriate overview of the skills and knowledge a teacher needs to possess, to be able to differentiate in personalised math education. Therefore, a CTA about differentiating in personalised math education will be conducted.

3. Method

In this chapter, the method of this study is described. It starts with a description of the research design of this study. As described before, a CTA is used in this study, therefore the application of the steps of a CTA is described thereafter. Subsequently, the participants of the study and their context are elucidated. Then data collection is described followed by the procedure. Finally, it is explained how the data is analysed.

3.1 Research design

This study is aimed at providing insights into the skills and knowledge a teacher needs to have, to be able to differentiate in personalised math education in primary schools and compare it with the insights about differentiation in traditional math education from Keuning et al. (2017). Therefore, it is a qualitative grounded theory study because the intent of a grounded theory study is to generate or discover a theory of a process, action, or interaction (Strauss & Corbin, 1998). This study provided a theory about the skills and knowledge a teacher needs to have to differentiate in personalised math education by conducting a CTA.

3.2 Cognitive task analysis

In this study a cognitive task analysis (CTA) was used to provide a theory of the skills and knowledge a teacher needs to have to differentiate in personalised math education. A CTA is a technique for identifying, analysing, and structuring skills and knowledge that experts use to perform a complex task (Clark, 2014). This leads to an integrative, coherent description of the prerequisites for performing professional tasks properly (Van Merriënboer, 2010).

The usage of a CTA enables the comparison of the outcomes of this study with the outcomes of the study from Keuning et al. (2017) since they used a CTA to obtain insight into the skills and knowledge a teacher needs to differentiate in traditional math education. According to Keuning et al. (2017) their study was the first study that used a CTA for a complex teacher skill. They concluded in their study that a CTA is a valuable method to investigate the skills and knowledge a teacher needs to have to perform a complex professional task.

The procedure of the conducted CTA in the present study is similar to procedure used by Keuning et al. (2017) which is based on the five common steps that are used in the most dominant CTA methods according to Clark, Feldon, Van Merriënboer, Yates, and Early (2008). First a literature review was conducted. Thereafter the format in which the collected data is represented was determined. This study followed the 4C/ID model by Van Merriënboer and Kirschner (2013) which is the most extensively developed training design model (Clark et al., 2008). Therefore, the collected data was presented in a skill hierarchy in which constituent skills were presented supplemented with an overview of the required knowledge which enables a teacher to perform these constituent skills. Subsequently, the data was collected by observing math lessons followed by semi-structured interviews (stimulated recall) with each teacher individually and an expert meeting with teachers. Finally, the collected data was analysed and presented in the chosen representation format.

3.3 Participants

A total of 12 teachers who teach in personalised math education where ICT is used as a tool in the middle or upper class (grade 1 up to grade 6) at a primary school participated in this study. These teachers were recruited through the connections of the ELAN department of the University of Twente and by using the snowball method. The participating teachers were asked if they knew other teacher who could participate in this study. This did not result in an appropriate number of teachers to reach theoretical saturation, while achieving theoretical saturation is the aim of in-dept interviews (Johnson & Rowlands, 2012). Therefore, teachers were also recruited in a different way. Primary schools that offer personalised math education by means of ICT were searched by consulting the schools' website and asking the director of the school whether they offer personalised math education by means of ICT. Thereafter, the teachers of these schools were contacted to ask if they wanted to participate in this study. From the 12 participating teachers, six teachers participated in the expert meeting. Of these six teachers, two teachers had not been observed and interviewed. In total 10 teachers were observed and interview individually. The characteristics of the participants of this study are shown in Table 1.

Table 1
Teacher characteristics

Teacher[1]	Sex	Age	Years of teaching experience	Years of experience in personalised math education	Full-time	Highest level of education
Annet	Female	43	20	2	No	Higher Education
Dennis	Male	58	35	5	Yes	Higher Education
Stan*	Male	39	16	4	Yes	Higher Education
Monique	Female	32	9	2	No	Higher Education
Maaike	Female	32	10	2	No	Higher Education
Jacqueline*	Female	59	30	5	No	Higher Education
Jet*	Female	48	17	2	Yes	Higher Education
Angelique*	Female	61	17	1	No	Higher Education
Arianne*	Female	46	24	2	No	Higher Education
Sophie*	Female	25	2	2	No	Higher Education
Janneke**	Female	36	14	1	No	Higher Education
Jessica**	Female	47	22	3	Yes	Higher Education

[1] The names of the teachers are fictitious to ensure the anonymity of the teachers
* Only observed and interviewed, did not participate in the expert meeting; ** Only participated in the expert meeting.

Furthermore, characteristics of the teaching context are shown in Table 2. Since personalised math education is organised in different ways, the teachers are classified in context group A, B, C, D, or E in table 2. A description of how the teachers generally organize personalised math education is given for each context group.

Table 2
Characteristics of the teaching context

Teacher[1]	Grade(s)	Total number of pupils	Maximum number of pupils in a lesson	Software Used	Context group
Annet	2	21	21	Math, Rekentuin	A
Dennis	3/4	24	24	Math, Rekentuin	A
Stan	3/4	24	24	Math, Rekentuin	A
Monique	5/6	21	21	Math, Slimleren, Rekentuin	B
Maaike	2/3	32	32	Math, Rekentuin	B
Jacqueline	7/6	34	34*	Math, Rekentuin	B
Jet	3/4	28	15**	Gynzy	C
Angelique	2	19	15**	Gynzy	C
Arianne	5/6	56	15**	Gynzy	C
Sophie	2/3/4/5/6	37	21	Muiswerk	D
Janneke	4/5/6	27	11	Snappet	E
Jessica	2/3/4	10	10	Snappet, Rekentuin	E

[1] The names of the teachers are fictitious to ensure the anonymity of the teachers
* At Wednesdays, the maximum is 21, because the teacher only teaches the pupils of the sixth grade then; ** This is the general rule, but the teachers can deviate from it.

In the first context, *context A* the whole group of pupils are present in class during a math lesson. During a math lesson a pupil is having a coaching conversation with the teacher, is following instruction, or is working independently on goals related to the instruction or on individual goals. It differs per lesson whether the teacher gives instruction or conducts coaching conversations with individual pupils. The teacher determines the goal of instruction, this can be a repairment goal based on failure or a new goal. During the coaching conversation the learning process of the pupil, the goals reached and the planned goals to work on are discussed. Two teachers, Stan and Annet also provide individual instruction based on the pupil’s educational needs during a coaching conversation. If a pupil is not having a coaching conversation or following instruction he or she is working independently on the goal(s) of the instruction, or on individual goals. During working independently, the pupils are working in *Math*, *Rekentuin,* or are using other materials. *Math* is a software program that consist of materials for mathematics for each learning goal divided over different levels. The materials are instructional videos, exercises in the form of games or printable worksheets. *Rekentuin* is an adaptive software program in which the pupils can do additional exercises to improve memorization, since it gives time slots for an exercise. The exercises in *Rekentuin* are adaptive which implies that the exercises are automatically adapted to the level of the pupils, based on his or her results. Furthermore, the teacher is walking around if (s)he does not provide instruction to help pupils during working independently when this is needed.

In the second context, *context B* personalised math education is organised in almost the same way as in context A. The only difference is that planned coaching conversations with individual pupils are not conducted; instead instruction is provided every day. In addition, the pupils of Monique can also choose for working in *Slimleren* while working independently. *Slimleren* provides adaptive exercises for each learning goal.

In the third context, *context C* personalised math education is organized differently. These teachers are mathematics specialists at their school with open classrooms and a learning square in the middle. This means that there are no walls between the classrooms and the learning square. The mathematics lessons, which are given in an open classroom are scheduled for each group separately. Generally, the pupils of each grade are divided into two groups. So, Jet gives four mathematics lessons each day. Therefore, these lessons are quite short and mainly focused on giving instruction. *Gynzy*, the software used in this context sets goals for each lesson, except for the lessons on Friday. These lessons are about the goals in which the pupils fail. However, *Gynzy* does not set goals for each lesson for the second half year of the sixth grade. Therefore, Arianne determines the goals of instruction by herself for the pupils from the sixth grade. After the instruction and after the mathematics lesson the pupils are having time to work on the adaptive exercises related to their lesson in *Gynzy*. When a pupil is not having a mathematics lesson he or she is having a spelling lesson, or is working independently at the learning square. While working independently pupils are also working on what the teacher planned for the day or for the week; this can include making extra math exercises based their individual educational needs. This is possible because *Gynzy* provides extra adaptive exercises for each goal. During working independently there is always a teacher or teacher assistant at the learning square, to provide help when it is needed.

In the fourth context, *context D* the organization of personalised math education has some similarities with *context C.* In this context the teacher also is a mathematics specialist and mathematics lessons are also scheduled for groups of pupils. Three pupil groups are formed: the pupils from the second grade, the pupils from the third and fourth grade together, and the pupils from the fifth and sixth grade together. During the mathematics lessons the teacher gives instruction. This is an instruction about a goal which is determined by the teacher. When the pupils are not following a mathematics lesson they are following another lesson, or they are working independently in a classroom, or at the learning square. During working independently, the pupils work on their planned work of the day. This also includes exercises based on the mathematics lesson of that day, these exercises are selected by the teacher. Additionally, the pupils are working in the software program *Muiswerk.* The pupils make a test in *Muiswe*rk and based on their errors they make exercises. After making these exercises they make the test again and they pass the test when they have answered a certain percentage of exercises the right way. Based on the passed test the pupil can achieve a level in *Muiswerk.* When a pupil wants to make a test he or she has to sit at a table in front of a teacher. During working independently, the mathematics specialist or other teachers are walking around in the classroom to help pupils when this is needed.

In the last context, *context E* the organization of personalised math education has similarities with *contexts C* and *D*. However, the organization of the mathematics lessons differs. Janneke, provides a mathematics lesson for each grade separately. Therefore, these lessons are quite short and mainly focused on giving instruction. The goal of the instruction lesson is set by *Snappet,* except for the lessons on Friday. In these lessons the teacher provides instruction based on goals in which the pupils failed. Jessica gives one mathematics lesson for all the grades together. However, the pupils can choose whether they follow each part of the instruction, or only the part of the instruction for their grade. Jessica, selects a domain of instruction and selects goals for each grade by herself. Furthermore, the teachers have in common that the pupils are going to work on adaptive exercises related to the goal for which instruction was delivered in their lesson in *Snappet*. The pupils work on mathematics during working independently as well. They are working on individual goals then by working on extra adaptive exercises in *Snappet*, or by using other materials. The pupils of Jessica also have the option to work in *Rekentuin* during working independently. The teacher is walking around when no instruction is provided, to help pupils during working independently, if this is needed.

3.4 Data collection

As described in the section about the cognitive task analysis, the data of this CTA was collected by observing mathematics lessons followed by a semi-structured interview with each teacher individually and an expert meeting with teachers. This section presents a description of how the data was collected in the lesson observations, interviews and expert meeting.

3.4.1 Lesson observations and interviews

In this study lesson observations followed by semi-structured interviews were conducted to gather insight in the way teachers operate and decide while differentiating during a mathematics lesson, and what this presupposes in terms of constituent skills.

The teachers were observed and filmed during the mathematics lesson(s). Three to ten fragments of the lesson(s) were selected for the semi-structured interview. The researcher selected fragments in which the teacher applied differentiation by dealing with differences between pupils and used a list of possible actions of a teacher when he or she differentiates in personalised education as a guideline for selecting these fragments, see Appendix A. These actions are based on operationalisations of differentiation (Prast, Van de Weijer-Bergsma, Kroesbergen, & Van Luit, 2015;

Roy, Guay, & Valois, 2013; Van de Grift, Van der wal, & Torenbeek, 2011) and on the reviewed literature about personalised education.

The observation was followed by a semi-structured interview in which a semi-structured questionnaire was used, see Appendix B. The questionnaire consists of three parts. The first part of the interview consists of questions about teachers' background characteristics. In the second part the simulated recall method was used. The stimulated recall method is a retrospective method for identifying teachers' decision moments and thought processes (Vallacher & Wegner, 1987). The selected fragments from the lesson observation were looked back, and in-depth questions were asked about the way the teachers had acted and their underlying thoughts and considerations. The third part of the interview consisted of seven main questions followed by further questions based on the teacher's response on the main question to acquire a comprehensive picture of how a teacher differentiates. In the first four main questions the teachers were asked how he or she performs each of the four phases of differentiation determined by Keuning et al. (2017). Thereafter, the teachers were asked what the role is of ICT in differentiation, because ICT is used as a tool in personalised education. Subsequently, the teachers were asked what the role is of the pupil in personalised education, because a pupil often also gives direction to his or her learning process in personalised education according to literature. Finally, the teachers were asked if they experienced differences in differentiation between personalised math education and traditional math education, and if so, what these differences were. All interviews were recorded and transcribed.

3.4.2 Expert meeting

After the lesson observations followed by semi-structured interviews, an expert meeting with six teachers took place. The general aim of the expert meeting was to find the actions, decision moments and the systematic approaches of teachers when they differentiate. First each teacher created a systematic overview of the steps they took in each phase of differentiation individually. Then the teachers were divided into two mixed groups. The groups consisted of three teachers from different context groups (context A, B and E). Each group made one systematic overview of the steps they take in each phase of differentiation. Thereafter, the teachers placed post-its with the necessary skills and knowledge to perform a step and criteria of when this step is performed right on the systematic overview. Furthermore, the necessary skills and knowledge for differentiation in traditional math education were compared with the required skills and knowledge for differentiation in personalised math education. The expert meeting was filmed and transcribed.

3.5 Procedure

Before collecting the data, the BMS Ethics Committee of the University of Twente has given permission for conducting this study. The teachers who wanted to participate in this study were informed about the purpose of this study by means an e-mail or during a phone call. Thereafter appointments were made for when the researcher visited the teacher at their school for an observation and an interview. Before the planned visit the parents were asked permission to film their children during the lesson observation by means of a letter.

When the researcher visited the school, the teacher was asked to sign for the permission to be a participant in the study before the lesson observation started. The teacher's mathematics lesson(s) on that day were filmed and observed. When parents did not give permission to film their child this pupil was not filmed during the lesson. After the lesson the researcher took some time to select the fragments for the semi-structured interview. Subsequently, the teacher was interviewed, the interview took on average 1,5 hours.

All teachers were invited for the expert meeting, but not all of them were able to come. The meeting took place at a location which was a convenient location for most of the teachers. The meeting took approximately one working day (9.30 till 16.00). All the teachers were asked for permission to film this meeting prior to the start of the meeting.

3.6 Data analysis

The qualitative data of this study consists of the transcripts of the interviews and the transcript of the expert meeting, and the two systematic overviews made during the expert meeting. The data was analysed by using the three stages of coding for a grounded theory study: open coding, axial coding and selective coding (Boudah, 2011).

In the open coding stage, the actions and thoughts of the teachers were coded. For example, "I gave him a short instruction, so he can continue" is coded as giving individual instruction and "He does not have the motivation to figure out how something works by himself" is coded as knowledge about the motivation of the pupil. Thereafter, all codes were assigned to one of the phases of differentiation: preparing a lesson period, preparing a lesson, enacting a lesson and evaluating a lesson, or as required knowledge which enables a teacher to differentiate.

In the axial coding stage, the codes were combined with the systematic overviews made during the expert meeting in order to search for overarching codes in the four phases of differentiation and in the required knowledge. In addition, the researcher determined overarching codes for the codes that did not overlap with the systematic overviews. Some of the overarching codes were taken together to form a category. Thereafter categories were determined based on the overarching codes.

Subsequently, the skill hierarchy and the required knowledge were determined in the selective coding phase by mapping the relationships between the overarching codes and the formed categories. The systematic overviews were used as a guideline to search for these relationships. The overarching codes and categories were only integrated in the skill hierarchy or required knowledge if it was based on codes that at least came from the transcripts of five interviewed teachers.

Furthermore, the mentioned differences between differentiation in personalised math education and traditional education were coded in the transcripts of the interviews and the expert meeting. These codes were used in order to determine the differences as distinguished by the teachers. In addition, the skill hierarchy and the required knowledge found in this study were compared with the skill hierarchy and the required knowledge for differentiation in traditional math education by Keuning et al. (2017), in order to determine the differences.

4. Results

The results of the conducted CTA: the skill hierarchy and a description of the required knowledge, will be presented in this chapter. In addition, the results of comparing the findings from this CTA with the findings from Keuning et al. (2017) in their CTA about differentiating in traditional math education, were presented.

4.1 Skill hierarchy

As described before, differentiation consists of four chronological phases which cannot be seen separated according to Keuning et al. (2017). A teacher prepares a lesson period (phase 1), prepares a lesson (phase 2), enacts a lesson (phase 3) and evaluates a lesson (phase 4). Within these phases, differentiation in personalised math education consists of different constituent skills as shown in the skill hierarchy in Figure 2. The constituent skills in the developed hierarchy that are next to each other can be performed consecutively, simultaneously or in random order. The skills beneath each other have a vertical relationship, which means that the skills lower in the hierarchy are conditional or supportive for higher placed skills. The constituent skills will be described for each phase of differentiation. All the described constituent skills were based on the expert meeting, unless something else is indicated. Besides, it is mentioned for each constituent skill among how many teachers from the ten observed and interviewed teacher the constituent skill is found.

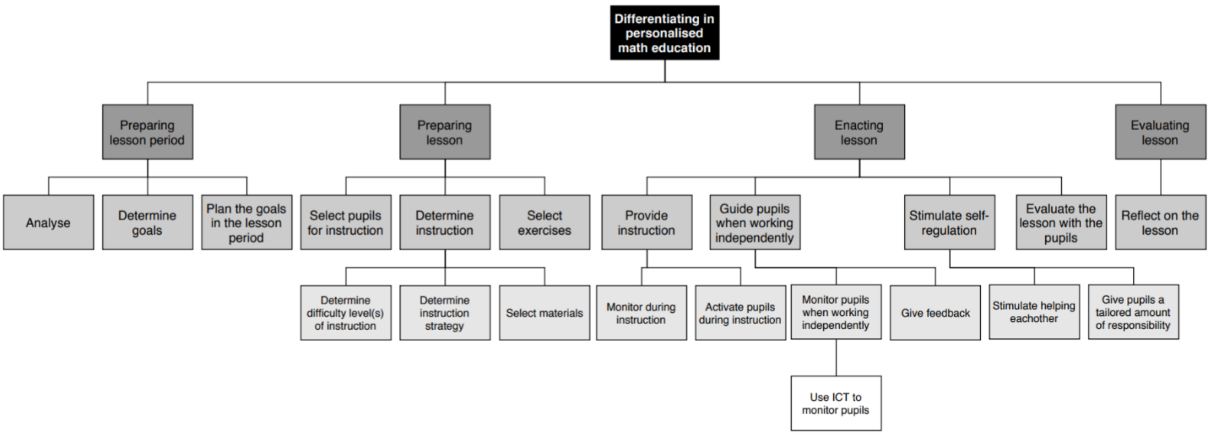

Figure 2. Skill hierarchy of differentiating in personalised math education.

4.1.1 Preparing a lesson period

During the preparation of a lesson period, the teachers lay a foundation for dealing with differences in personalised math education. All the teachers prepare periods of half a year and six of the observed and interviewed teachers combine this with shorter periods of four to eight weeks. Three constituent skills are important in preparing a lesson period: *analyse, determine goals* and *plan the goals in the lesson period.*

All ten observed and interviewed teachers mentioned that they *analyse* pupils' results to gather insight into the initial situation of the individual pupils when they prepare a lesson period.

These results consist of the test results and the results of pupils' daily work in the software used. All teachers analyse the standardized student monitoring tests and four teachers also analyse the tests they conduct over a shorter period of time. Each pupil makes the standardized student monitoring test that corresponds to his or her level. Monique: "Each half year they do the standardized student monitoring test on their level, so one does the middle test and the other one does the end test, it is all mixed, everyone does his or her own test which fits with where they are ready for". Two teachers mentioned that their pupils analyse the results of the standardized student monitoring test by themselves and two other teachers mentioned that they let the pupils do this by themselves sometimes. These four teachers are from the contexts in which the teachers are planning the goals for the instruction themselves and use software to offer different kinds of practice materials (context A and B). Dennis said about this: "Based on an analysis of the errors that we conduct, or the pupils themselves we determine on which components the pupil has to work on". The teachers from the context where the teacher conducts coaching conversations with their pupils during mathematic lessons (context A) prepare these conversations by analysing the work the pupils did and the goals the pupil has ticked. Annet said: "When I prepare a learning conversation, I looked at the mathematic maps of the pupils' that will have a coaching conversation, I check whether they have ticked goals and what they did during the last few weeks. Then I know what I want to ask".

All the observed and interviewed teachers mentioned that they *determine goals* when they prepare a lesson period. The teachers determine the individual goals, cluster the pupils with the same individual repairment goals and determine the new goals for the upcoming period. Eight teachers determine the individual goals of the pupils, but they differ in how they do it. Two teachers determine the individual goals of the pupils during a conversation in which they make a personal plan with the pupils which includes learning goals for mathematics, but also for other subjects, or for their personal development. The six other teachers determine individual repairment goals based on the analyses and sometimes let the pupils determine their individual repairment goals by themselves as well. An example of an individual repairment goal is: 'to watch the clock up to 5 minutes accurately'. Maaike said the following about this: "When the pupils analyse their test they write down by themselves which objectives they master insufficiently, they put a smiley next to these goals and then they know that they have to work on these goals during this period". Six teachers mentioned that they cluster the pupils with the same individual repairment goals to determine the repairment goals of the upcoming period. In addition, nine teachers mentioned that they determine the new goals for the upcoming period. Six of these teachers determine the new goals based on the goals set in the standardized student monitoring tests or based on the national learning plans. These are teachers from two contexts in which the teachers determine the goals by themselves (context A and B). Monique: "When you determine the new goals, you look at the goals from the standardized student monitoring test and the national learning plans which goals they have to master". For the other three teachers who are math specialists in a software supported context (context C) the new goals of the upcoming period are set by the software used, however they check whether these goals are appropriate for their pupils and make changes if needed.

Eight teachers mentioned that *they plan the goals in the lesson period* when they prepare the lesson period. They make a schedule in which they plan when the goals will be treated in a mathematics lesson during the upcoming period. For example, some teachers plan the repairment goals in the lessons at the beginning of the period, followed by lessons based on the new goals. Marieke: "We always start with a period of 10 weeks in which we plan the repairment goals and thereafter plan to work on the new goals. Due to this the pupils will start with the new goals with an appropriate foundation". For the three teachers from context C (the software-supported context) the goals are already planned into the period by their used software, however they check whether this planning is appropriate and make adaptations if necessary. One of the ten teachers did not mention this skill and the other teacher only plans the domains in the lesson period, and not the goals.

4.1.2 Preparing a lesson

When the teachers are preparing a lesson, they provide a basis for differentiating when they enact a lesson. The constituent skills of preparing a lesson are: *select pupils for instruction, determine instruction* and *select exercises.*

Eight teachers mentioned that they *select pupils for instruction* when they prepare a lesson. They determine which pupils should follow the instruction based on their educational needs with regard to the planned goal(s) of the instruction. The teachers determine these educational needs by looking at pupils' progress with regard to the planned goal in the software used and the evaluations of previous lessons related to the planned goal. Jet: "Like with the lesson of this morning, I told this pupil beforehand: 'you already reached this goal. I can see that in Gynzy. You do not have to participate in this instruction, you can make the lesson exercises by yourself". When the planned instruction contains a repairment goal, the teacher consults the preparation of the lesson period in order to determine for which pupils this repairment goal applies. Sometimes, the teachers also select pupils for subgroups when he or she decided to apply ability grouping in the instruction. This means that the teacher gives instruction, within these instruction subgroups are having a shorter, longer or different kind of instruction that fits their educational needs. Two teachers do not select pupils because they give a general instruction to the whole group of pupils in their mathematics lesson, or because they already have a few pupils in class during a mathematics lesson.

All ten teachers mention that they *determine the instruction* when they prepare a lesson. This skill consists of three constituent skills: *determine the difficulty level(s) of the instruction, determine the instruction strategy* and *select materials.* Seven teachers mentioned that they *determine the difficulty level(s) of the instruction*. The teachers determine the difficulty level(s) by checking to what extent the pupils master the goal of the instruction. Angelique: "When I prepare a lesson I will first check the level of the pupils with regard to the goal". The teachers determine to include different goals in the instruction which are similar to each other but differ in difficulty, or they determine the difficulty level of instruction based on a middle line of the educational levels of the pupils. Three observed and interviewed teachers did not mention that they determine the difficulty level of the instruction. Furthermore, all teachers mentioned that they *determine the instruction strategy*. An example of a strategy that the teachers use is the Concrete-Representational-Abstract Instructional Approach, which implies that the teachers shift from concrete to abstract in their instruction. Arianne: "I determine how I will go from the concrete level to the abstract level". Another example of a strategy is deciding to repeat something that has been instructed before and is related to the planned goal of the instruction to build further on this in the instruction. Another possible strategy is the strategy of drill and practice. Finally, all the teachers mention that they *select materials* to use in the instruction. The teachers emphasize that it is important to relate their instruction to practice. Jacqueline: "I always try to relate my instruction to practice, and select examples, for this lesson about scales I brought a tractor on scale, so I could show a practical example". The selected materials can be practical examples but can also be worksheets that can be used during instruction.

In addition, all teachers mentioned that they *select exercises* for after the instruction, that match the different educational levels of the pupils, when they are preparing a lesson. These teachers differ in how they select these exercises. The three teachers from context C (the software-supported context) are using adaptive software that already selected exercises linked to the objective of the lesson. However, for one lesson a week (mostly on Fridays) no exercises are selected in the adaptive software since this is a lesson in which the teacher provides instruction based on goals in which the pupils failed. Therefore, these teachers have to select which of the extra adaptive exercises provided in Gynzy the pupils have to make after the instruction. The other teachers select worksheets or websites with exercises on different levels or they search where pupils can find exercises related to the goal of the instruction in the software used. In the adaptive software, the exercises are adapted automatically to the level of the pupils, in Math the teacher or pupil can determine the level of the exercises.

4.1.3 Enacting a lesson

The phase of enacting a lesson consists of four constituent skills. These constituent skills are: *provide instruction, guide pupils when working independently, stimulate self-regulation* and *evaluate the lesson with the pupils.*

The first constituent skill, *providing instruction* was found among all teachers. When the teachers are providing instruction, they give the prepared instruction about the planned goal and adapt instruction if they think it is necessary based on what they monitor. Providing instruction consists of two constituent skills: *monitor during instruction* and *activate pupils during instruction*. All teachers *monitor during instruction*. They are asking questions and giving task to the pupils and walk around and observe if the pupils understood instruction. In addition, they monitor if pupils are paying attention or not. When a teacher monitors he or she is able to adapt the instruction if it appears that one or more pupils have not understood instruction. Dennis said: “I gave a task to divide into three, however some pupils were dividing it into two and came to a totally different number, I saw that later on. I noticed that they had not picked up it by themselves. So, I gave instruction again and divided it into three”. Furthermore, all teachers *activate pupils during instruction*. This skill was not mentioned in the systematic overviews during the expert meeting. The teachers use wiping plates or iPads and ask all children to write down their answers on given tasks or ask questions during the instruction and show it. So, all pupils will be activated to think about the answer and have to write it down. Arianne said: “Now I let them all join on their Ipad. Then they are all involved, otherwise they will sit back”. Besides, the teachers are activating pupils by asking questions to a pupil. For example, they are asking a question to distracted pupils or pupils who are distracted quickly. Jet: “Certain children I give a turn more often, I pay attention during the lesson if they get distracted or do other things. Then I give them a turn”.

The second constituent skill of enacting a lesson, *guiding pupils when working independently* is found among all teachers. When the pupils are working independently they are working on the selected exercises related to their instruction or they are working on their individual goals. Guiding pupils when working independently consists of two constituents skills: *monitor pupils when working independently* and *give feedback*. All teachers *monitor pupils when working independently*. The teachers for example monitor by walking around and check where the pupils are working on and how they do it and to see whether pupils are having questions or needing help. Maaike said: “I walked past her and when I saw that she had not filled in some assignments, she had filled in only the easiest ones with round numbers. And she had done it well, but then I saw that she did not make the exercises with comma numbers, so we had to work on that”. Four teachers also monitor the pupils when working independently, by conducting coaching conversations with pupils individually. Three of these teachers are from the context where coaching conversations are implemented in the organisation of personalised math education (context A). The other teacher did not include it in the organisation of personalised math education, but she mentioned that she is having coaching conversations with pupils but that she does not plan these conversations with all the pupils individually. The teachers are monitoring the learning process of the pupils during the coaching conversations. They are asking questions to get an idea of the achieved goals and the goal the pupil is working on and how this goes and what they need to achieve the goal. Besides, they are asking the pupil on which goal her or she will work when the previous goal is achieved. Maaike said: “You have to conduct many coaching conversations, you give them space and ask them when they do not like something: ‘what would you need to come further?”. Monitoring pupils when working independently consists of one constituent skill: *use ICT to monitor pupils*. Eight teachers also *use ICT to monitor their pupils*. For example, they are using applications in which they can see the windows of the pupils’ Ipads or laptops and check what they are doing. Another example is that the teachers are using a dashboard from the software used in which they have an overview of all the pupils and see where they are working on and how they do it. Jet said: “I can see how many mistakes they made or when pupils are doing something else. Now it has to be adapted for me, but then I can also see the windows of the pupils. Then I walk to a pupil and say I saw you were doing other things”. This skill was not mentioned in the systematic overviews created during the expert meeting. All teachers *give feedback* to guide pupils when working independently. This feedback is often based on what a teacher monitored or noticed during a coaching conversation. This can be feedback to a group of pupils, or an individual pupil about behaviour, the process or the product. For example, Stan said: “This girl was practicing the table of two, which she already knew, so therefore I asked, do you know the table of eight too?”. The feedback a teacher gives can also be personal instruction for a pupil who is struggling, or is having a question. The aim of this type of feedback is that the pupils can continue to work after the obtained feedback. For example, Monique said: “I told him: ‘what are you doing, it is multiplying with the reverse, you swapped the wrong thing”. Two teachers of context A are also giving feedback in the form of personal instruction during a coaching conversation.

The third constituent skill of enacting a lesson, *stimulate self-regulation* is found among all teachers. Although, this skill is not found in the systematic overviews of the expert meeting. The teachers stimulate pupils to make their own decisions in their learning process and solve their problems independently by giving them responsibility. Annet: “The pupils make their own decisions and also determine their pace of learning. In addition, they choose how they want to learn, some pupils will always pick materials while others want to do it on paper directly. Pupils learn to look at themselves, how do I learn?”. Stimulating self-regulation consists of two constituent skills: *stimulate helping each other* and *give pupils a tailored amount of responsibility*. Eight teachers *stimulate their pupils to help each other*. They stimulate the weaker pupils to ask help from pupils who are stronger in mathematics, and they stimulate the stronger pupils to help the weaker pupils. The teachers are stimulating pupils to help each other during the instruction, or when they are working independently. Monique said: “I try to let the pupils explain things to each other, therefore they become more independent”. This skill is not found among two other teachers. Furthermore, eight teachers *give their pupils a tailored amount of responsibility*. They consider to what extent a pupil can deal with having responsibility over his or her own learning process to be able to give pupils a tailored amount of responsibility. Dennis for example said: “I am working as a coach and as a coach I give students responsibility over their own learning process, but I hold some students very tight and I decide for them you are going to do this and you are going to do that”. This constituent skill is not found among the other two teachers.

The last constituent skill of enacting a lesson, *evaluating the lesson with pupils* is found among nine teachers. They ask the pupils who had problems, who has achieved the goals, what they have learned, or if they are able to work further on it. Dennis said about this: “Well the evaluation at the end of the lesson is important because the children are looking process wise: ‘Can I do something with it, did I learn something?’. It is an evaluation for themselves, and for me to monitor who can do this and who cannot. You see, I let them take the initiative, they are making the decision did I achieve the goal or not”. One teacher did not evaluate the lesson with the pupils during the observation and did not mention it in the interview. The only thing she mentioned is that each pupil has to evaluate the lesson by themselves by writing down to what extent he or she masters the goal in his or her own map, at the end of the lesson.

4.1.4 Evaluating a lesson

After the lesson, the teachers will also look back at the lesson by themselves. Therefore, this phase consists of one constituent skill: *reflect on the lesson*.

All teachers *reflect on the lesson* during evaluating a lesson. The teachers focus on the product and the process of the lesson when they are reflecting on the lesson. Nine teachers mentioned that they reflect on the product of a lesson. These teachers check the results of the exercises the students made and/or notate which pupils achieved the goal and which pupils will need some extra support or instruction. The part-time teachers are writing down this evaluation for their co-worker. Annet: “I write down who understand the lesson and who needs some extra attention, I also do this because I have to transfer it to my co-worker”. Five teachers mention that they reflect on the process of a lesson. They search for an explanation why a pupil did not achieve a goal and think about what they can do differently when he or she is going to give instruction about this goal again or when he or she is helping the pupil(s) who did not achieve the goal. Arianne: “I look at what I can do differently to help the pupils better. For example, I think of how I can help a pupil who has not achieved a goal in another way so that he or she will achieve the goal”.

4.2 Knowledge

In addition to the abovementioned skills, differentiation in personalised math education also requires a knowledge base. This knowledge consists of three types of knowledge: knowledge about the pupils, subject-related knowledge and knowledge about the software used.

4.2.1 Knowledge about the pupils

It is important that a teacher knows their pupils according to all the teachers. They mentioned that it is important to know from each pupil his or her level in mathematics, strengths and weakness in mathematics and working attitude. In addition, a teacher needs to have knowledge about the pedagogical-didactical needs of the pupils: for example knowing what works to activate a pupil, or knowing what kind of instruction works for a pupil. Stan said for example: "I know my pupils and I know some pupils that are struggling when the numbers become bigger. This was also the case for this pupil and I helped her before with a paper, so I asked her to pick up that paper again."

4.2.2 Subject-related knowledge

It is also important that a teacher has subject-related knowledge in order to be able to differentiate in personalised math education. The subject-related knowledge consists of knowledge about the learning progression of mathematics and pedagogical content knowledge. This knowledge is important because in personalised math education each pupil can be working on something else in the learning progression while working independently on their own goals. Besides that, teachers in personalised math education do not use a curriculum as a guideline for what needs to be instructed or which didactics can be used. Monique: "It asks from you as a teacher to have knowledge about the learning progression because you do not have anything to fall back on. So, you need to know what the next step is in the learning progression and what a step back in the learning progression is".

4.2.3 Knowledge about the software used

In addition to knowledge about the pupils and subject-related knowledge teachers, knowledge about the software used is also essential. The knowledge about software used can be distinguished in three types of knowledge. At first, a teacher needs to know how the software used works. Secondly, a teacher needs to know what kind of exercises are offered in the software used and where (s)he can find them. Finally, a teacher needs to have knowledge about the data they can find in the software used and where this data is based on. This knowledge is of importance since all the teachers were using software to provide personalised math education.

4.3 Comparing the results of the CTA's

The results of the CTA conducted in the present study about differentiation in *personalised* math education (personalised CTA) are compared with the results of the CTA about differentiation in *traditional* math education (traditional CTA) conducted by Keuning et al. (2017). The results of this comparison are presented for each phase of differentiation, and for the required knowledge. Some of these differences were also mentioned by the teachers during the expert meeting or in the interview.

4.3.1 Preparing a lesson period

In this phase, the constituent skills to *analyse* and to *determine goals* found in the personalised CTA were also found in the traditional CTA. However, there is a difference with regard to the constituent skill to *determine goals.* This difference concerns determining individual goals. A teacher personalised math education has to be able to determine the individual goals for all the pupils, while a teacher in traditional math education only has to be able to the individual goals for pupils with special educational needs. Besides, there are also found some other differences.
The constituent skill to *plan the goals in the lesson period* was only found in the personalised CTA and the constituent skill to *determine the didactical approach* was only found in the traditional CTA. However, it should be noted for all the constituent skills which are only found in one of both CTA's, that this does not directly mean that the teachers in the other context did not do this at all, but that there is probably placed less emphasis on it.

4.3.2 Preparing a lesson

In this phase the constituent skills to *select pupils* and to *determine instruction* and its constituent skill, *to select materials* found in the personalised CTA were also found in the traditional CTA. Nevertheless, there are also some differences between the constituent skills of this phase found in the personalised CTA and found in the traditional CTA. The constituent skills of the constituent skill to *determine instruction*: to *determine the difficulty level of the instruction* and to *determine the instruction strategy* and the constituent skill to *select exercises* were only found in the personalised CTA. Furthermore, the constituent skills to *critically study curriculum materials* and to *set goals for group as a whole* were only found in the traditional CTA. However, the constituent skill to *set goals for group as a whole* has similarities with the constituent skill to *plan the goals in the lesson period* found for the phase of preparing a lesson period in the personalised CTA.

4.3.3 Enacting a lesson

In this phase, similar constituent skills were found in the traditional CTA for the constituent skills: to *provide instruction,* to *stimulate self-regulation* and *evaluate the lesson with pupils* found in the personalised CTA. Despite, some constituent skills were only found in the personalised or traditional CTA. The constituent skill to *activate pupils in the instruction* was only found in the personalised CTA and the constituent skill to *organize instruction(s)* and the constituent skill *introducing the lesson and its constituent skills* were only found in the traditional CTA. Furthermore, the constituent skills of the skill to stimulate self-regulation: *stimulate helping each other* and *give pupils a tailored amount of responsibility* found in the personalised CTA were not found in the traditional CTA. Finally, the constituent skill to *guide pupils when working independently* and the corresponding constituent skills were only found in the personalised CTA. However, this constituent and its constituent skills partly corresponds to the constituent skill providing adapted instruction and its constituent skills found in the traditional CTA.

4.3.4 Evaluating a lesson

In this phase, one constituent skill was found in the personalised CTA about differentiation in personalised math education, *while two constituent skills were found in* the traditional CTA. However, it seems that what is meant with the constituent skill to *reflect on the lesson found in the personalised CTA* is a merger of the constituent skills *short-term evaluation* and *long-term evaluation* found in the traditional CTA. However, the 'traditional teachers' write down results of the long-term evaluation in the curriculum as a reminder for next year, while the teachers of personalised math education write down the results their reflection to apply in one of the next lessons.

4.3.5 Knowledge

Knowledge about the pupil and subject-related knowledge were found as the required knowledge in the personalised CTA and the traditional CTA. However, knowledge about the pupils' working attitude was only found as the required knowledge about the pupils in the personalised CTA. In addition to knowledge about the pupils and subject-related knowledge, knowledge about the software used was also found as the required knowledge in the personalised CTA. Knowledge about the software used was not found as the required knowledge in the traditional CTA.

5. Conclusion and discussion

The aim of this study was to obtain insight into the necessary skills and knowledge to be able to differentiate in personalised math education and whether these skills and knowledge correspond to the necessary skills to be able to differentiate in traditional math education as found by Keuning et al. (2017). The performed CTA resulted in a unique overview of the constituent skills and the knowledge a teacher needs to possess, to differentiate in personalised math education. These skills and knowledge were compared with the necessary skills and knowledge to be able to differentiate in traditional math education according to Keuning et al. 2017. Based on this comparison it seems that most of the skills and knowledge a teacher needs to possess, to be able to differentiate in personalised math education correspond to the skills and knowledge a teacher needs to possess, to be able to differentiate in traditional math education. However, there are also some differences. These differences were described in section 4.3. Most of the differences are constituent skills or required knowledge found in the personalised CTA which were not found in the 'traditional CTA' or the other way around. For example, the constituent skill to introduce a lesson and its constituent skills were only found in the traditional CTA. Most of the found differences may be explained by the aspects in which personalised education differs from traditional education.

Personalised education differs from traditional education in the way a curriculum is used. In personalised education a curriculum is mainly used as a source, while a curriculum is mainly used as a guideline for what to do during a lesson in traditional education (Studulski, 2015). This difference may explain why the constituent skill to critically study curriculum materials was only found in the traditional CTA and the constituent skills to determine the difficulty level of instruction, to determine the strategy of instruction and to select exercises were only found in the personalised CTA. In personalised education teachers have to be able to determine the difficulty level of the instruction, to determine the strategy of instruction and to select exercises by themselves. While in traditional education the teachers have to be able to critically study the curriculum materials to determine if the suggested difficulty level of the instruction, instruction strategy and exercises are suitable for their pupils.

Another difference is that in traditional education the teacher often gives direction to the pupil's learning process, while in personalised education in addition to the teacher the pupil himself/herself also gives direction to his or her learning process. Therefore, there is more emphasis on stimulating student self-regulation in personalised education. This may explain why the constituent skill to stimulate self-regulation is found in both CTA's but that constituent skills were only found for stimulating self-regulation in the personalised CTA.

Furthermore, personalised education focuses on providing tailor-made learning for every individual pupil, while traditional education focuses on providing tailor-made learning for groups of pupils or individual pupils who need a lot of extra support. This difference and the aforementioned difference may explain why the constituent skill to guide pupils when working independently and its constituent skills were only found in the personalised CTA, but partly corresponds to the constituent skill ‘providing adapted instruction’ and its constituent skills found in the traditional CTA. Since a pupil can give direction to his or her own learning process and there is a focus on providing tailor-made learning for each individual pupil, each pupil can work on different goals and assignments during ‘working independently’ in personalised education. While in traditional education, the pupils or groups of pupils usually work on the same goal(s) and/or exercises. Therefore, it seems more important that a teacher is able to guide pupils when working independently, to be able to differentiate in personalised education. This probably explains why the constituent skill to guide pupils when working independently and its constituent skills were only found in the personalised CTA.

Additionally, personalised education differs from traditional education with regard to the usage of ICT. In personalised education ICT is used on a structural basis to be able to offer personalised processing exercises whereas ICT is not used on a structural basis in traditional education. Therefore, software is only used on a structural basis in personalised education. This may explain why knowledge about the software used is only found as required knowledge in the traditional CTA.

Most of the other differences may also be explained by these characteristics in which personalised education differs from traditional education. However, it seems that these characteristics in which personalised education differs from traditional education cannot explain why the constituent skill to introduce a lesson and its constituents skills, and the constituent skill to organize instruction(s) were only found in the traditional CTA, and the constituent skill to activate pupils in the instruction was only found in the personalised CTA. This does not directly mean that the teachers in the other context did not do this at all, but that there is probably placed less emphasis on it.

To conclude, the necessary skills and knowledge to be able differentiate in personalised math education generally correspond to the necessary skills and knowledge to be able to differentiate in traditional math education, but there are some differences. Most of these differences are nuance differences, because the emphasis is place on other things in personalised education since it differs in some aspects from traditional education.

These findings are relevant for practice and research. Therefore, the value of this study for practice and research will be discussed in the next sections, followed by a description of the limitations of this study and some recommendations for future research.

5.1 Value for practice

This study is valuable for practice because the provided insights into the skills and knowledge a teacher needs to possess, to differentiate in personalised math education can be used in the development of a professional development trajectory, or in the redesign of teacher training curricula. The number of primary schools that implement personalised education most probably will increase because personalised learning is a new popular trend in education (Elferink, 2017). Therefore, it seems desirable that pre-service and in-service teachers are prepared for teaching at a school that offers personalised education. Since differentiation is an essential teacher skill in personalised education (Prain et al., 2012) and differentiation is seen as a complex teacher skill (Inspectie van het Onderwijs, 2017; Keuning et al., 2017) it seems important that differentiating in personalised education is included in a professional development trajectory or in the redesign of a teacher training.

Furthermore, the insights gained can be valuable for teachers and school leaders, because they can obtain an idea of what personalised education requires from a teacher in terms of dealing with differences between pupils in comparison to traditional education. This can for example be valuable when a school board considers implementing personalised learning.

5.2 Value for research

This study is valuable for research because it contributes to what is known about the skills and knowledge a teacher needs to possess, to be able to differentiate by investigating this for personalised math education. Previously, it was only investigated what skills and knowledge a teacher needs to possess, to be able to differentiate in traditional math education by Keuning et al. (2017). This study also provides insight into what extent the skills and knowledge a teacher needs to possess differ between personalised math education and traditional math education.

Besides, the findings in the present study are a valuable addition to what is known about the practices of a teacher in personalised education, because the findings in this study obtained further insight into the teachers' differentiation practices in personalised math education. Differentiation is an essential teacher skill in personalised education (Ministerie van OCW, 2014; Prain et al., 2012).

In addition, the insights into the skills and knowledge a teacher needs to possess, to differentiate in personalised education can be used for developing lesson observation schemes that can be used in future studies.

According to Keuning et al. (2017) their study was the first study that used a CTA for a complex teacher skill. They concluded that a CTA is a valuable method to investigate the skills and knowledge a teacher needs to have to perform a complex professional task. In this study a CTA was used to investigate the skills and knowledge a teacher needs to have, to be able to differentiate in personalised math education. This resulted in rich insights into the constituent skills and knowledge a teacher needs to have to be able to differentiate in personalised math education. This study showed that a CTA indeed is a valuable method to use for analysing a complex teaching skill. This may encourage other educational researchers to conduct a CTA for other complex teacher skills, for example the skill 'dealing with behavioural problems'. Researchers can use the procedure of the CTA conducted in this study which is similar to the procedure of the CTA conducted by Keuning et al. (2017) as an example or guideline for determining the procedure of their CTA.

5.3 Limitations and future research

Although this study is valuable for practice and research, there are also some limitations that should be mentioned. One limitation is that this study was not aimed at finding teachers who are the best experts in differentiating in personalised education since this would not have been achievable because personalised learning is a new trend in education (Elferink, 2017). This is in contrast with the study from Keuning et al. (2017), they searched for teachers who were the best experts in differentiating in traditional education. This may have affected the comparison between the personalised CTA and the traditional CTA. Another limitation of this study is that data analysis in this project was conducted by one researcher, this may have influenced the interpretation of the data and the results of this study. In addition, the teachers were only observed in mathematic lesson(s) during one day in this study, while personalised math lessons may differ between days. However, it was not feasible to observe mathematics lesson(s) for more than one day in this study.

Besides, it cannot be said whether the findings in this study can be generalized to other disciplines, because this study explicitly focused on the discipline mathematics. Since effective strategies and approaches can be identified per discipline, the implementation of a teacher skill will differ with between disciplines with regard to the effective strategies and approaches (Keuning et al., 2017). However, it is plausible that despite the differences, the underlying knowledge and skills of the teacher skill differentiation will be comparable for each discipline, because the underlying skills and knowledge are not related to a subject-related strategy or approach. However, future research should prove whether it is indeed the implementation that differs or that the underlying skills and knowledge differ for another domain like reading or spelling.

Additionally, it is not known whether the findings in this study can be generalized to other contexts, because this study explicitly focused on personalised math education in primary schools. However, based on this study it can be stated that the skills and knowledge a teacher needs to have to be able to differentiate in personalised math education generally correspond to the skills and knowledge a teacher needs to have to be able to differentiate in traditional math education at a primary school according to Keuning et al. (2017), but there are some differences. However, it will be valuable to investigate whether the results can be generalized to differentiation in other contexts in which personalised learning is applied like in secondary education or secondary vocational education in future research.

Based on this study it also cannot be said whether differentiating in personalised math education is more or less complex for a teacher compared to differentiation in traditional math education. It seems plausible that differentiation in personalised math education is more complex, because a teacher has to deal with more differences since it focuses on providing tailor-made learning for every individual pupil. However, differentiation in personalised math education can also be less complex since ICT is used as a tool which makes differentiation easier to handle for a teacher in personalised education according to Kester et al. (2018). Future research should provide further insight into the (potential) differences in complexity between differentiation in personalised math education and differentiation in traditional math education.

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Appendices

Appendix A: Guideline for selecting fragments

De leerkracht..	**Fragmenten**
Geeft verschillende instructies passend bij de behoeften of het niveau van de leerlingen/ een leerling (extra lang, minder/meer complex).	
Gaat na of de leerlingen/een leerling de lesstof van de instructie hebben begrepen door vragen te stellen of opdrachten te geven of het werk van de leerling te bekijken.	
Gaat tijdens de verwerking na of de leerlingen/ een leerling hun opdrachten op een juiste manier uitvoeren.	
Geeft de leerlingen/ een leerling verschillende verwerkingsstof/opdrachten te geven (verschil in hoeveelheid/complexiteit).	
Helpt of geeft feedback aan een leerling met of zonder vraag.	
Zet ICT in tijdens in om de opdrachten/verwerking aan te laten sluiten bij de behoeftes van de leerlingen.	
Stimuleert zelf regulerend leren: Wijst de leerlingen op hun eigen verantwoordelijkheid bij het maken van keuzes over het leerproces/ geeft de leerlingen eigen verantwoordlijkheden in hun leerproces.	

Appendix B: Questionnaire of the semi-structured interview

Introduceren interview - Opbouw interview
Deel 1. Algemene vragen 1. Wat is uw leeftijd? 2. Wat is uw (hoogst afgeronde) vooropleiding? 3. Sinds welk jaar bent u werkzaam in het onderwijs? 4. Met welke types onderwijs heeft u ervaring en hoelang? 5. Op welke type school geeft u momenteel les? En hoelang? 6. Welke groep(en) geeft u les? 7. Uit hoeveel leerlingen bestaat de (grootste) groep waaraan uw les geeft? 8. Wat is de samenstelling van de groep(en) waaraan u les geeft? (niveaus e.d.) 9. Welke software tools gebruikt u bij uw rekenles en hoelang maakt u al gebruik van deze tools?
Deel 2. Bespreking van de fragmenten

Vragen stellen om het handelen en denken van de leerkracht in kaart te brengen. Door te vragen naar wat een leerkracht doet, wat voor keuzes hij of zij maakt en op basis waarvan.

Voorbeelden van vragen:
- Wat doe je hier?
- Waarop is die keuze om dat te doen gebaseerd?
- Wat dacht je hier? Wat ging er in je hoofd om?
- Wat was je doel? Wat was de aanleiding?
- Wat had je nodig om dit te kunnen doen?
- Wat waren je verwachtingen?

Deel 3: Verdere vragen over het differentiëren

1. Hoe bereidt u een periode voor?

Doorvraag opties:
- Hoe lang is een periode?
- Hoe bereidt u een periode voor? Wat heeft u daarvoor nodig? Wat is de rol van ICT?
- Hoe brengt u de onderwijsbehoeften in kaart?

2. Hoe bereidt u een rekenles voor?

Doorvraag opties:
- Hoe brengt u de onderwijsbehoeften in kaart?
- Wat is de rol van ICT?
- Hoe kiest u het lesmateriaal?
- Hoe kiest u de inhoud van de instructie?
- Wat is de rol van de periode voorbereiding bij het voorbereiden van een les?

3. Hoe voert u een les uit?

Doorvraag opties:
- Wat doet u tijdens de les om de les af stemmen op de verschillen tussen de leerlingen?
- Hoe differentieert op de verschillende (gepersonaliseerde) niveaus in de instructies?
- In hoeveel niveau/ levels differentieert u de instructie?
- Hoe differentieert u tijdens de verwerking van de lesstof?
- Hoe ontdekt/ weet u de verschillende niveaus/ verschil in onderwijsbehoeften tijdens een rekenles?
- Wat is de rol/invloed van de leerlingen hierbij?
- Wat is de rol van de lesvoorbereiding bij het uitvoeren van de les?

4. Hoe evalueert u een rekenles of een (les) periode?

Doorvraag opties:
- Wat evalueert u dan?
- Wat is de rol van de periode voorbereiding, lesvoorbereiding en de les uitvoering bij het evalueren?
- Hoe evalueert u de progressie, het leerproces en de behaalde doelen van leerlingen?
- Wat is de rol van de leerlingen bij het evalueren van hun progressie, leerproces en hun behaalde doelen?

5. Wat is de rol van ICT bij het differentiëren?

Doorvraag opties:
- Op welke manier zet u ICT in tijdens een gepersonaliseerde rekenles?
- Welke invloed heeft het gebruik van ICT op de complexiteit van differentiëren?

<u>6. Wat is de rol van de leerling?</u> *Doorvraag opties:* - Welke keuzes/ verantwoordelijkheden rondom het leerproces van het gepersonaliseerde leertraject liggen bij de leerlingen? - Hoe stimuleert uw het zelfregulerend leren? <u>7. Welk verschil ervaart u tussen het differentiëren bij gepersonaliseerde rekenles en het differentiëren bij een traditionele rekenles? (indien eerder gewerkt met traditionele rekenlessen)</u> *Doorvraag opties:* - Welke invloed heeft het op de complexiteit? - Wat vraagt het van u? - Welke overeenkomsten zijn er voor u tussen differentiëren in gepersonaliseerd onderwijs of ander/ regulier onderwijs?
10. Afsluiting - Inzien beeldmateriaal - Vragen naar andere leerkrachten - Uitnodigen expert meeting - Bedanken