University of Groningen

Curious minds in the classroom

Wetzels, Anna

IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.

Document Version
Publisher's PDF, also known as Version of record

Publication date:
2015

Link to publication in University of Groningen/UMCG research database

Citation for published version (APA):
Wetzels, A. (2015). *Curious minds in the classroom: The influence of video feedback coaching for teachers in science and technology lessons*. [Thesis fully internal (DIV), University of Groningen]. University of Groningen.

Copyright
Other than for strictly personal use, it is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license (like Creative Commons).

The publication may also be distributed here under the terms of Article 25fa of the Dutch Copyright Act, indicated by the “Taverne” license. More information can be found on the University of Groningen website: https://www.rug.nl/library/open-access/self-archiving-pure/taverne-amendment.

Take-down policy
If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Downloaded from the University of Groningen/UMCG research database (Pure): http://www.rug.nl/research/portal. For technical reasons the number of authors shown on this cover page is limited to 10 maximum.

Download date: 15-03-2025

Curious Minds in the Classroom

The Influence of Video Feedback Coaching for Teachers in Science and Technology Lessons

Annemie Wetzels

Lay out: KiWi Ontwerpburo
Printed by: Proefschriftmaken.nl | Uitgeverij BOXPress

ISBN: 978-94-6295-367-3
NUR-code: 773

The research described in this dissertation was funded by the Curious Minds program, which is supported by the Dutch Ministry of Education, Culture and Science (OCW) and the National Platform Science & Technology (Platform Bètatechniek), and co-funded by the Heijmans Institute (University of Groningen).

Curious Minds in the Classroom

The Influence of Video Feedback Coaching for Teachers in Science and Technology Lessons

Proefschrift

ter verkrijging van de graad van doctor aan de
Rijksuniversiteit Groningen
op gezag van de
rector magnificus prof. dr. E. Sterken
en volgens besluit van het College voor Promoties.

De openbare verdediging zal plaatsvinden op

donderdag 29 oktober 2015 om 16.15 uur

door

Anna Francisca Maria Wetzels

Geboren op 30 oktober 1960
te Belfeld

Promotor:
Prof. dr. P.L.C. van Geert

Copromotor:
Dr. H.W. Steenbeek

Beoordelingscommissie:
Prof. dr. F. Laevers
Prof. dr. A.E.M.G. Minnaert
Prof. dr. J.H. Walma van der Molen

Contents

Chapter 1

Introduction

CHAPTER 1: Introduction

1.1 Background

Teacher professional development is essential for increasing and maintaining both the quality of teaching and children's level of learning, and thus, essential for improving the overall quality of schooling (Day, 1999; Imperley, Wilson, Barrar, & Fung, 2007). The general aim of this dissertation is to describe the design of a professional development program for teaching science and technology in the earliest school years from a complexity viewpoint and to report the results of the related effect study.

Why is teaching science and technology in preschool and grades 1 and 2 so important? Young children are already little researchers, developing intuitive theories of their environment, based on their daily experiences and on innate core knowledge (Carey & Spelke, 1996; Van Geert, 2011). However, these intuitive theories are not always in line with scientific reality. Teachers can help children to gain an accurate understanding of fundamental theories, but this does not happen by simply replacing the intuitive knowledge with the right conceptions by means of direct transmission. Mere transmission of knowledge does not establish real change in the minds of children. How then can teachers help children to change their misconceptions over time with correct scientific reality?

Children ask questions such as: What are stars? Why does an apple fall down? Why does the sun stay high in the sky? Why do leaves turn brown in autumn? Where does the snow come from? Children show a lot of curiosity for everything that happens in their environment (Loewenstein, 1994). Children love to observe, touch, taste and further examine everything they encounter, as most parents with young children will confirm. What is striking is that once these children go to school, this curiosity seems to slowly vanish (Engel & Randall, 2008; Engel, 2009; Engelhard & Monsaas, 1988; Osborne, Simon, & Collins, 2003), and when children reach grades 7 and 8, many children hardly show any curiosity for this kind of natural phenomena at all.

In order to gain more insight into the process of vanishing curiosity, which eventually might be a natural and inevitable phenomenon, Engel (2006) observed the way teachers encourage curiosity in classrooms and made an overview of teachers' utterances during various activities and classes. She discovered that no matter what activity or class, teachers generally just check knowledge or remind children to stay on task and thus hardly stimulate curiosity at all.
A good example of this behavior during science class is the following:

> For instance, in one fifth-grade classroom, the teacher had set out an activity

> meant to show the children something about how Egyptians first invented wheels. She gave small groups of children a long slab of wood, some small wooden wheels, some blocks to transport on the slab of wood, and a string with a small measurement tool that, when attached to the slab, could measure the distance and time the slab was traveling when pulled. The children were also given a worksheet on which they were to report how easy it was to pull the slab when the number of wheels were added and subtracted. Children were eager to work with the materials, and the room seemed lively with activity. The teacher moved about the room, offering hints and suggestions about how to pull the slab, so that the children could fill out the worksheets. She made frequent comments commending the kids on achieving the goal of filling out their worksheets. At one point a child started to fiddle around with the materials, pulling the string in unexpected ways, moving the wheels, and adding other small objects to the slab. The teacher replied, "Kids, I'll give you time to experiment at recess. Now it's time for science." (Engel, 2006, p. 7).

Thus, it seems that teachers hardly ask questions in the classroom and hardly encourage inquiry and curiosity in the classroom. Since inquiry and curiosity serve as the basis of science and technology learning, children's diminishing interest in science and technology during their primary school careers (Osborne et al., 2003) could be associated with their experiences in the earliest school years. This suggests that in addition to leading to diminishing interest, these early negative experiences could also result in negative attitudes towards science and technology in young children.

Young children's diminished interest in science and technology is likely to increase the probability of negative experiences with this science and technology. Since negative experiences with science and technology in school are correlated with less self-efficacy in science later in life (Bleicher, 2004), it is to be expected that children who have had such negative experiences will very likely not choose for a career in science and technology related topics later in life. This is extremely problematic in an age that depends on science and technology more than ever before. Scientific literacy is necessary for everyone, not only for those who pursue science and technology careers because everybody needs the ability to engage with science and technology and to use scientifically informed ideas to reflect on socio-scientific issues (Guerin, 2015). One merely needs to consider the myriad of problems society is dealing with at the moment, such as energy and water supply, waste disposal, global warming, problems of developing countries with regard to their economies, poverty and the labor market. All these problems need science and scientists to help our earth and its inhabitants move smoothly into the 22th century.

This leads to the conclusion that it is important for children to acquire early positive science and technology experiences, and to have their natural curiosity and interest in inquiry be stimulated from the early school years on (i.e., in preschool and grades 1 and 2 (group 1-4 in the Dutch school system). Various countries have already started nationwide programs to stimulate science and technology education for young children (e.g. in Germany, Haus der Kleinen Forscher ("http://www.haus-der-kleinen-forscher.de/en/," n.d.), in the Netherlands, the Dutch Institute for Educational Policy in Science and Technology (PBT), and the Curious Minds project, which will be described in more detail in the section 2.1).

An important starting point in this discussion is that the people who should provide these early positive experiences are the teachers. Their quality of teaching is crucial for pupils to keep a positive attitude towards science (Osborne et al., 2003). In other words, teacher and student co-construct knowledge in a socially situated learning perspective (Granott & Parziale, 2002; Sorsana, 2008). Science learning and teaching are created in the interaction dynamics between a child, an adult (in this study the teacher), and the materials as used in the transactions (Steenbeek & Uittenbogaard, 2009). If the interaction is positive, teacher and child can lead each other into a self-sustaining positive talent spiral, (Van Dijk, Van Geert, & Steenbeek, 2010) in which teacher and child stimulate each other to show higher levels of science reasoning and of teaching behavior that elicits scientific reasoning. The teacher plays a very important role in instigating this positive spiral. In other words, science and technology talent in children, which is extensively described in the Curious Minds project (Post, 2009; Van Benthem, Dijkgraaf, & De Lange, 2005) and which involves interest, curiosity, inquiry, diverse forms of reasoning, logical thinking and problem solving develops in this interaction. For this reason, we hypothesize that it is possible to stimulate the science and technology talents of young children by improving the skills of their teachers ("Start Science Sooner," 2010).

Nonetheless, improving skills of teachers in a professional development trajectory cannot be seen as a simple cause-and-effect process. Teachers work in a complex world and a complex school environment with several context variables that all have an influence on their behavior. A complexity viewpoint or ecological viewpoint (Dishion & Stormshak, 2007) is needed when taking all these factors into account, namely all the factors within a person and within society that act simultaneously and mutually interact to contribute to behavioral change to a greater or lesser extent. This complexity viewpoint is addressed in this dissertation by means of focusing on three intrinsic properties of complex dynamic systems, namely the iterative (or recursive) character of a process, the inter- and intra-individual variability of teachers' behavior, and the occurrence of patterns and mechanisms of change on various interdependent time scales (Steenbeek & Van Geert, 2013).

1.2 Research questions

The first aim of this dissertation is to develop and describe a coaching program for teachers (Video Feedback Coaching for Teachers, in short VFC-T) that influences teachers' behavior in order to stimulate pupils' scientific reasoning. The focus of the intervention is to develop a coaching trajectory that can be implemented in classrooms without costly investments in material and training hours. An important question is what such an intervention for teachers in lower grades for teaching science and technology should look like. In particular, what intervention characteristics are necessary when developing a coaching program aimed at changing teachers' behavior so they can teach science to young children? We realize that any such an intervention implies intervening in a complex and dynamic system, namely a concrete teacher in a concrete school context. This implies that a multitude of intertwining factors influence a teacher's professional development trajectory that must all be taken into account.

A second aim of this dissertation is to examine what the effect of the intervention is on a teacher's professional well-being. For instance, does the intervention enable teachers to feel comfortable to use the learned content regarding teaching science and technology in the classroom? Addressing teachers' well-being when designing the intervention is important because this will enhance their motivation for using the learned content in the classroom.

The third aim of the dissertation is to examine the results of the intervention: did it change the behavior of the teachers in the classroom, and did the teachers' behavioral change also change the behavior of their pupils?

1.3 Overview of the Chapters

The coaching program is described in chapter 2. The program is based on various general principles in the fields of talent and talent development, learning and teaching and behavioral change. This chapter is dedicated to the first aim of this dissertation, namely the development of a coaching program that influences teacher's behavior in order to stimulate pupils' scientific reasoning. The chapter starts with a description of the background of the program and continues with the way this coaching program is embedded in a nationwide program to stimulate science and technology in children, the Curious Minds project. Next, it proceeds with describing how the general principles of the Curious Minds project and general principles of behavioral change have been implemented in the coaching program. Additionally, the coaching program itself is described, as well as the training program for coaches.

Chapter 3 gives a theoretical overview of aspects that contribute to the effectiveness of interventions regarding teachers' professionalization. Subsequently, effectiveness and effectiveness studies are re-interpreted by using a complexity approach. Finally, a multiple case study empirically illustrates the complexity approach to the effectiveness of interventions. The chapter provides an additional answer to the first research question. The influence of the environment and various aspects of an intervention are described from a complexity view point as well as from a more 'standard' viewpoint.

Chapter 4 gives an answer to the second research question, namely, to what degree the VFC-T and the subsequent science and technology teaching in the classroom have a positive effect on teachers' well-being and motivation. For this effect study, a mixed method design is used, with qualitative and quantitative methods, to address both results in the classroom and the way teachers react to the program.

The effect study in chapter 5 gives an answer to the third research question: what are the results of the intervention in terms of teachers' and pupils' changed behavior in the classroom. Instead of just looking at the results that can be observed after the intervention, the study also focuses on changes during the intervention in the teachers as well as in the pupils. Behavioral change in this chapter is studied by observing to what degree teachers show changed behavior in their actual teaching with respect to stimulating pupils' scientific reasoning skills, and subsequently, to what degree their pupils show changed behavior with respect to their level of scientific reasoning skills during the science and technology lessons. This study uses micro genetic measures and focuses not only on changes in teachers' and pupils' behavior, but also on their interaction patterns in the classroom during science and technology lessons. In line with our complexity and dynamic approach, the results are given both on a group and an individual level.

Finally, chapter 6 provides a summary of the dissertation and a general discussion of the previous chapters. Possible consequences of the results of this dissertation for educational practice in the classroom are discussed, as well as the implication for teacher education regarding science and technology in the earliest school years. Furthermore, some implications for future educational research are discussed.

CHAPTER 2:

Description of the Design of the Coaching Program, the Training for Coaches, and their Theoretical Background

CHAPTER 2:
Description of the Design of the Coaching Program, the Training for Coaches, and their Theoretical Background

Chapter 2 gives an overview of the coaching program and the training for coaches. In 2.1, the cornerstones and the way the program is embedded in a nationwide program to stimulate science and technology in children, the Curious Minds project is described. In 2.2, three important concepts that help stimulate science and technology talent in daily practice are described and in 2.3 general principles of behavioral change that have been implemented in the coaching program are described. Finally, in 2.4, the coaching program itself is described, as well as the training program for coaches. A summary of this chapter is given in 2.5.

2.1 Curious Minds and Science & Technology

This research project is part of the Curious Minds project, a Dutch nationwide program for improving science and technology in primary education (Van Benthem et al., 2005). The Curious Minds project aims to investigate all aspects of young children's science learning from multiple angles and from multiple disciplines. The knowledge from these multiple angles and multiple disciplines is necessary when designing a program that can enhance the various aspects of children's science learning. This chapter describes the corner stones of the VFC-T, as found in the basic concepts and assumptions of the Curious Minds program and in the concept of talent moments.

2.1.1 Society and Science & Technology

Science plays an important role in our society today. One could say that science and society are intimately related because of the way society creates science and vice versa (Nowotny, Scott, & Gibbons, 2001). Consider, for instance, the impact and dangers of nuclear power on global wealth and welfare, as well as on climate change and security. The public debate on these kinds of topics is wide-ranging and participants in this debate need knowledge on many subjects for their contribution to be worthwhile. This implies that science is of a broader concern than only for the "real scientists"; in fact, everybody will need to engage in science related topics when participating in the discussions in, for instance, nuclear power, poverty in developing countries, or genetic engineering (Mooney & Kirshenbaum, 2009). However, participants in the public debate do not need specialized knowledge. What they need, in fact, is basic knowledge of key concepts and principles in order to avoid serious misconceptions. For instance, if people understood that doing science means following the empirical cycle (De Groot, 1961), they would not think that scientists claim absolute truths, and they would understand that for a scientist to be wrong sometimes is an intrinsic part of doing science. This example stresses the importance of using a key concept such as the empirical cycle in education.

Apart from the fact that society needs more knowledge of basic science concepts and science related subjects, there is also a shortage of higher educated individuals in science and technology (Hodson, 2003). Therefore, it is necessary that more attention is paid to the issue of science and technology education, not only in secondary education but from the earliest school years on ("Start Science Sooner," 2010). In The Netherlands, this awareness has led to the establishment of the Curious Minds project (in Dutch: TalentenKracht programma) in 2006 as a nationwide (extended with one Belgian group of researchers) research project in which Dutch and Belgian research groups work together to study and stimulate young children's talent for science and technology (Post, 2009; Van Benthem et al., 2005).

According to the Curious Minds project, one of the main aspects of children's science and technology talent is curiosity. The initiators of the Curious Mind project (Van Benthem et al., 2005) observed that young children, aged 3-6, sparkle when showing their curiosity and natural interest in everything that happens in their surroundings. Young children want to know everything about the stars, astronauts and dinosaurs and ask questions about everything that comes to their mind, as all parents will confirm. As we have seen in section 1.1., this curiosity seems to disappear as children grow older. The researchers in the Curious Minds project want to investigate the process from the emergence to eventual decline of curiosity from multiple angles and from multiple disciplines. The focus of this investigation should be on all aspects of science and technology talent, such as interest, curiosity, inquiry, diverse forms of reasoning, thinking logically, and solving problems, i.e., a combination of affective, motivational and cognitive aspects of science and science learning (Van Benthem et al., 2005; Van Geert, 2011).

2.1.2 Defining children's science and technology talent

The definition of the Curious Minds project for 'talent' is based on an extensive review regarding science and technology talents for young children (Van Geert, 2011). The literature with regard to talent and excellence (e.g. Simonton, 1999, 2001) states that talent can be assumed to emerge from a multidimensional, multiplicative, and dynamic process, and is a rather complex behavioral phenomenon, in which both genetic traits and inherited epigenetic trajectories play a role. We shall define talent, in general, of a certain individual as follows: an individual´s talent is his or her potential to develop and reach a certain level of excellence in a domain specific area. This potential is reflected in observable actions that are sometimes excellent in relation with the age group or other group the individual belongs to, and sometimes excellent in relation with the actions of the same child at another age or moment in time (Van Geert & Steenbeek, 2007).

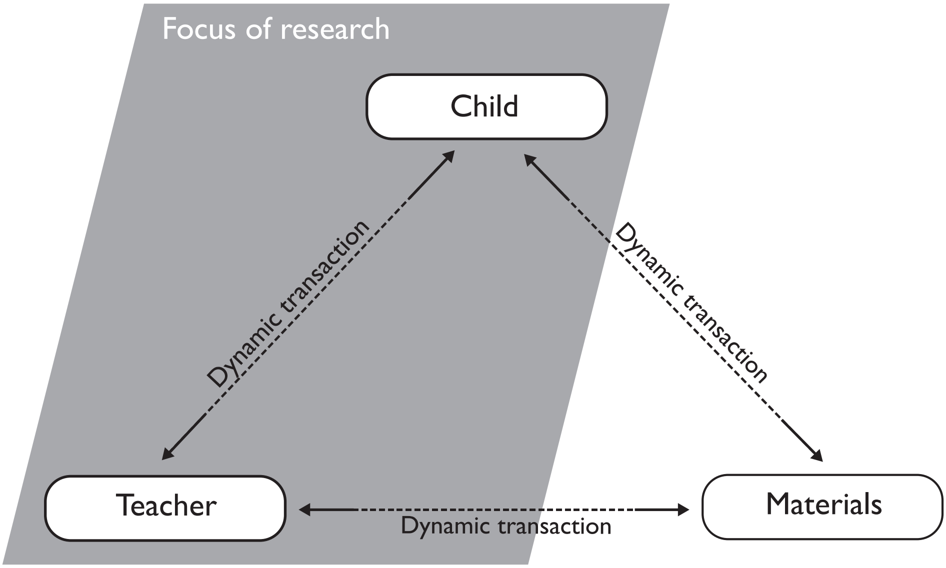
Science and technology talent, in particular, is the child's potential to develop a certain level of excellence, which is reflected in the child's display of affective and motivational (e.g. interest and curiosity) and cognitive (knowledge construction) aspects of science and science learning. Examples of observable actions are, for instance, children's reasoning, hypothesizing, predicting, observing and explaining scientific phenomena. In the following sections some important characteristics of this definition are described more extensively.

Static vs. dynamic: Science talent is only one of many talents children can have. When speaking about talent in general, the most frequently used definition of talent is a static one, a person's ability to excel in a certain area, a giftedness (Howe, Davidson, & Sloboda, 1998). However, this research project, as part of the Curious Minds project, defines talent not as a static, but as a dynamic feature that expresses itself in a child's real-time action, and that can develop over time (Van Geert & Steenbeek, 2007). Talent can thus be compared with a flower garden: what a garden grows depends on the fertility of the ground. However, not only is fertile soil necessary for growing beautiful flowers, but also sowing, irrigating, pruning, and weeding. Like a flower, talent can only properly develop if it is sown and taken care of (Van Dijk et al., 2010). Science and technology talent is a talent that changes over time in an individual child. At a young age, much science and technology talent is present, as young children are curious and enthusiastic, and show more spontaneous science-related reasoning and problem-solving behavior than older children (i.e., they excel in comparison to older children). This talent vanishes if insufficiently stimulated by the environment, i.e., school and parents.

Talent in relation with other children/self: A child's talent is often defined in terms of superior performance of a particular child in comparison with the performance of other children. In this project, this traditional meaning of talent is not used. Here, a child's talent is not primarily compared with that of other children of the same age, but with the same talent of this single child at another age or moment in time, e.g. a particular lesson in comparison to another lesson (Van Geert & Steenbeek, 2007). This implicates that basically every child has a certain talent for science and technology. Talent is thus not defined as excellence bestowed on only a few children. Every child within his/her own developmental trajectory can show talent (moments of excellence relative to performance as usual), and can consequently maximize his/her own potential (Steenbeek, Van Geert, & Van Dijk, 2011). Maximizing potential focuses on various kinds of expressions of science talent, e.g. the use of scientific reasoning and knowledge of science content, the use of scientific language, and the ability to think about the basics of scientific models. Maximizing science potential also focuses on attitudes, motivations, values or emotions towards science, for instance, curiosity and interest in science and science related subjects.

The role of interaction and the talent triangle: Science and technology talent in children develops in the interaction dynamics between a child, an adult (in this project the teacher), and the materials used in these interactions (Steenbeek & Uittenbogaard, 2009). The iterative character of the interaction between child and teacher during a task is especially important because each action of a child or a teacher influences the subsequent action of either child or teacher respectively (Guanglu, 2012; Steenbeek & Van Geert, 2013). An important aspect of the focus on the interaction between child and adult is that over time adult and child can lead each other into a self-sustaining positive talent spiral (Steenbeek et al., 2011), in which both stimulate each other to show talented science reasoning and instruction. However, this can also lead to self-sustaining suboptimal performance, for instance, the self-sustaining state of lack of interest and learned helplessness in science-related thought of the students as well as the teachers. The adult, therefore, can have a very important role in instigating a positive spiral. That is, it is the *interaction* between adult and child that forms the basis of talent development. Talent is, from this viewpoint, not to be seen as a gift, but as an ability that emerges and develops within the right circumstances.

Figure 1 | *The talent triangle*



In the talent triangle (figure 1), it can be observed that children develop their talents by means of a dynamic transaction of the child with teachers and materials, in which both the teacher and the material and the child himself have an influence on each other and work together to co-construct children's skills and knowledge (Van Geert, 1998). These three components play their own specific role in this process. Because we hypothesize that it is possible to improve the science and technology talents of children by improving the skills of their teachers ("Start Science Sooner," 2010), this research project shall focus on two specific edges of the triangle, namely the adult and the child and their interactions, i.e., teacher development in combination with children's learning. A detailed description of the role of the third edge of the talent triangle, the task, is certainly important, but falls outside the scope of this dissertation. We shall assume that the material context provided in this process is rich enough to support the desired adult-child dynamic transactions.

Multiple timescales: The interactions within the talent triangle are performed in the here and now, and have a positive influence on pupils' development in the short term, for instance, during a particular science activity in the class. However, the dynamics in the interaction between teacher and pupil in the short term also have an impact on pupils' development in the long term, for instance, over the course of their primary school career. This principle of nested timescales (Lewis, 2002; Smith & Thelen, 2003; Steenbeek & Van Geert, 2008) entails that activities done on the real time scale, the here and now, (micro development) have an impact in the long term developmental timescale (macro development) and also the other way around. An example of this mutuality can be seen in the classroom when a teacher helps children to understand air pressure. The question in the here and now is whether a piece of paper falls at the same speed as the same piece of paper crumpled into a ball. The teacher can ask if the paper's weight stays the same by crumpling, and what is different between the two objects. The teacher's question influences the pupils' answer (the surface area of the piece of paper is greater than that of the ball) at this moment in the lesson. The teacher's assistance also has an effect on the pupil's future understanding of air pressure, when the teacher's help is no longer necessary for the pupil. However, this is also true when the reverse is the case: the children's understanding of the current question in this particular lesson is strongly determined by the understanding which they have already developed earlier, and by the history of experiences which they already have with this particular type of question, lesson and object.

2.1.3 Assumptions about science and technology talent

Starting with the characteristics of talent and talent development, as described in the previous section, five assumptions endorsed by the Curious Minds project will be introduced that form the basis of this research project and the related professional development/coaching program for teachers (Steenbeek & Van Geert, 2009b).

The Curious Minds projects starts with the assumption that *every child is talented and can develop his/her talents in interaction and co-construction with his or her environment*. However, what do we mean by saying that every child is talented? We mean that every child potentially has the ability to show talented science and technology behavior, such as interest, curiosity, inquiry, diverse forms of reasoning, logical thinking, and problem solving skills. Hence, every child can show talented behavior in a particular lesson, compared with performance-as-usual, i.e., with his/her performance in another lesson. A positive intertwinement between the child and his/her environment, i.e., the teacher, is therefore necessary, which means a teacher and a child influence each other mutually in a positive direction, as well as an environment that stimulates the child in an optimal way to show this talented behavior. Science and technology talent is therefore a feature that can be further developed and stimulated over time, just as the flowers in the garden are tended to with sowing, watering and weeding. In addition, not only can children show talented behaviour: The teacher can also show talented behaviour in stimulating children's talents. This means that in order to stimulate children's talented behaviour, the teacher's skills for talent development with children should also be stimulated. This is not only true for teachers and children, but also for parents and for school principals.

The second assumption is that *young children show curiosity for their environment*. Although there is not one clear definition of curiosity, some important features are widely used, for instance, the tendency to seek new information and to explore novelty in one's environment. Berlyne (1966, 1970) distinguishes two dimensions in curiosity. The first dimension describes an axis ranging from an intrinsic desire for knowledge to a desire for new experiences and sensations, whereas the second axis ranges from specific curiosity, focused on the search for specific information to a more general form of curiosity, focused on a general search for new stimulation. Important aspects in the description of curiosity are therefore novelty, information, and environment leading to exploratory behavior (Jirout & Klahr, 2012). Loewenstein (1994) states that curiosity is a desired feature for humans because humans have a need to resolve the gap in knowledge and the understanding they experience in their daily lives. The same is true for children (Jirout & Klahr, 2012). Curiosity is an important asset for children because it is associated with effectiveness of learning (Howard-Jones & Demetriou, 2009) and with questioning, which in turn can also be associated with effectiveness of learning (Klahr, Zimmerman, & Jirout, 2011). When learning science in their early school years, children can use this natural curiosity to develop other skills necessary for their further education, for instance hypothesizing, predicting, observing and explaining (Conezio & French, 2002; Engel, 2006, 2009; Greenfield et al., 2009).

The third assumption is that *parents and teachers can have the ability to see, recognize and stimulate talented science and technology behavior, position this behavior within a developmental perspective, and act accordingly*. Therefore, adults need to gain insight into interaction processes and into the way children learn from these processes (Alfieri, Brooks, Aldrich, & Tenenbaum, 2011) because this insight can help to optimize the way adults stimulate talented science and technology behavior. Steenbeek et al. (2011) describe the perception adults have of children's science talent as it demonstrates itself in real-time activities, as well as the way adults can stimulate this talent. An interesting outcome from this study was that teachers tend to see the cognitive aspects of talents, and to disregard its affective and motivational aspects. It is important for teachers to learn to see all aspects of science talent. Consequently, a talent-stimulating environment for young children can be created, in which children are motivated to make use of the aforementioned processes hypothesizing, predicting, observing and explaining. When teachers act in a talent-stimulating way, observing, recognizing and using opportunities to stimulate children in the classroom can become inherent and pervasive daily activities for teachers, which enhances children's science and technology learning.

The fourth assumption states that *teachers can develop themselves not only as "teaching experts" but also as "talent-experts"*. This entails that they can learn to see children's talented science behavior in the classroom, and recognize where it fits in the development of a child. The interactions in the talent triangle show how teachers can adapt their own behavior at any moment to stimulate children as optimally as possible in order to enhance children's talented processes, for example reasoning, hypothesizing, predicting, observing and explaining, and thus create so-called "talent moments" (see section 2.1.4). Teachers who are "talent-experts" approach their pupils in the same fascinated and curious way as the pupils ideally do when they are confronted with stimulating science experiments in the classroom. In order to be able to do this, teachers should have adequate content knowledge, as well as pedagogical content knowledge of science and technology (Appleton, 2003; Opfer & Pedder, 2011). Moreover, teachers should have interest and curiosity regarding science and technology themselves. Teachers however, often do not have enough knowledge or real interest in science and technology, and hence feel insecure about teaching these subjects (Dickinson, Burns, Hage, & Locker, 1997; Engel & Randall, 2008; Jarvis & Pell, 2004; Walma van der Molen, 2008).

The fifth assumption describes *the importance of case based learning*, a way of learning to apply learned content in real life situations (Borko, Koellner, Jacobs, & Seago, 2011; Lehmann & Gruber, 2006; Seago, 2004). Learning by paying careful attention to examples is the best way for teachers and parents to learn to recognize talented behavior, and so to become the talent expert as described in the fourth assumption (Geerts, Steenbeek, Van der Werff, & Van Geert., n.d.; Steenbeek & Van Geert, 2009a). An important way to learn is by using video clips of relevant classroom situations of oneself (Borko, Jacobs, Eiteljorg, & Pittman, 2008; Seidel, Stürmer, Blomberg, Koberg, & Schwindt, 2010) as this is an excellent way of providing performance feedback to teachers (Kluger & DeNisi, 1996; Noell, Witt, Gilbertson, Ranier, & Freeland, 1997) or by using video clips of other teachers (Rosaen, Schram, & Herbel-Eisenmann, 2002; Seago, 2004). Steenbeek et al. (2011), for instance, concluded that both professionals and parents enjoyed working with video clips, because these clips provided ample possibilities for triggering content-based reflections about talented behavior regarding science topics for both adults and children.

2.1.4 Stimulating science and technology talent through talent moments

Children's knowledge construction, which corresponds with the cognitive aspect of their science talent, can only take place within and with the help of their social context, as already mentioned by Vygotsky in his concept of the zone of proximal development (Vygotsky, 1978). The talent triangle (figure 1) offers a representation of how this social aspect of children's knowledge construction can be put in practice in the here-and-now of a classroom. When a teacher pays attention to a child's learning moments, he or she can in turn provide adequate information so that the child can develop his/her interests and knowledge further within the zone of proximal development. Knowledge construction occurs in the circular dynamics between teacher and child, in which both positively influence each other to reach a higher level of performance (Van Geert & Steenbeek, 2005). The moments during which this knowledge construction is optimized can be seen as teachable science moments. A teachable science moment is any event ranging from a short interaction to a complete science lesson or activity, in which the co-constructive process of talented scientific thinking and acting takes place (Bentley, 1995; Hyun & Marshall, 2003). The term talent moment is used in this dissertation as a special case of such a teachable science moment to emphasize the fact that these moments arise when students are excited, engaged and primed to learn, and teachers are excited and engaged to teach, and excel in the way they engage their students. In short, they are the moments during which both teacher and child show science-related talented behavior (Steenbeek et al., 2011). Given this definition, these talent moments are especially fit for talent-stimulating behavior.

The implementation of the five assumptions in the classroom entails that a teacher is aware of the talent moments in the classroom and has the skills to initiate and elicit them. Stimulating children's science and technology talent takes place in the classroom, in the here and now, on the spot, in a concrete interaction between teacher and pupil. The seemingly intangible activity of stimulating talent can be achieved by the teacher by focusing on small scale activities in the classroom, by focusing on his own actions and the actions of children, and by reacting as positively as possible during these often short moments: the talent moments. In this definition, the talent moment is a spontaneous learning moment in the classroom with some important characteristics: the talent moment gives teachers the opportunity to discuss a science and technology topic. During this learning moment a pupil is enthusiastic, explores and sees connections, in short, shows aspects of talented science behavior, and the teacher can excel by, for instance, asking stimulating questions (Steenbeek, Van Geert, et al., 2011; Van Geert & Steenbeek, 2007). A teacher can thereby see or elicit children's talented science behavior within a normal lesson and within the normal curriculum.

Consequently, children's and teachers' science and technology talent, and accordingly children's science and technology learning, can be stimulated by increasing the duration, amount and quality of talent moments within the classroom. The concept of talent moments now leads us to a core feature of the current research, namely that teachers need to learn how they can recognize these moments, how they can elicit them, and how they can shape the talent moments to deepen the content of lessons. Teachers need to experience that all lessons are appropriate for eliciting talent moments. However, science lessons can provide more possibilities because of the nature of the subject.

In practice, the talent moments are recognizable as interactions between a teacher and a pupil during conversations, or parts of conversations, where a teacher observes pupils and recognizes opportunities. These observations lead to a targeted instructional action that a pupil can use to learn. Moreover, this type of action increases the probability that such talent moments will occur in the future. In accordance with the third assumption, observing, recognizing and using these opportunities in the classroom, (and thereby creating talent moments in the classroom), can become an inherent and pervasive daily activity that enhances children's science and technology learning, not only during science lessons, but also during all other curricular activities.

2.2 Stimulating Science and Technology Talent in Daily Practice

When children's science and technology talent is successfully stimulated in schools from the earliest school years on, young children can develop a level of understanding of scientific concepts and principles that goes far beyond the level they would develop in other circumstances (Gelman & Brenneman, 2004; Mantzicopoulos, Patrick, & Samarapungavan, 2008; "Start Science Sooner", 2010). The programs that succeed in successfully stimulating children's science talent (Gelman & Brenneman, 2004; Mantzicopoulos et al., 2008; Sarama & Clements, 2009) are usually based on ways of learning that give learners room to construct their own solutions because this practice ensures the most effective learning experience. These programs build upon Piaget's theory, which stresses the finding that the interaction between experiences and ideas of children creates knowledge (Piaget, 1970). This theory explains the development of children's basic concepts as the result of internal processes of construction by the children themselves based on children's own actions and sensory experiences. In addition, this theory stresses the importance of children's exploration and inquiry skills.

Various names have been used over the years to address the learning approaches that focus on the importance of children's own discovery or construction of essential information, e.g. discovery learning (Bruner, 1961), problem-based learning (Schmidt, 1983), inquiry learning (Rutherford, 1964), and constructivist learning (Jonassen, 1991). However, used in isolation as the basis of didactic strategies in classrooms, these approaches are not as effective as they are in combination with the use of the theory of co-construction of knowledge, i.e., a cooperative construction of knowledge by a child together with the adult, who can take the responsibility or lead in guiding the process. The importance of incorporating the co-construction process of knowledge, as it takes place in the interaction between teacher and pupils (Kristina Kumpulainen & Wray, 2002), is also shown by various studies regarding the role of the teacher in recent years (Alfieri et al., 2011; Kirschner, Sweller, & Clark, 2006; Mayer, 2004).

In a research project preceding the current one, the literature with regard to Curious Minds and co-construction of knowledge was used as a basis for observations in the classroom as well as for interviews and discussions with school directors and teachers in order to build our knowledge about what schools needed in order to improve their science and technology lessons. In addition, the aim of these actions was to discover important antecedents and features of talent moments. In two reports (*Eindrapportage Expertisecentrum TK*, 2010; Steenbeek & Van Geert, 2009b) the results of this research project were described. The following main recommendations were reported: Teachers need to give adequate support to their pupils if they want to stimulate children's science talent by enhancing the number of talent moments in their classrooms. Therefore, teachers need to develop specific pedagogical and didactic skills. Furthermore, in the final report of the Expertisecentrum TalentenKracht (2010) the participating teachers reported that they needed science knowledge, but they also reported that they felt more need for particular skills, namely the skills they considered essential for stimulating science talent in the classroom, for instance asking open questions, the use of follow up questions, giving room for answers, listening and responding to what pupils say. The skills that teachers mentioned are consistent with research with regard to effective classroom interaction (Kristina Kumpulainen & Wray, 2002).

The results of the Expertisecentrum TalentenKracht (2010) in combination with the literature with regard to constructivist and inquiry learning lead to some important recommendations with regard to creating more talent moments and enhancing pupils' reasoning skills. First, with regard to the lack of knowledge teachers mentioned, teachers and learners should be provided with a fundamental concept that can help them understand science and technology as a coherent, meaningful system and that gives structure to their teaching (Richland, Stigler, & Holyoak, 2012). For science and technology, the use of the empirical cycle was recommended, as it is both a key concept for real science and science learning, as well as a means of structuring science teaching. Because this research project focuses on lower grade teachers, their knowledge of this key concept in addition to their knowledge of relatively simple to use concepts in the classroom, as for instance floating and sinking, is considered sufficient. Secondly, teachers should become acquainted with the concepts and associated strategies of questioning and scaffolding, so they can give room and support to their pupils' reasoning skills. The use of these three important concepts as mentioned in the recommendations helps teachers to stimulate science talent in the classroom.

2.2.1 Empirical cycle

The empirical cycle is an often-used strategy in science and scientific research (Goodwin, 2003), and provides a straightforward and practical model that can be used in classrooms of all levels with the pupils during the lessons. The use of the empirical cycle is a fundamental key strategy that children should learn in order to obtain a basis in science thinking and scientific understanding, so that they understand how science works in reality. Moreover, it gives structure to science learning for teachers and pupils. In science learning, especially when experimenting in the classroom with, for instance, air pressure, floating and sinking experiments or with the mixing of various kinds of substances, it is difficult for teachers to know what to actually do. In classrooms, this tends to end up in unstructured or over-structured (with the use of worksheets) hands-on activities, during which a teacher no longer plays a role (Mayer, 2004; Parkinson, Hendley, Tanner, & Stables, 1998). In order to avoid either of these extremes, the use of the empirical cycle gives both teachers and children structure during hands-on activities, and provides opportunities for teachers to interact with the pupils during the lessons. The model consists of five consecutive steps that can be used when conducting an experiment: formulating the draft of a research question for an experiment, formulating a hypothesis concerning the outcome of the experiment, setting up the experiment in order to assess the truth or falsehood of a hypothesis, observing what happens during the experiment, and finally drawing a conclusion that validates or modifies the hypothesis, leading either to changes or consolidation of the belief system (knowledge), which serves as a basis for new questions so the cycle can be repeated (De Groot, 1961; Dejonckheere, Van De Keere, & Mestdagh, 2009).

Within the consecutive steps of the empirical cycle, several important learning activities are included, as there are hypothesizing, observing and explaining and reasoning, which makes the model not only important as a structure for teachers and pupils, but also provides possibilities for scientific reasoning.

2.2.2 Questioning

The second strategy, questioning, is a very important aspect of teachers' work in classrooms because it is an essential component of many instructional methods (Wilen, 1987). Asking good questions helps to enhance pupils' curiosity (Goodman & Berntson, 2000), provides pupils with opportunities to learn (Wasik, Bond, & Hindman, 2006) and with opportunities to reason and to explore (Lee, 2010). Gall (1970) reviewed the kind of questions used in classrooms from 1912 to 1970. She concluded that from 1912 to 1970 the kind of questions used had not fundamentally changed. She observed that only 20 % of the questions used invited children to really think, whereas the other 80 % were procedural or required knowledge to be recalled. Harrop & Swinson (2003) as well as Hestenes, Cassidy, & Niemeyer (2004) replicated these results. Hestenes et al. (2004) found that teachers ask more (80-83%) low-level questions, i.e., questions that require children to label or produce previously acquired knowledge and less high or medium level questions (11-12% and 6-7% respectively), i.e., questions that invite children to use previously acquired knowledge to hypothesize and reason about cause and effects of a particular phenomenon. The questions teachers ask are usually focused on the reproduction of previously learned knowledge and facts, instead of on stimulating thinking processes (Engel, 2009; Engelhard & Monsaas, 1988). Over the last century, it appears that teaching has hardly improved with regard to the use of questions that challenge pupils' cognitive skills for scientific reasoning.

Many categories of questions can be distinguished. Open ended and closed questions (Lee, Kinzie, & Whittaker, 2012) , "how", "why" and "is" questions (Goodman & Berntson, 2000), factual recall, low and high convergent questions (Cunningham, 1987) are examples of categories of questions that are mentioned in the literature and that all have different goals and effects on pupils' learning (Wilen, 1987). Teachers need to know what effects various kinds of questions have, and which ones can best be used when teachers are aiming to enhance their pupils' thinking skills. For instance, open questions stimulate pupils' thinking more than closed questions because these questions are not limited by the question itself (Hargreaves, 1998; Rivera, Girolametto, Greenberg, & Weitzman, 2005). Moreover, the answers pupils will provide are in general more elaborate. The research project in this dissertation uses Oliveira's (2010) categorization in student-centered questions and teacher-centered questions. Student-centered questions are questions whose answers teachers cannot assess as right or wrong, in contrast to teacher-oriented questions, which require reproduction of knowledge, for example "what is an atom?". Student-centered questions, for example "what do you see when I pour oil in water?" or "what do you think will happen when I pour oil in water?" give room to pupils' thinking and reasoning, and gives room for corrections of key concepts because pupils are not asked for what they already know, but for what they think, which may invoke new or unexpected elements.

2.2.3 Scaffolding

In addition to the two former strategies, a strategy is needed that gives teachers guidance in how to give the right support to pupils' scientific reasoning. This third strategy is scaffolding, a process that enables a person (a child) to solve a problem, carry out a task or achieve a goal which would not be possible without the help of another person (the teacher). The teacher can help the child with the parts of a task that are not yet within his capacity, so that the child can complete the task successfully with help (Wood, Bruner, & Ross, 1976). This scaffolding 'consists essentially of the adult "controlling" those elements of the task that are initially beyond the learner's capacity, thus permitting him to concentrate on those elements of the task that are within his range of competence' (Wood, Bruner & Ross, 1976, p. 90). The relation between scaffolding and Vygotsky's (1978) theory of the zone of proximal development is obvious. Vygotsky suggested that learners actually have a gap between what they show that they know (the actual level of development) and what they are potentially capable of (the zone of proximal development). He claimed that it is necessary to compare a student's capability to carry out a task independently with the same student's capability to carry out the same task with the assistance of a more experienced person, for instance a teacher or any other instructor. The zone of proximal development can be reached by using scaffolding, i.e., customized help during a task of someone who has a higher level of cognitive abilities and who is part of the social environment of a student. This way, social interaction between learners and more knowledgeable people such as teachers, instructors and parents stands at the basis of learners' cognitive growth.

Van Geert & Steenbeek (2005) and Granott, Fischer, & Parziale (2002) add a dynamic systems perspective to scaffolding, which involves iterativeness and reciprocal effects of teaching and learning. Their perspective deals with what happens with the student's capability level over time, what happens with the scaffold level a teacher shows over time and how these two levels act in relation with each other.

In practice, to do justice to the aforementioned aspects of dynamics during scaffolding, a teacher must pay meticulous attention to pupils' behavior. In so doing, teachers constantly obtain insight in the learning process of their pupils, so they can require a good understanding of what pupils can do without help, what their possibilities are with the help of a teacher, and thus, what level of scaffolding is needed. During scaffolding, teachers gain insight into their own possibilities in providing help to their pupils until the pupils do not need it anymore. For their pupils, the teacher's use of scaffolding techniques is important because it gives them the possibility to work in the classroom independently, and to receive help only in so far as it is needed for them to work again on their own, the moment that they have learned to do the task independently (Mayer, 2004; Palincsar & Brown, 1984).

2.3 General Principles and Practices of Behavioral Change

By applying the aforementioned strategies, namely the use of the empirical cycle, questioning, and scaffolding in their daily practice in the classroom, teachers can help their pupils to reach a high quality of scientific reasoning. In practice, not many teachers already use these strategies in the classroom (Myhill & Warren, 2005; Oh, 2005; Van de Pol, Volman, & Beishuizen, 2010). Therefore, it is necessary to examine what teachers need to learn in order to actually apply them in the classroom, that is, in order to actually and permanently change their behavior such that, as a consequence of this change, the behavior and learning of the pupils will change. Knowledge about the strategies is needed, but knowledge alone is not sufficient to accomplish behavioral change. In addition, regardless of what the content of an (educational) intervention is, general principles or practices of effective behavioral change should be invoked in order to optimize the chance that people actually change their behavior in the desired direction.

This section provides a (non-exhaustive) description of important principles and practices, which were derived from general and educational research on the effectiveness of behavioral interventions. In this section, seven elements that were explicitly addressed in the design of the coaching program are briefly described. Two elements concentrate on the intervention itself, with a focus on content-related knowledge and skills, and the duration of the intervention. Two elements are related with the teacher's learning during the intervention, i.e., the role of intrinsic motivation for teaching and the role of self-regulation, and three elements are used by the coach in the coaching process, namely the use of positive and negative feedback, modelling and reflection.

2.3.1 Focus on content-related knowledge and skills

Interventions will be more effective if they focus on content-related knowledge and skills. That is, the chance that behavioral change takes place is enhanced when an intervention is focused on specific actions that can be changed, i.e., specific behavior and skills that can be defined in advance, and that have a high probability of affecting teachers' and pupils' behavior. This implies that the specific content of an intervention is crucial in the design of an intervention and needs to be addressed instead of focusing on general pedagogical principles only (Garet, Porter, Desimone, Birman, & Yoon, 2001; Harwell, 2003). Teachers in primary education often lack knowledge of the subjects they teach, for instance science and technology. Moreover, they lack not only content knowledge, but also knowledge of the content-related teaching practices, the pedagogical content knowledge (Shulman, 1987), or in other words, the way they can teach the subject in the classroom in a concrete way (Cohen & Hill, 2000; Loucks-Horsley et al., 2010; Smith, 1999). During the design of an intervention, it is important to determine what the content is that pupils need to learn, in order for teachers to acquire this key knowledge. For instance, when a teacher wants to learn how to teach science and technology in lower grades, different knowledge is needed than when a teacher wants to learn how to teach science and technology in higher grades. In lower grades, stressing a key concept like the empirical cycle can be sufficient, in addition to knowledge that teachers already have, for example, about floating and sinking, whereas in higher grades more substantial knowledge has to be added, for example, about air pressure or gravity.

2.3.2 Duration of an intervention

The effectiveness of an intervention depends on its duration. The duration aspect of an intervention consists of two aspects: the period of time during which the intervention is carried out, and the amount of contact hours the intervention takes over that time. Literature suggests that both components of duration need to be extended over time in order to be effective in passing on knowledge and in sustaining changes over time (Garet et al., 2001; Harwell, 2003). However, an exact "tipping point" or ideal amount of time and hours does not exist because this depends on the kind of activities undertaken. The studies show that substantial time is necessary, which can be problematic in schools, because schools do not usually have enough time or money to undertake longer trainings (Veen, Zwart, Meirink, & Verloop, 2010).

2.3.3 Intrinsic motivation for teaching

The effectiveness of an intervention is positively affected by the amount of intrinsic motivation of the persons who undergo the intervention. Intrinsic motivation is the motivation that makes a person perform a certain behavior for its own sake, where the motivation comes from performing the behavior in itself (Brief & Aldag, 1977). Teachers' intrinsic motivation for educating their pupils in general is high, and forms the basis of their vocation for being a teacher (Dinham & Scott, 2004). This makes it an important asset, also because intrinsic motivation contributes to a higher level of instructional behavior (Kunter et al., 2008). Three basic concerns of teachers are relevant for stimulating intrinsic motivation, and therefore need to be addressed adequately, namely, the concern for competence, autonomy and relatedness (Minnaert, Boekaerts, & de Brabander, 2007; Ryan & Deci, 2000; Steenbeek & Van Geert, 2007).

In practice, this intrinsic motivation is under strain because of various kinds of contextual pressures (Appleton, 1999; Goodrum, Hackling, & Rennie, 2001; Pettelier & Sharp, 2009). This strain has as a consequence that many teachers are not - or insufficiently - intrinsically motivated to learn new teaching behavior with regard to, for instance, teaching science. Such lack of motivation can be explained by various factors. The first is that teachers are obliged to carry out many things they have no influence on, for instance, teaching science and technology (Goldspink, 2007). The second element is that teachers often feel they lack the knowledge to teach science and technology in class (Goodrum et al., 2001; Jarvis & Pell, 2004; Palmer, 2002). The third element is that teachers often do not know how to interact with their pupils in order to teach science and technology effectively (Furtak, 2006; Roehrig & Luft, 2004). To ensure high quality teaching, intrinsic motivation needs to be stimulated by addressing the basic aforementioned concerns in order for real behavioral change to occur. In order to reach a balance in these concerns, the concern for competence needs to be addressed during an intervention by giving teachers adequate knowledge and skills for teaching science and technology. The concern for autonomy can be addressed by giving a teacher the possibility to work independently without outside pressure on what to learn himself exactly and what a lesson should look like. Finally, the concern for relatedness has to be addressed by giving a teacher the possibility to give more attention to teacher-pupil interaction.

2.3.4 Self-regulation

Self-regulation is an element that influences the effectiveness of an intervention. Self-regulation is a process which gives a person the possibility to take control of his or her own motivation and behavior with regard to tasks at hand, by being actively involved in the process (Schunk, 2005). The main principles behind the influence of self-regulation are, on the one hand, the issue of self-control, i.e., allowing a person to learn to perform a behavior without external pressure (Bandura, 1976), and, on the other hand, the issue of self-efficacy, a person's belief to perform a particular behavior successfully (Maurer, Weiss, & Barbeite, 2003). Self-regulation in a professional development trajectory is an important condition for its effectiveness because in order to actually learn, a professional needs to have the possibility to have an influence on his or her own learning process (Pintrich, 2000). This is, according to Pintrich, possible by goal setting and by planning activities that are helpful to reach these goals. Both aspects influence behavioral change positively because of the way they give learners the possibility to monitor, regulate, and control their motivation and behavior. Hence, it is of utmost importance that it is the person him- or herself who sets the goals, and not some external influence, such as a school board or a coach.

2.3.5 Positive and negative feedback

The use of feedback contributes to the effectiveness of an intervention. Feedback, in general, is helpful information or criticism that is given to someone, which allows a person to know what can be done to improve his or her performance. Feedback can be positive, that is, giving a positive reaction to accomplishments, strengths, and correct responses, but also negative, that is, giving a negative reaction to lack of accomplishments, weaknesses, and incorrect responses. The question is which of the two is more effective in order to change behavior. The literature suggests both. Bandura & Cervone (1983) and Ryan & Deci (2000) claim that positive feedback is most effective, whereas Carver & Scheier (1998) and Locke & Latham (2006) claim that negative feedback is the most effective. However, participants in any intervention have a need for feedback, positive feedback, as well as constructive feedback on shortcomings (Fishbach, Eyal, & Finkelstein, 2010; Fredrickson, 2009). The first will invoke a pleasant, i.e., positive affect; the latter unpleasant, i.e., negative affect (Diener, 1984). Recent evidence suggests that the combination of positive and negative affect, with a high ratio of positive to negative affect, is more effective in influencing individuals' behavior in the desired direction than positive or negative affect only. Positive affect provides individuals with a positive inclination towards behavioral change (Cacioppo, Gardner, & Berntson, 1999), whereas negative affect, if it is a result of constructive feedback on shortcomings, has a greater positive impact on individuals' actual behavioral change (Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001). Fredrickson (2009, 2013) reasons that a certain positivity ratio must exist where the negative affect of feedback on shortcomings is overcome by the positive affect of positive feedback on desired behavior. Although at present, an exact ratio cannot yet be given, for the time being, Fredrickson (2013) stated that, within bounds, higher positivity ratios are better than lower ones, which implies that a certain, however small, amount of feedback on shortcomings is needed for successful behavioral change to occur.

2.3.6 Modeling

Interventions are more effective if they use the principle of modelling. In the work of Bandura (1971) modelling is described as learning through the influence of examples. However, modelling is a broader concept than imitation per se, as modelling gives a learner the tools to use a similar strategy in a different environment (Tharp & Gallimore, 1988). It can be used in many contexts, such as in the relation between a teacher and her pupils, as well as in the relationship between a teacher's coach and the teacher him- or herself. Both relationships have the same characteristic, i.e., they comprise relationships with scaffolding as a core feature. Moreover, just as pupils learn to explore their zone of proximal development (Vygotsky, 1978) while being scaffolded, the same is true for their teachers. In the process of coaching, the coach should actually apply principles of questioning, the use of the empirical cycle, and scaffolding in his own communication with the teacher, and these actions can be seen as a form of model for the teacher, who can then apply the modelled principles in his relationship with his students. Modelling alone is not sufficient for teachers to use these strategies in practice (Parker & Hess, 2001). However, the combination with other important principles and skills, as described in this paragraph, i.e., questioning, the use of the empirical cycle, and scaffolding without help, should give a teacher enough tools to use.

2.3.7 Reflection

Interventions are effective to the extent that they use reflection. Reflection or reflective practice is a way of looking back on concrete and sufficiently meaningful actions as a way of continuous learning (Paterson & Chapman, 2013). Actions, responses, emotions, and experiences are consciously looked upon during the process of reflection. This knowledge is used to enhance existing knowledge and ideas, in order to create a higher level of understanding (Moon, 2001). Reflection is an important way to bring together theory and practice by considering theory within the context of daily work (Loughran, 2002). Various studies show that the effectiveness of teacher education that is only focused on theoretical instruction is less than the effectiveness of teacher education based upon reflective methods (Harwell, 2003; Noell et al., 1997; Rose & Church, 1998).

The use of video recordings enhances the effect of reflection because it helps to make actual behavior visible (Fukking, 2005; Seidel et al., 2010). Examples of effective reflective programs that use video recordings as a basis are, for example, Video Enhanced Reflective Practice (VERP) (Strathie, Strathie, & Kennedy, 2011) and School Video Interaction Guidance (in Dutch: School Video Interactie Begeleiding) (Van den Heijkant et al., 2004). During a VERP session, video clips in various areas are reflected upon together by a participant and a facilitator or a coach, in order to identify moments that show successful behavior and moments that show areas for development during attuned interaction (Kennedy, Landor, & Todd, 2011, 2015). By using reflection in combination with video recordings, unconscious behavior can be brought to a conscious level (Van den Heijkant et al., 2004).

2.4 Video Feedback Coaching for Teachers (VFC-T)

The aim of this research project was to develop a coaching program for teachers that improves a teacher's skills for stimulating children's science learning, and influences teacher's behavior in order to stimulate pupils' scientific reasoning. In the design of such a program, the principles and practices of effective behavioral change discussed in the preceding sections must be included, as well as the knowledge teachers need in their classroom while teaching science and technology (section 2.2). In this particular case, all previously described elements were combined in the program Video Feedback Coaching for Teachers (VFC-T).

However, restrictions were needed in the design because we wanted teachers to receive a clear and effective amount of knowledge that was also manageable for them. Therefore, from all the available theory, teachers received general information about young children's science and technology talents, as was formulated in the Curious Mind project. In addition, they received information about how teachers can stimulate that talent by using the three strategies of questioning, the use of the empirical cycle and scaffolding. Next, in order to effectively change the behavior of teachers in the classroom, we explicitly included the aforementioned elements that are crucial for genuine behavioral change (section 2.3) in the current *Video Feedback Coaching for teachers* (VFC-T). In 2.4.1., an extensive description of the VFC-T will be given. In order for coaches to be able to provide adequate and effective coaching, they should be given the opportunity to learn about the coaching principles and practices. This opportunity is given in the form of a training program for coaches, which is described in section 2.4.2. This description will pay explicit attention to the links with section 2.3, describing the general principles of effective behavioral and cognitive change in teachers as well as in pupils.

2.4.1 Description of the VFC-T

The VFC-T is designed as an intervention in the classroom that consists of two parts: the theory part and the coaching part. During a short two hour theory session in a small group of co-workers, teachers receive general information about young children's science and technology talents and about how teachers can stimulate that talent by using the three strategies of questioning, the use of the empirical cycle, and scaffolding (as described in section 2.3.1). At the end of the theory session, teachers define their learning goals (section 2.3.4.) for the following coaching trajectory. In this way, the principle of self-regulation and the importance of self-control in goal setting are stressed. Four coaching sessions take place in the four to six weeks following the theory session ('duration', as described in section 2.3.2). Teachers are asked to perform a science and technology activity with a small group of students. A small group is used so that teachers have ample room to use the learned strategies during the activity. The lessons, each lasting about 20 to 30 minutes, are recorded on videotape. The coach is present during the activity and selects video fragments while observing in the classroom. Immediately after the lesson, the teacher and the coach together reflect for about 30-45 minutes on the lesson with the learning goals and the video fragments as a basis (as described in section 2.3.7). Thus, the coaching reflects all the principles as described in the previous section.

In order to give a complete picture of the VFC-T, the following points of concern are additionally described:
An important element of the VFC-T is the use of video material. Some practical considerations need to be taken into account with regard to this element. First, to record video material in the classroom, it is important to have the consent of teachers as well as parents. Secondly, the camera is primarily directed at the teacher, with the possibility to follow the teacher throughout the classroom. However, the configuration should include some of the pupils' actions as well, in order to register the interactions between teacher and pupils because these interactions are important elements of the coaching session that follows the science lesson.

The intensity and duration of the VFC-T is not only defined by the time necessary for the effectiveness, but also by cost effectiveness, i.e., the time schools and teachers can dedicate to this intervention as an application of the principle of optimal intensity and duration of an intervention. Much longer coaching trajectories will most likely be experienced as an additional burden by teachers, who are already overloaded with work, or who at least perceive themselves as being overloaded. The end report of the Pilot Expertisecentrum Talenten-Kracht (2010) and a pilot study with two teachers showed that a number of four coaching sessions sufficed for most teachers to learn the desired skills. The interviews with the teachers afterwards indicated that coaching every week or every other week was necessary for the teachers to experience continuity in their learning process. This indicates that the duration of the intervention varies from five to eight weeks, where the precise amount differs for the teachers, depending on their schedule. Every coaching session starts with a videotaped science lesson in the teacher's own classroom, followed by 30-45 minutes of coaching, in total approximately one hour at a time. A practical problem was that during the coaching sessions, the teachers were absent in their classroom for some time. In the participating schools, a co-worker in school taught the teachers' pupils during this hour, together with his or her own class.

In order to give teachers possibilities for self-regulation during the coaching trajectory (as described in section 2.3.4.), they are asked to formulate one to three personal learning goals preceding the first coaching sessions. Learning goals should be related to the information the teachers had received concerning the use of questioning, the empirical cycle and scaffolding during science class. The coach's feedback is aimed at two kinds of events. The first are the events during which teachers demonstrated that they acted according to their learning goals in the lessons. The second are the instances the goals could be easily reached during the lesson by just slightly modifying behavior during class. An important guideline for the coach is to give teachers enough room to formulate their own learning goals. A pitfall for coaches is to take over this process, where the coach should only support the teacher and eventually make small adjustments. Another opportunity for self-regulation for teachers is that they can choose the science content of their own lessons. Some ideas for possible lessons are given during the introduction session (e.g. www.proefjes.nl), so they have an idea about possible science topics. They are free to choose from the given ideas, but they can also use ideas of their own.

The theory teachers learn, as described in 2.2., and their opportunities for self-regulation are important elements that address a teacher's basic concerns, namely the concerns for competence and for autonomy. In this way, intrinsic motivation (2.3.3.) will be encouraged.

2.4.2 The training for coaches

Effectiveness of a professional development program not only depends on all elements that are included in the program, but also on the way the program is implemented by the coaches. This means that although the theoretical basis of an intervention might be adequate, its effectiveness can be negatively influenced by less sufficient execution of the prescribed activities of an intervention, or by adding intervention activities that were not prescribed (Boelhouwer, 2013; Boomstra, 2014). Treatment integrity, the degree to which an intervention is implemented as intended, should be promoted as much as possible by documenting the intervention and by training of the coaches (Perepletchikova & Kazdin, 2005). For this reason, specific attention should be paid to the documentation of the intervention and to the training of the coaches in the development of the intervention.

Coaches are trained by means of a VFC-T handbook for coaches (Wetzels, Steenbeek, & Fraiquin, 2011) and by providing a two-hour training program four times. In the first two training sessions, this training for coaches includes mainly the acquiring of knowledge and skills needed for a correct implementation of the VFC-T in practice. This includes knowledge about the background of the coaching program as described in section 2.3. and knowledge about the VFC-T as a whole (section 2.4.1). A special focus is on elements that are crucial for the coaching process, namely, the role of positive and negative feedback (2.3.5), modeling (2.3.6.) and reflection (2.3.7) because using these elements is typically the responsibility of the coaches in the coaching process. The skills with regard to working with this knowledge are practiced by using video-recordings of prior coaching trajectories. During the last two sessions, the coaches show videos of their own coaching sessions, which are reflected upon by the whole group of coaches.

2.5 Summary of the Chapter

This chapter gives a description of the design of the VFC-T, as well as of the background it is based upon. Therefore, the general principles in the fields of talent and talent development, learning and teaching and behavioral change that are used in this dissertation are described. The chapter starts with a description of the background of the program and of the way this coaching program is embedded in a nationwide program to stimulate science and technology in children, the Curious Minds project (section 2.1). Subsequently, it described the way in which the general principles of the Curious Minds project (section 2.2) and general principles of behavioral change (section 2.3.) have been implemented in the coaching program. Finally, the coaching program itself is described as well as the training program for coaches (section 2.4.).

The VFC-T, as described in this chapter, is used for teacher professional development with regard to learning how to teach science and technology in the lower grades. Chapters 4 and 5 will provide the results of the effect studies regarding teachers' well-being and teachers' and children's behavioral change when using the program.

CHAPTER 3:

A Complexity Approach to Investigating the Effectiveness of an Intervention for Lower Grade Teachers on Teaching Science

This chapter is accepted as :
Wetzels, A.F.M., Steenbeek, H.W., & Van Geert, P.L.C. (2015).
A complexity approach to investigating the effectiveness of
an intervention for lower grade teachers on teaching science.
Manuscript accepted, pending revision.

CHAPTER 3:

A Complexity Approach to Investigating the Effectiveness of an Intervention for Lower Grade Teachers on Teaching Science

3.1 Introduction

Children who are currently in preschool will enter the labor force around 2030, and will work until their retirement, around 2070. Nobody knows what the world will look like then, but it is likely that in order for children to be prepared for their professional career in the future, they must learn the skills for the 21st-century, namely critical thinking, problem solving, and decision making, among other skills (Binkley et al., 2012). The recognition that teachers play a central role in children's mastering of these skills is a necessary premise to acknowledge when considering interventions in education systems aimed at preparing children for the rapidly changing world (Ferguson, 1991; Grigg, Kelly, Gamoran, & Borman, 2012; Harwell, 2003; Hattie, 2003). This means that teachers need to teach the latest developments in numerous areas to their pupils. This implies that, in order to keep pace with a rapidly changing world, teachers' professional development needs to continue after their formal education. However, much of the professional development that the market offers to teachers could be more effective than it is now (Mayer, 2004; Pressley, Graham, & Harris, 2006). The reason for this lack of effectiveness is not always situated in a poor design of the intervention itself, but rather resides in the multitude of intertwining factors in the complex system surrounding a teacher and his classroom that influence the effectiveness of an intervention (Goldspink, 2007). Moreover, an intervention program can be effective during the intervention period, but the question is if these positive effects are sustainable when the interveners and the support and attention they give to school and teachers disappear. Often the effects disappear relatively soon after the intervention is carried out (Han & Weiss, 2005; Noell et al., 1997).

In this chapter we describe the effectiveness and sustainability of teacher professional development interventions from a complexity view point as well as from a more 'standard' viewpoint. That is, the first aim of this study is to give a theoretical overview of effective aspects of interventions regarding teachers' professionalizing using recent literature. The second aim is to re-interpret effectiveness and effectiveness studies using a complexity approach. The third aim is to empirically illustrate a complexity approach to the effectiveness of interventions using a multiple case study (Hetherington, 2013).

3.2 Explaining the Effectiveness of Interventions Aimed at Teachers' Professional Development

3.2.1 Professional development

Professional development for teachers is a continuous process of professional growth (Day, 1999; Evans, 2002; Keiny, 1994) that is necessary for them to learn to use the knowledge acquired in teacher training in practice, and, after that, to keep up with developments in society. After initial teacher training, the first part of professional development consists of the experience a new teacher gains at his or her job. Already in 1938, Dewey observed that this increase in experience alone did not necessarily result in more sustained knowledge or sustained better teaching. Unsurprisingly, the learning curve of teachers rapidly declines after the first few years (Barth, 2004). To keep the learning curve constant, teachers are provided with an overwhelming choice in professional development activities (Hattie, 2009). However, it is likely that most training opportunities are not effective in creating sustained improvement of teacher effectiveness because they are not in line with teachers' motivational and intellectual requirements (Day, 1999; Imperley et al., 2007).

The criteria for the effectiveness of a professional development intervention for teachers are not unambiguous (Guskey, 2003). For this paper, we use a classification applied by Garet, Porter, Desimone, Birman, & Yoon (2001) and Desimone (2009). According to this classification, teachers' change in knowledge and attitudes, teachers' change in behavior in the classroom, and pupils' results are the three elements that provide indications for the intervention's effectiveness (Desimone, 2009; Garet et al., 2001). Obtaining these goals in the long run, and thus providing an effective and sustainable intervention depends not only on the intervention itself, but also on whether the intervention has been successfully implemented (Durlak & DuPre, 2008; Harwell, 2003; Noell & Gansle, 2009). It is essential that intervention results endure after the interveners leave the school. Unfortunately, the effects of interventions tend to disappear relatively soon after the intervention is carried out (Han & Weiss, 2005; Noell et al., 1997). What, in addition to the quality of implementation, does the available literature tell us about the main aspects that have an influence on the effectiveness of professional development interventions?

3.2.2 Important aspects of a professional development intervention

Teachers are highly critical consumers of professional development activities. Day (1999) states that professional development for teachers "is not simply a cognitive process … it demands emotional commitment. It will involve the head and the heart" (p. 47). Garet et al. (2001) and Desimone et al. (2009) make a distinction between various types of aspects that positively contribute to the effectiveness of an intervention. The first are properties of the intervention itself, the intervention-specific aspects. The second type of variables relate to the teacher as a person, and the third relate to the school organization within which a teacher works, i.e., the school context (Han & Weiss, 2005). In addition to these variables, we must distinguish aspects of implementation quality.

3.2.2.1 *Intervention specific aspects*

Interventions are characterized by three structural and three substantive characteristics (Armour & Yelling, 2004; Birman, Desimone, Porter, & Garet, 2000; Garet et al., 2001). Structural elements are form, duration and collective participation (Garet et al., 2001). As for form, traditional forms of education, such as workshops and external trainings without follow-up in the classroom, are not as effective as training within the school or classroom with a connection to the teaching practice (Fabiano et al., 2013; Goldenberg & Gallimore, 1991; Loucks-Horsley et al., 2010). Teacher training in combination with direct performance feedback produces the strongest training effect (Noell, Witt, Gilbertson, Ranier, & Freeland, 1997; Rose & Church, 1998). The duration aspect can be understood in two ways: the period of time over which the intervention is spread, and the amount of contact hours. Literature suggests that both components of duration need to be extended over time in order to be effective in passing on knowledge and in sustaining changes over time (Garet et al., 2001; Harwell, 2003), although schools often do not have enough time or money to undertake longer trainings. Collective participation, i.e., participation by a group of teachers from the same school, is also a positive structural aspect of interventions that allows teachers who work together to share learning experiences, so they can integrate their new learning experiences with their own school background and curriculum (Garet et al., 2001; Harwell, 2003).

As regards the substantive elements in an intervention, first, there must be a focus on content. Teachers often lack subject matter knowledge, including the related teaching practices in specific content domains, together known as the pedagogical content knowledge (Shulman, 1987). When comparing interventions based on general pedagogical knowledge, or on content knowledge, or on pedagogical content knowledge, the literature shows more positive effects on students achievements when the education activities are focused on the pedagogical content knowledge (Cohen & Hill, 2000; Loucks-Horsley et al., 2010; Smith, 1999), apparently because the latter gives teachers more concrete ideas for their lessons. Secondly, the intervention needs to be based on active learning, by means of reflection on the way a subject can be taught in the classroom, such as discussion and dialogue. In this way, the participating teachers obtain opportunities to practice what they learn in the classroom and discuss it with a colleague or a coach (Harwell, 2003). Finally, coherence with other learning activities is necessary (Garet et al., 2001) so that something learned can be integrated with a range of activities within a school.

3.2.2.2 *Teacher specific aspects*

To begin, teachers' sense of self-efficacy is important for their level of openness to new ideas (Berman, McLaughlin, Bass, Pauly, & Zallman, 1977; Durlak & DuPre, 2008). In addition, teachers should feel the need for using the learned content in their own classroom (Harwell, 2003), and they should feel intrinsically motivated to use the new practices in their daily routines because teachers' intrinsic motivation is very often the basis from which they started teaching (Dinham & Scott, 2004). Humans in general are basically in search for self-motivation and self-development since these aspects contribute to human well-being (Deci & Ryan, 2002; Diener, 1984).

When performing a school intervention, it must be kept in mind that attempts toward changing teachers' habits and behaviors can be a threat to teachers' intrinsic motivation in the classroom. More specifically, it is important that teachers' basic concerns (Frijda, 1986), namely autonomy, relatedness and competence (Minnaert et al., 2007; Ryan & Deci, 2000; Steenbeek & Van Geert, 2007) should not be threatened. Autonomy plays a role in that teachers should feel like they can make their own decisions concerning when an intervention is carried out at a school. Secondly, teachers often feel like they lack the competence to act the way they are expected to during the intervention (Goodrum et al., 2001; Jarvis & Pell, 2004; Palmer, 2002). Primary teachers take a general degree in teaching; consequently they do not have content knowledge of specific domains such as science, which can result in feeling uncomfortable during professionalization courses aimed at teaching science to young children, for instance. And finally, teachers need to feel connected with colleagues and pupils when teaching, especially in a period when things change in their classroom.

3.2.2.3 *Context specific aspects*

Changes in teachers' behavior do not occur in the vacuum of the classroom only. Various political, bureaucratic and systemic factors influence teachers' adaptation to new working methods in schools (Adelman & Taylor, 2003; Goldspink, 2007). In this study, we shall confine ourselves to the school specific factors because these factors can be addressed directly during an intervention. They include organizational support in training, for instance, extra time for study, practice and reflection on each other's practices with co-workers, as well as supervision and support by the school principal during the intervention's implementation and afterwards (Fullan, 2007; Gottfredson & Gottfredson, 2002). Once external support from trainers or researchers ends, the school system should be ready to integrate the elements of the intervention in the existing practices. All levels of an organization, i.e., the classroom level, the teacher team level, and the level of the school board should work together in order to create sustainable change (Coburn, 2003; Goldspink, 2007). Shared decision making regarding the intervention is an aspect that adds to a better implementation (Durlak & DuPre, 2008). If the intervention focuses on a group of teachers from the same school, it can promote teachers to work together, share mutual experiences, and find solutions to joint difficulties in the new way of working (Loucks-Horsley et al., 2010).

3.2.2.4 *Aspects regarding implementation*

As Boomstra (2014) describes, implementation (i.e., realizing the intervention) is an important aspect to consider when assessing the effectiveness of an intervention. The theoretical basis of an intervention can be adequate, but the effectiveness can be negatively influenced by less sufficient execution of the intervention, or even by intervention activities that were never prescribed. Gearing et al. (2011) described four elements that contribute to minimizing the distance between the theoretical basis of an intervention and the delivery of components of the intervention in real practice: 1) a good intervention design and protocols, 2) good intervention training, 3) sufficient monitoring of intervention delivery, and 4) sufficient monitoring of intervention receipt. These four components also need to be taken into account when designing an effective intervention. In addition, treatment integrity is an important aspect that greatly contributes to successful interventions. Treatment integrity is the extent to which an intervention is implemented as it was designed. When an intervention is not provided by trainers as intended, whatever effects occur will not be due to the intervention as such (Noell, Gresham, & Gansle, 2002). Documentation of the intervention, for example, can assure treatment adherence, whereas training of the trainers according to the documentation can assure their competence in providing the intervention as intended (Perepletchikova & Kazdin, 2005).

In fact, models that describe the effectiveness and sustainability of teacher professional development interventions from a standard viewpoint assume that a linear addition of all these factors can explain the effectiveness of an intervention in general. This might be true if a model is viewed as a purely statistical statement. That is to say, if the individual and temporal aspects of the intervention process are not taken into account, the effectiveness of an intervention across contexts and occasions can indeed be “explained” on the basis of how it combines and implements the elements discussed in the preceding section. However, the actual performing of an intervention in a concrete context cannot be modelled as a sum of the variables (Molenaar & Campbell, 2009). First of all, the actual performing of an intervention in a concrete context is a process taking place in time. Second, it is a process taking place in a particular context, with specific individuals and people who carry out the treatment. Third, it is a process taking place in a complex system, namely, a system of intertwining teacher, child, school, cultural and community variables. It is highly likely that the statistical model emerging from sample-based effectiveness studies - which is a linear additive model - does not apply to the individual and complex processes of performing particular interventions. The point discussed in the next section is that understanding intervention effectiveness requires a complexity point of view in order to capture the temporal and idiosyncratic aspects of interventions. Nonetheless, it is important to make a distinction between designing an intervention, and performing an intervention. While designing an intervention, one can use the standard statistical model of effective components as a partial guideline. However, this is only a partial guideline in the sense that the designer of the intervention should be aware that performing the intervention will take place in a complex dynamic system with many intertwined and dynamically changing processes that are likely to be highly idiosyncratic, and in which the researcher inevitably becomes an embedded component, even if the researcher is not carrying out the intervention him or herself (Van Geert & Steenbeek, 2014). In the next section, we shall try to redefine teachers' professional development using a complexity approach.

3.2.3 Teachers' professional development: a complexity approach

Looking at professional development as a simple cause-and-effect process does not do justice to the complexity of functioning as a teacher in a specific school context, and to the complex world in which teachers function (Goldspink, 2007; Opfer & Pedder, 2011). Complexity research reasons that various "forces" within a person and within society act simultaneously and mutually to contribute (or not) to behavioral change. In this way, these "forces" contribute to the extent that teachers learn and develop as a result of an intervention, and to all the processes that the intervention brings about during its deployment and afterwards. The individual teacher and his or her classroom behavior can be seen as such a complex dynamic system in itself.

A complex dynamic system is a system consisting of many interacting elements or components that change each other's properties and consequently show self-organization, the emergence of self-sustaining states and patterns of states (Goldspink, 2007; Jörg, 2011; Van Geert & Steenbeek, 2010). This means that various influences occur that become coordinated and that explain the changes and stabilities in the individual teacher‘s learning process over time (Steenbeek & Van Geert, 2013). These influences are very diverse, and range from the teacher's own previous experiences with activities aimed at professional development to a teacher's work load, the external pressure a teacher experiences in the form of inspection reports and standardized school performance tests, and the importance a teacher assigns to the content to be learned. In short, the teachers' professional learning emerges out of the teacher-context dynamics.

Most current research in developmental psychology recognizes the importance of studying human learning and development in context (Van Geert, 2009). However, this context is usually seen as an independent and distal variable, e.g. as in studying the statistical association between the kind of school and the academic performance of children (Van Geert & Steenbeek, 2005). Using a complexity approach perspective, it is important to examine the context as a proximal, dynamic factor, meaning that the context is continuously created by the actions of the participants, and that the actions of the participants are continuously determined by the created contexts. According to the complexity approach, context and person influence each other, as there is a "reciprocal determinism" between the two (Steenbeek & Van Geert, 2007). In this case, the school context in which the teacher functions must not be considered as a stable context, but as a dynamic one, which changes itself over time in association with the changes in the teacher(s) and many other components of the student in the school system.

An intervention or activity aimed at improving the teacher's behavior can be regarded as an important component that changes the context in which the teacher functions, and acts as a kind of "perturbation" of the complex dynamic system of school-student-teacher relationships. Given the mutuality of person and context, it is also clear that the exact way in which a particular intervention unfolds is not independent of the reactions of the teacher to the intervention, or of the teachers' input in the intervention. The teacher's 'simplex system', i.e., the teacher's connected set of beliefs, representations, values, emotions, habits, practices and material tools plays a central role in this process. This 'simplex system' serves as a simplifying representation of the overarching complex system in which a person participates, and organizes the participants' actions (for more information about the notion of 'simplex systems', we refer to Van Geert & Steenbeek (2014).

That is to say, even if we guard the faithful implementation of a particular intervention, its concrete form over time will unavoidably be influenced by the teacher(s) and by the effect the intervention has on the teacher(s) and other significant parts of the school context. At the same time, the intervention changes the teacher as a learning individual as well. In this process of change, it is important to examine the *fit* between a specific intervention with a specific teacher in a specific context with a specific provider of the intervention. This fit is not only an idiosyncratic process, which means that the outcome is specific for this specific individual (or specific team of teachers), but also a dynamic process, in that it changes as a result of the interactions.

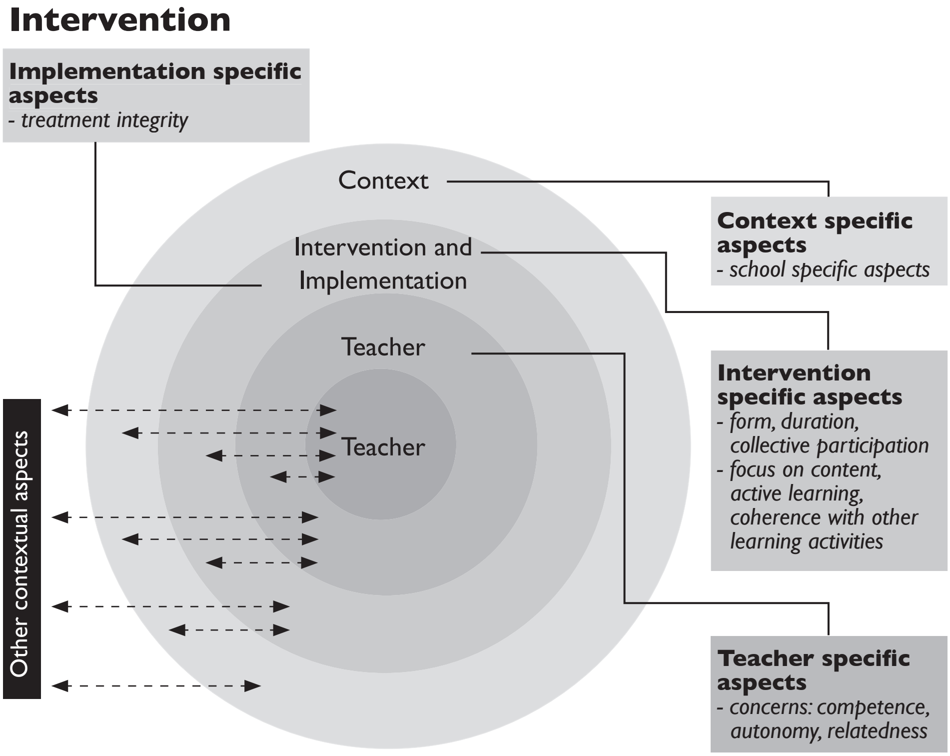
With regard to the effect of interventions for teachers in a specific school context, this means that the (above described) intervention-specific aspects, teacher-specific aspects, context-specific aspects and aspects regarding implementation interact and combine in various ways, in such a way that a particular intervention can have multiple outcomes, dependent on the dynamics of the specific context-teacher relationship. The fact that average results can be seen for a particular sample or population of individuals does not imply that this average result is true for each member of the sample or population (Jarvis & Pell, 2004; Rose, Rouhani, & Fischer, 2013). In order to understand how and to what extent interventions work, they should be studied in the context of actual intervention processes taking place in individual teachers (Barlow & Nock, 2009; Molenaar & Campbell, 2009). In fact, what counts is the way in which the teacher assimilates something that is in principle a perturbation of the ongoing daily process, namely the intervention. The assimilation can take several dynamic forms. For instance, it may be the starting point for a positive change cycle. It may also cause resistance and changes that actually compensate for the attempt to change the current attractor state, etc. Thus, from a complexity view point, implementation is the effect that the introduction of the perturbation (in this case the intervention) has on the current state of the 'teacher's system'.

As can be seen in figure 2, a reciprocal influence exists between a teacher and every single group of aspects that plays a role in the intervention. This figure illustrates how a teacher and all aspects influence each other during the intervention. The arrows show how the teacher and all aspects influence each other. This figure stresses the importance of the fit between a teacher and each single group of aspects in order for an intervention to be (more or less) effective for a particular teacher. Secondly, the figure stresses the fact that influences exist between the teacher and all the different aspects at the same time, and that the influences are not one-directional, but multi-directional.

Thirdly, figure 2 shows that, when describing a concrete, locally situated intervention in a complex dynamic system, it is difficult to explain the effective aspects in isolation. In a complex dynamic system, these groups of aspects, for instance, context based and teacher specific aspects, are all intertwined during the actual process of an intervention, and the effectiveness for an individual teacher dynamically emerges from this interaction.

This implicates that, when conducting an intervention study, researchers should take into account that the separate aspects are important, but also that all these aspects are intertwined in a real world situation. This means that the combination of both approaches is meaningful. On the one hand, the standard sample-based average effect of the intervention with various aspects as largely independent variables contributing linearly to the statistical group effect can inform us about the net effect of an intervention for a particular group or population, and is typically important for the level of policymaking. On the other hand, the case-based dynamic understanding of how the actual intervention process leads to a particular result for a particular person (or for a particular school or team of teachers) is typically important for the level of actual intervening, i.e., this approach provides information about how actual interventions can be carried out and adapted within the limits of implementation integrity. In the third main section of this paper, we shall now illustrate the importance of both approaches by describing a multiple case study, in which two primary school teachers participated in an intervention aimed at teachers' professional development, especially with regard to improving the quality of their science lessons.

Figure 2 | *An intervention using a complexity approach*



3.3 Empirical Illustration: The Design of a Science Teaching Intervention and its Effects, Using a Complexity Approach

3.3.1 Theoretical background

Various studies have shown that an important determinant for young students' success in science education is the students' curiosity, a quality that young children start with naturally (Jirout & Klahr, 2012; Loewenstein, 1994). However, once young children go to school, this curiosity seems to vanish. Engel (2009) observed that teachers hardly encourage inquiry and curiosity in the classroom. This lack of stimulation might explain the diminishing interest in learning science in the first school years of children (Osborne et al., 2003). This finding implies that it is important to start from the early school years on with encouraging children's natural curiosity and scientific reasoning, and thus, with acquiring positive science experiences. Teachers play a significant role in providing these positive experiences, and therefore it is important to design and implement professional development trajectories aimed at improving teacher's knowledge, skills, and attitudes in teaching science.

In our study, the goal was to design an intervention for improving the quality of teachers' science teaching, based on principles from (School) Video Interaction Guidance (Kennedy et al., 2011; Van den Heijkant et al., 2004), The aim of the intervention was to enable lower grade teachers, without preliminary experience in teaching science, to teach science in their own classroom by carrying out small scientific experiments. Our hypothesis was that in the concrete situation of each particular teacher, the effective aspects would work together in a specific way, and in fact amplify each other to produce a specific effect of the intervention. We also assumed that these processes of self-amplification or self-reduction are likely to be highly idiosyncratic, and thus will show high inter-individual variability. We expected that there would be an effect of the intervention in each particular teacher, but that this effect would greatly differ between the teachers due to the idiographic process, i.e., specific interplay of the intertwining aspects within each teacher.

3.3.2 The content of the intervention

When developing the intervention, we started from the following basic assumptions. The first assumption is that children are curious about their environment. The second assumption is that teachers have some knowledge of basic science principles, for instance, of floating and sinking and gravity. This implies that it should be possible for teachers to start with simple experiments in the classroom that do not require specific teacher training. The emphasis of the intervention was not on scientific content knowledge, but on pedagogical content knowledge in science lessons (Smith, 1999). Teachers needed to learn and experience how to enhance children's curiosity and scientific reasoning during these lessons. Therefore, teachers received information about questioning (Oliveira, 2010), about the empirical cycle, and about scaffolding., in a two hour theory session. Scaffolding (Granott et al., 2002; Mattanah, Pratt, Cowan, & Cowan, 2005; Van Geert & Steenbeek, 2005) was explained as a way of helping pupils to reach a higher level than they could reach on their own by being given parts of the solution to a problem. The aim of scaffolding is that pupils ultimately can give solutions independent of a teacher's help. The empirical cycle (De Groot, 1961) was explained as a five step inquiry scheme to provide structure to a science lesson with steps that stress asking a research question, hypothesizing, designing a research model, observing and explaining the observed result.

After the theory lesson, teachers prepared a science lesson four times to be given in their own classroom with a small group of children. Each lesson was recorded on video. Afterwards the coach selected relevant video fragments with a focus on teacher questioning, the use of the empirical cycle, and scaffolding in the interaction with the children. These fragments were reflected upon by teacher and coach together using the principles of Video Enhanced Reflective Practice (VERP) (Kennedy et al., 2011). The focus of the coaching sessions was to enable the teacher to discover in interaction with the coach, how to change behavior by discussing fragments that were representative of the teacher's behavior.

3.3.3 The design of the intervention

In section 2.2. some important aspects were specified that contribute to the effectiveness of an intervention and the way these aspects can best be addressed. The next sections describe how these aspects were incorporated in our science teaching intervention.

3.3.3.1 *Intervention specific aspects*

The form of the intervention was designed as training within the classroom with elements that have proven to be effective, as there is a direct connection between the teaching practice (Loucks-Horsley et al., 2010) and the use of direct performance feedback (Noell et al., 1997). The duration of the intervention was defined by the total period of time in which the intervention sessions were given and the amount of contact hours. The intervention lasted five to eight weeks. Every coaching session consisted of a science lesson of 20 to 30 minutes in the teacher's own classroom, followed by 30-45 minutes of coaching. This duration was defined by a combination of time and cost effectiveness. Because of the importance of collective participation, we started by asking schools for all teachers of the lower grades to participate. This requirement seemed virtually impossible to meet, but as there were three participants in one school, and four participants in the other school, it gave teachers the possibility to share their experiences. The focus in the intervention was on improving teachers' pedagogical content knowledge, by means of active learning. That is, during the four lessons with subsequent coaching, teachers were given the possibility to put the learned framework into practice and to reflect on their own lesson with the help of a trained coach. Moreover, the focus was on coherence with other learning activities. This aspect was not incorporated in the design of the intervention, although schools usually volunteered for participating because they viewed science as an important topic in the school curriculum. Thus, a broader interest in the topic implicated that more activities regarding science lessons are already being undertaken at the school, although not necessarily in coherence with other learning activities.

3.3.3.2 *Teacher specific aspects*

The teacher specific aspects were addressed by taking teachers' concerns (autonomy, relatedness and competence) into account, so that teachers could feel more intrinsically motivated to use the newly learned content.

Firstly, the teachers' competence concern was addressed by presenting the teachers with an interactive lecture on the knowledge they need when teaching science. The aim was to let teachers experience that they already possessed enough content knowledge to teach science to young children, e.g. about floating and sinking, gravity and air pressure experiments. Furthermore, during the video coaching, the coach addressed not only learning points, but also showed the teachers video shots, in which the teacher showed very competent behavior.

The autonomy concern was addressed firstly by letting teachers voluntarily participate in the intervention. Schools were asked to include only teachers who were enthusiastic about teaching science and who wanted to learn how to improve their teaching skills at this topic. Furthermore, participating teachers were asked to teach science lessons of their own choice in their classroom during the trajectory. Moreover, teachers were asked to formulate their own learning goal, as autonomous goal setting allows them to be responsible for their own learning trajectory and leads to better results in the process of behavioral change (Koestner, 2008).

As for the relatedness concern, we asked schools to let more than one teacher of one school team participate, so that these teachers could experience and discuss the theory session together. In addition, the improved questioning and reacting to pupils contributed to the relationship between teacher and pupil.

3.3.3.3 *Context specific aspects*

Only school specific factors were included in the design of the intervention because they could be addressed directly. Organizational support in training, for instance, extra time for study and practice, and supervision and support by the school principal during the intervention's implementation and afterwards, were important activities within the design. School principals were asked to endorse the starting points of the intervention, to agree with the time the intervention would take, and to support their teachers by providing substitute teachers in the class during the coaching sessions. The principal and the colleagues who did not participate in the intervention also had the opportunity to attend the theory sessions, so that all teaching staff had the same level of knowledge, even though not everyone participated in the overall coaching program. In school A, three teachers participated in the coaching program, and in school B four did, which made the sharing of mutual experiences possible.

3.3.3.4 *Aspects regarding implementation*

The intervention as a whole was clearly documented. A manual of the intervention was made available to enable dissemination of the intervention to other trainers and to ensure treatment integrity (Wetzels et al., 2011).

3.4 Studying the Effect of the Intervention Using a Complexity Approach

The following multiple case study is part of the effect study that was conducted in order to examine the effectiveness of VFC-T, the coaching program for teachers supporting the teaching of science in the lower grades. The aim of this case study was to illustrate how, in the concrete situation of a particular teacher, the effective aspects work together in a specific way, and in fact either amplify each other or reduce the influence of the intertwined aspects to produce a specific effect of the intervention. We also assume that these processes of self-amplification or self-reduction are likely to be highly idiosyncratic, and thus will cause high inter-individual variability between teachers.

3.4.1 Participants

Two teachers participated: Laura (age 46, teaching experience 23 years) from school A and Anne (age 53, teaching experience 22 years) from school B. Both teachers were representative of their co-workers in the same school as classroom teachers of pre-schoolers (age 4-6), and had almost the same knowledge of science and science education as well as experience in teaching science. For the coaching trajectory they each chose four children from their class, children they considered representative for the whole class with regard to their age, performance level, and ethnic background. The pupils' age ranged from four to six years, and none of them were from an ethnic or cultural minority because in the part of the country where the study was carried out the number of children of ethnic or cultural minorities is relatively small.

3.4.2 Data collection, variables and analyses

The study uses a mixed method, combining quantitative and qualitative analyses (Creswell & Plano Clark, 2011). Data were collected by using video recordings of the classroom activities, which were captured with two digital camcorders, one focusing on the teacher, and the other one on the participating pupils. Afterwards, the video recordings were coded, using a coding scheme for the variables “amount of questions” and “level of reasoning”.

Two coding schemes were developed for coding teachers’ (Wetzels, Steenbeek, & Van Geert, 2015) and pupils’ utterances (Wetzels, Steenbeek, & Van Geert, 2015). The coding scheme regarding teachers’ utterances was operationalized as the variable ‘teachers’ scientific reasoning eliciting questioning’ (TSEQ), and it was developed using literature that stresses the importance of questions regarding the empirical cycle for science learning (De Groot, 1961; Dejonckheere et al., 2009; Engel & Randall, 2008; Oliveira, 2010). All questions were selected and coded, if possible, in terms of the steps of the empirical cycle. (see section 3.2): ‘knowledge questions’, ‘prediction questions’, research design questions’, ‘observational questions’ and ‘questions about the explanation’. Additional categories of questions were: ‘follow up questions’, ‘other questions relating to the content’, and ‘other questions’.

The coding scheme (table 1) regarding pupils’ utterances was operationalized as the variable ‘pupils’ level of reasoning’ (from now on PLS), and is based on skill theory (Fischer & Bidell, 2006). It describes the cognitive level in pupils’ utterances on an interval scale, according to the complexity level. For each lesson, which lasted about 20-30 minutes, the highest level one of the pupils reached was coded per minute, and subsequently the mean score for each lesson was calculated. When children said nothing during a minute, it was coded as zero because in this case the teacher did not elicit children’s reasoning at all. At the least complex level we coded a 1. A 2- 5 code indicated increasing complexity. (Meindertsma, Van Dijk, Steenbeek, & Van Geert, 2012; Rappolt-schlichtmann, Tenenbaum, Koepke, & Fischer, 2007))

Table 1 | *Coding scheme for pupils' level of scientific reasoning (PLS)*

Code	Complexity level	**Description**	**Example**
0		No answer is eclicited by the teacher	
1	Sensorimotor mapping	Child observes characteristics of an object	This is a blue pencil
2	Sensorimotor systems	Child states a relationship between action and result	The pencil floats because you placed it in the water
3	Single representation	Child refers to one part of the explaining mechanism	The pencil floats because it is small
4	Representational mapping	Child refers to two or more parts of the explaining mechanism	The pencil floats because it is small and light
5	Representational system	Child refers to all explaining mechanisms	The pencil floats because it is light for its size in the water

Differences between pre- and post-intervention and pre-intervention and intervention lessons for each individual case were analysed using Monte Carlo permutation analyses (Todman & Dugard, 2001), a non-parametric permutation test, particularly suitable for small sample sizes. The probability that results are caused by chance alone was estimated by simulating the chance-alone condition. This simulation is done by randomly shuffling all results a numerous times (1000 or more). The original result is then compared with the distribution of the results obtained by the random model, using a *p*-value of .05, to determine the probability of whether the observed result for each particular teacher might be due to chance alone.

After the last post-intervention, the participants were interviewed by using a semi-structured interview technique. Questions focused on the way the teachers had experienced the coaching trajectory and on the changes the teachers observed regarding their own behavior and regarding the children in the classroom.

3.4.3 Results

3.4.3.1 *Quantitative findings - TSEQ and PLS*

The results of Laura (as represented in figure 3a) show that the amount of TSEQ increased significantly after the two pre-intervention lessons and the theory session. This higher amount of TSEQ stayed at a higher level during the four coaching sessions (*p*=0.02). However, it dropped sharply two months after the coaching sessions, during the post-intervention lessons, which implies that no statistically significant results were seen in the longer term (*p*=0.50). With regard to the variable PLS (figure 3b), a significant increase was found during the coaching lessons (*p*=0.02) in comparison with the two pre-intervention lessons, and this higher level was continued during the post-intervention lessons (*p*=0.03).

On the contrary, with Anne (figure 4a and 4b), no significant changes occurred during the four coaching sessions, nor two months after the coaching sessions, during the post-intervention lesson, both regarding the amount of TSEQ (short term *p*=0.87, long term *p*=0.69) and the PLS (short term *p*=0.89, long term *p*=0.77).

In the interview, both teachers were positive about the form of the intervention in that they gave the intervention a very positive rating (Anne gave a 7, Laura gave a 8 on a scale of 1-10). However, the quantitative variables show a high amount of inter-individual variability with regard to the teachers' questions, and the pupils' 'level of reasoning'. Presumably related to the differences between the teachers, Anne shows a higher amount of intra individual variability than Laura.

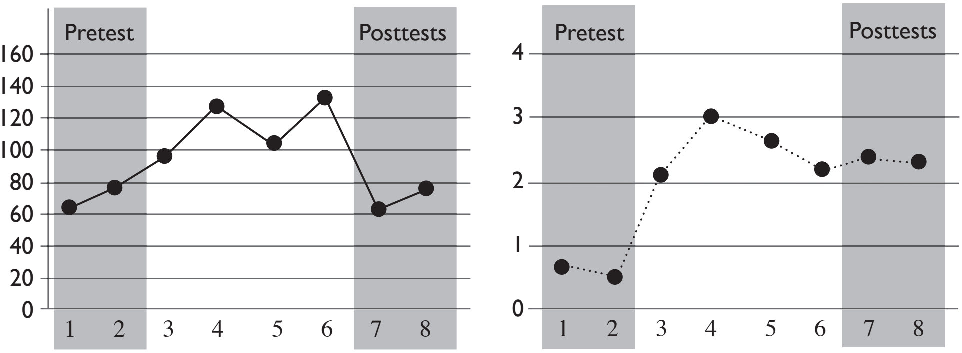
3.4.3.2 *Comparison of the two trajectories regarding the influencing aspects and the intertwining between them*

In the following section we qualitatively describe (by giving examples) how all aspects have an influence on the effectiveness of the intervention in the multiple case study, not only alongside each other, but also intertwiningly influencing each other, using the interview data of both teachers.

The science teaching intervention was designed with several effective aspects incorporated (section 3.3.). The intervention-specific aspects, both structural and substantive, were the same for both teachers, as well as the treatment integrity, as the coach was the same for both teachers and used the same documentation.

Some examples of differences between the two trajectories can be clearly observed: for instance, the difference regarding the fit between school and intervention. Laura recognized that the intervention fit extremely well with the cornerstones of her school's teaching, namely the Reggio Emilia approach (Edwards, Gandini, & Forman, 1993). One of the aspects in the coaching program was scaffolding, requiring a fit with the level of the child and providing specific attention to each individual child. This manner of working with specific attention for individual children is a key feature of the Reggio approach, and Laura was happy to see how both merged together. That is to say, important content aspects of the school background and of the intervention were clearly consistent with one another, which might have resulted in amplifying Laura's enthusiasm. On the contrary, in Anne's school, science was an important subject; however, most teachers in that school were not required to participate in the science program themselves, since the responsibility was given to a specially appointed science teacher, which likely led to self-reduction. That is, Anne felt like the coaching did not help her with the regular teaching, probably did not see any result that she considered valuable, and most likely, for this reason, concluded that the coaching required too much of her time, as she repeatedly said during the interview.

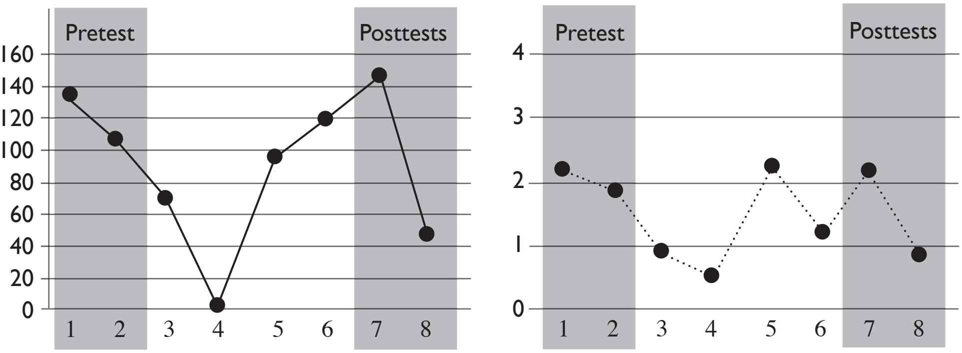
Figure 3a + 3b | *Results Laura*



3a. Amount of empirical cycle questions

3b. Mean level of reasoning pupils

Figure 4a + 4b | *Results Anne*



4a. Amount of empirical cycle questions

4b. Mean level of reasoning pupils

Regarding the teacher specific aspects, clear differences between the teachers could be seen with regard to feelings of competence and autonomy. During the pre-intervention lessons, Laura did not feel competent in teaching science, but she wanted to gain more knowledge and skills on this subject. She was very critical at the start of the theory session, but she became increasingly enthusiastic, and she understood the advantages of teaching science in this challenging way. On the contrary, Anne had some experience with science education, but primarily with the science coordinator giving science lessons in her classroom. During the theory lesson she mentioned that she wanted to help with the research, but that she felt she already knew enough about science teaching, although she had never put this knowledge in practice herself. This indicated a clear difference in the fit between the intervention and the teacher's simplex systems (see: Van Geert & Steenbeek, 2014).

Regarding their feeling of autonomy, it was clear that Laura was positive about the opportunity to participate: "Our principal told us about the opportunity. And the topic seemed very interesting to me and my colleagues, so we said yes". In contrast, Anne's answer was: "Oh, we had to do this. All the other colleagues said no, and someone had to participate. And then I said yes, but it took much more time than I expected". In fact, it seems that Laura's decision was based on the content of the program, and enhanced her feeling of autonomy, whereas Anne decision was not content-based, and even seemed to threaten her feeling of autonomy.

Furthermore, both teachers set their own learning goals. During the interview, Laura said : "the most important learning goal for me was to hold myself away from talking and answering, and give the children room for their answers. And I do much better at this now". She could still recall her learning goal two months later, and could describe what she had learned. Anne could not recall what her goal had been. In her own word: "it was such a long time ago". Stated in terms of concerns, Laura seems to address her basic concerns through the coaching. On the contrary, Anne very clearly explained that the coaching did not address any of the concerns she finds interesting, in the sense that she complained about the amount of time it required, without identifying any feeling of positive results (the concern that she expressed was an external concern, namely the willingness to participate in scientific research, not the concern of changing her own competence) (Steenbeek & Van Geert, 2013).

Regarding the school-specific aspects, two aspects show clear differences between Laura and Anne, namely the nature and extent of the school support and the school wide approach. In Laura's school, the principal was involved in the process of teaching science. The principal wanted the school to participate in the intervention research because she intended to start with a few teachers in the lower grades, and to eventually extend this to the rest of the teachers in the school. To express her commitment and make this observable within the organization, she participated in the theory session and in the discussion on teaching science that emerged during that session. She ensured that teachers would have time to participate and that their pupils would be taken care of during the intervention time. Laura and her co-workers felt supported and they understood how important the intervention was for the future of the school. In contrast, in Anne's school, the teachers participated in the research project because the science coordinator asked them to. The school principal did not know about it, and during the theory session the teachers participated alone, without the science coordinator or the principal. During the coaching sessions, Anne's replacement in the classroom was taken care of, however Anne felt the trajectory took too much of her time.

Regarding the school-wide approach, the general idea at both schools was that in the end all teachers would learn how to teach science. In Laura's school, all four lower grade teachers participated, because the principal had asked them to be an example for the upper grade teachers, who would follow the trajectory at a later time. The principal had asked them in advance to think of a way to communicate the learned content to their upper grade colleagues at the end of the coaching program in order to inspire them too for the science teaching program. In Anne's school on the contrary, only three of six lower grade teachers participated, and no plans were made regarding whole school dissemination.

In the previous section, the intertwining of different aspects shows that in the case of Laura, she was enthusiastic about the intervention because its goals fit with the school's Reggio Emilia approach, the principal was enthusiastic, as well as her co-workers. Her personal concerns, school specific aspects and intervention specific aspects worked intertwiningly together in a positive spiral to produce a relatively positive result. However, in the case of Anne, the intertwining of aspects unravelled very differently, i.e., she was not enthusiastic nor was her principal, which led to a relatively negative result

3.5 Discussion

The aim of this article was to give a theoretical overview of effective aspects of interventions regarding teachers' professionalizing, to re-interpret the effectiveness of these aspects from a complexity view, and to illustrate this complexity view with a multiple case study. We have shown in these two cases that intervention specific aspects, teacher specific aspects, context specific aspects and implementation specific aspects intertwine, and act as a complex dynamic system. From a complexity view, we focus on an interaction-dominant analysis (Van Orden, Holden, & Turvey, 2003) of intervention effects, which entails the analysis of how these adjacent processes interact and change each other's dynamics, and in which each interaction pays attention to the specific conditions of the adjacent processes. In this study, this means that we first looked at how the intervention works at the level of real-time activities of individual teachers in the context of their schools, and subsequently we looked at the dynamic interplay between variables that matter at this level of analysis, such as individual concerns and individual evaluations of the value of the obtained effects. In this way, an intervention can be seen as a process, a sequence of activities of a teacher, her pupils and an intervener.

In large scale research it is impossible to pay attention to all the influences that can play a role in an intervention process. From a complexity perspective the description of all aspects is not possible because of the multitude of possible aspects, and because these aspects continuously change over time. It is important, however, to recognize that all contextual aspects influence each other intertwiningly and form positive or negative feedback loops. These effects need to be taken into account when assessing the effectiveness of an intervention, or when providing an intervention. Moreover, when designing an intervention from a complexity perspective, attention must be paid to the fit between intervention, teacher, provider, and the context in the broadest sense. The notion of the intertwining and reciprocal relations between all aspects requires flexibility and an open mind of the trainer. The trainer himself is in a complex dynamic system, embedded in the process itself, and therefore does not function as an external factor. While maintaining the intervention integrity, the trainer must be able to make adaptations at the right time and at the right place, by focusing on the intervention as an idiosyncratic, individual-based process. We speculate that the example at the end of the previous section could have worked out very differently if the principal had been very positive about the intervention. If she or he had shown this enthusiasm by participating in the theory session, Anne's concerns could have changed her motivation to more intrinsic motivation for participating, instead of the extrinsic motivation she had. This change into intrinsic motivation could also have had its influence on her idea about the learning goals and the length of the intervention. The results and the effectiveness of the intervention could have displayed a more positive picture for Anne in this situation.

Some limitations of this research need to be mentioned. Firstly, only a part of the influencing context is discussed. More aspects are important when studying an intervention's effectiveness (Boelhouwer, 2013; Boomstra, 2014), and these aspects can vary from the enthusiasm of the children, to bureaucracy that enforces teachers to unwanted work, and to the influence of a teacher's sick child at home. An exhaustive description, however, of the influencing aspects is not necessary in a complex dynamic system because what matters are the intertwining processes and the interactions between the influencing aspects. Secondly, the empirical illustration is limited to two cases, in which not all possible aspects are visible, and therefore cannot be taken into account. However, the results of this study shows the importance of a complexity approach when intervening.

Designing and implementing a sustainable intervention for professional development is not an easy task, not least because most systems resist change in the long run. This kind of resistance can only be understood from a complexity viewpoint concerning the role of interventions, in that all aspects are seen as components that sustain each other (Frenken, 2006). It can take up to three to five years for teachers to fully implement a new practice or program, and therefore expecting change in a short period of time is unrealistic (Loucks-Horsley et al., 2010). This can be regarded as a plea for long-term intervention processes, as well as longitudinal studies in order to examine the effects of interventions over a longer timeframe.

The complexity approach to interventions has some important implications for future empirical research, as well as for the design of interventions. In future research, results of small scale and large scale research should be combined, in order to obtain a better insight into all relevant aspects and their effect on teachers' behavior. In addition, research should concentrate on the effects that all contextual aspects have intertwiningly. Once more knowledge is available concerning how aspects influence each other contextually, this knowledge can be used to design more effective interventions and to implement them more effectively with higher chances that the system incorporates the new influence and that effects will last.

CHAPTER 4:

The Effect of a Coaching Program on Teachers' Well-being in Science and Technology Lessons in Primary Education

This chapter is submitted as:
Wetzels, A.F.M., Steenbeek, H.W., & Van Geert, P.L.C. (2015).
The effect of a coaching program on teachers' well-being in science and technology lessons in primary education.
Manuscript submitted for publication.

CHAPTER 4:
The Effect of a Coaching Program on Teachers' Well-being in Science and Technology Lessons in Primary Education

4.1 Introduction

Teachers' well-being is an important factor that co-determines the quality of their teaching (Osborne et al., 2003), which in turn greatly influences pupils' academic performances (Barber & Moursched, 2007; Rowe, 2003). Well-being is the result of a person's position on two independent dimensions: positive affect and negative affect (Bradburn, 1969; Diener, 1984). The more the positive affect exceeds the negative affect, the higher the feeling of well-being will be. Well-being and happiness are related terms in that they describe almost the same phenomenon, although well-being has a more neutral meaning than happiness. Teachers' (subjective) well-being is not something static and stable, but is a dynamic property, which is constantly being influenced by, and influences other, components of their teaching, such as teachers' feelings of self-efficacy, and the quality of the relation with their pupils (R. G. Lambert, McCarthy, O'Donnell, & Wang, 2009; Sugden, 2010). There is also a constant mutual influence between the quality of teachers' work and their level of well-being on the one hand and influences from the school-context on the other hand, such as school directors' demands to implement new policy with regard to science and technology education.

In order to study well-being, it is important to understand the elements that influence the teacher's positive and negative affect. For instance, one might assume that teachers' positive affect increases when teaching a class of children who are interested in and enthusiastic about the topic discussed, or when speaking with parents who are pleased with the way their child is being taught. Likewise, the negative affect probably increases when the school board decides to implement a new curriculum without giving teachers the opportunity to have an influence on the decision-making process, or when there is not enough time in class to discuss important subjects.

The aim of this paper is to report a study in which aspects that play a role in teachers' well-being, in connection with teaching science and technology (S&T), are examined, the role a teacher coaching program can play in dealing with these aspects, and the effect that such a coaching program can have on enhancing teachers' skills and knowledge with regard to teaching (S&T), and in their feelings of well-being while doing so.

4.1.1 Introducing science and technology in schools and how it potentially threatens teachers' well-being

To ensure children will appreciate and understand S&T later in life it is important for them to encounter it at a young age (Scientific American, 2010). In order to increase high-quality science and technology exposure for children, curricula of primary schools need to be changed in favor of S&T education. Various countries have started nationwide programs to stimulate high quality S&T education for young children (e.g. in Germany, Haus der Kleinen Forscher; in the Netherlands, the Dutch Institute for Educational Policy in Science and Technology (PBT)). In response to these programs, primary school administrators try to stimulate their pupils' enthusiasm for science education by initiating curricula in Science & Technology in all grades, from grade 1 to grade 8. Teachers on the other hand often feel threatened by the prospect of a change in their activities, which is imposed on them by the school administration, which might potentially negatively affect their level of well-being (Barber & Moursched, 2007). Teachers feel this threat especially when asked to teach new priority fields or things they are not particularly familiar with, such as science and technology.

Three important aspects concerning teaching S&T that affect well-being of teachers can be distinguished. First, teachers do not feel they can make their own decisions in general (Goldspink, 2007), and consequently also about the way they teach S&T. Secondly, teachers often feel they lack the competence to provide S&T lessons in class (Goodrum et al., 2001; Jarvis & Pell, 2004; Palmer, 2002), and finally, teachers often lack the knowledge as to how to pass on S&T knowledge in the interactions with their pupils (Furtak, 2006; Roehrig & Luft, 2004). This phenomenon is to be expected, because primary school teachers do not have an S&T background, and in their teacher education they are not specifically trained to teach S&T. This lack of confidence in their own capabilities partly relates to a lack of real knowledge and skills, and partly to their attitudes towards teaching S&T (van Aalderen-Smeets, Walma van der Molen, & Asma, 2012). These aforementioned aspects cause a negative affect, which has a detrimental influence on teachers' well-being, and consequently on their intrinsic motivation for teaching. This is regrettable, because this intrinsic motivation is very often the basis from which they started teaching anyway (Dinham & Scott, 2004). When teachers show enthusiasm, as an affective component of motivation, their instructional behavior has a higher quality (Kunter et al., 2008).

In order to enhance teachers' well-being, and increase their knowledge and skills in S&T instruction, we developed a coaching program for teachers. However, before we discuss this, we will first explore how young pupils learn about S&T, and what teachers need to do to enhance this learning.

4.1.2 How do children learn science and technology in schools?

Currently, most researchers agree that children's learning is not only a cognitive activity that takes place in children's' heads, but must also be conceived of as a socially situated, transactional process (Fogel, 2009; K. Kumpulainen, Hmelo-Silver, & Cesar, 2009; Murphy, 2007; Sorsana, 2008), in which a combination of cognitive, motivational, and social factors intertwiningly play a central role. That is, children's learning is socially 'embedded' and comprises not only their achievements, but also includes their goal orientations, evaluations, and emotions with regard to the specific topic at hand, such as science and technology. That is, motivational aspects resulting in children's explorations, interest and curiosity play a central role in their learning process (Steenbeek & Van Geert, 2013).

This motivation and curiosity are present in young childrens' lives when they explore everything that happens in their environment. They are natural young scientists, without ever being taught science and technology (Schwartz, 2009; Steenbeek et al., 2011). Parents usually encourage their children's exploratory behavior when they are still at home. When these children go to kindergarten however, this curiosity seems to vanish (Engel, 2009). It is possible that when children get older they simply become less curious, and eventually outgrow it. However, that possibility does not seem likely because older children, and even most adults, like to investigate their environment and like to perform real inquiry when this is stimulated (Loewenstein, 1994). So the vanishing of curiosity is quite likely related to the school environment. One of the reasons behind this phenomenon seems to be that teachers rarely ask substantive, curiosity-arousing questions in the class. The questions they do ask tend to measure or determine what knowledge a child already has (e.g., what is a polar bear?), rather than stimulate inquiry by the children (e.g, how can you get to know what a polar bear looks like?). Teachers rarely explore the questions children ask, but tend to remind the children to stay on the tasks they have to perform. Teachers seem to be busy with targets, test scores, and the transfer of knowledge but not with promoting inquiry in the class (Susskind, 1979; Tizard & Hughes, 2002). That is, if teachers ask questions, the minority of these questions require pupils to think; the other questions concern mere recalling of facts or are procedural (Gall, 1970). This actual situation is not in line with results of a survey of teachers, which revealed that they saw curiosity as a very fundamental characteristic for pupils, which they would like to further develop (Engel, 2006). The result of this educational practice seems to be that children lose their interest in science learning throughout their school years. In an extensive review of the literature on pupil's attitude for science learning, Osborne et al. (2003) state that the quality of teaching is crucial for pupils to keep a positive attitude towards science learning. If the teaching of S&T takes place in a manner that enhances skills for exploring and curiosity, the decline of pupils' motivation for science learning can be prevented.

To provide high-quality teaching, the teacher should act from a state of intrinsic motivation and of well-being. In acquiring a state of well-being, with more positive affect and less negative affect concerning their role as a teacher, attention must be paid to three innate concerns (Ryan & Deci, 2000; Steenbeek & Van Geert, 2007; Steenbeek & Van Geert, 2013) that should be satisfied and in balance with each other, namely the concerns for competence, autonomy and relatedness. For teachers, the concern for competence means that they need to strive for knowledge and skills for teaching; the concern for autonomy means that a teacher strives for working independently and can initiate new activities, without being dependent on outside pressure, and finally, the concern for relatedness means that the teacher strives for a good quality level of teacher-pupil interaction. A coaching program can provide teachers with tools to reach balanced concerns.

4.1.3 Intervening for improvement of S&T teaching: the video coaching for teachers (VFC-T)

The literature stresses the importance of using a mix of active and inquiry learning, children's self-regulated exploration and questioning, and educational guidance and teaching by teachers with high-level educational skills (Alfieri et al., 2010; Kirschner et al., 2006; Mayer, 2004) for successful S&T education to occur. This requires highly developed questioning skills that not all teachers possess, and for which they need to be thoroughly trained (Barber & Moursched, 2007; Roth, 1996). The intervention for teachers that we developed to enhance their potential for teaching science in the classroom focused on enhancing teachers' questioning skills, framed around the use of steps from the Empirical cycle, a method of research in which data is produced by experiment and observation (Dejonckheere et al., 2009). Therefore, theory about the empirical cycle (De Groot, 1961) and scaffolding (Van de Pol et al., 2010; Van Geert & Steenbeek, 2005) was provided.

The idea is that by working on requiring more knowledge and skills for teaching S&T, the teacher will experience a higher quality of teachable science moments (Bentley, 1995; Hyun & Marshall, 2003) during S&T lessons, causing more enthusiasm and motivation for S&T both in the pupils and in the teacher. This then will increase teachers' well-being, and enhance the fulfillment of the teacher's three aforementioned concerns.

In other words, we hypothesize that a positive S&T teaching-learning spiral will be boosted, causing a positive effect on various aspects that relate to teachers'

S&T teaching, and their pupils' S&T learning. Note that this regards a self-enhancing and self-supporting process, in which learning and enthusiasm in the teacher enhances learning and enthusiasm in students, and the other way around.

Training programs have virtually no effect if the chosen instructional method is not adequate. A coaching program can only be effective when combined with classroom observation, micro teaching, video feedback and practice in the classroom (Wade, 1984). Especially video-feedback is a powerful form of training to enhance teachers' skills (Seidel et al., 2011). With this in mind, we developed a Video Feedback Coaching Program for teachers (VFC-T). The program focuses on teachers' actions in the classroom, by means of coaching based on observable behavior, if necessary second by second, so that behavior moves to a conscious, rather than unconscious, level (Van den Heijkant et al., 2004).

4.1.4 Questions and hypotheses of the present study

The study is framed by the following questions:

1. To what degree does the intervention influence teachers' intrinsic motivation and well-being while teaching S&T?
2. To what degree does the intervention influence teachers' behavior with regard to the use of questions that elicit scientific reasoning eliciting in the classroom, as shown in their verbal utterances?

Our hypothesis was that trained teachers will experience a positive S&T teaching-learning spiral, causing a positive effect on various aspects that relate to teachers' S&T teaching, and their pupils' S&T learning. More specifically, we expect that this positive effect will show in teachers reporting higher levels of intrinsic motivation and well-being while teaching S&T (study 1). In addition, we expect trained teachers to ask more questions that are related to the 'empirical cycle, which can also be referred to as 'scientific thinking circle' (Dejonckheere et al., 2009; de Groot, 1961), and less questions that are 'knowledge-based'. Furthermore, we expect them to elaborate more on the answers pupils give, and to ask more supplementary questions.

4.2 Study 1

4.2.1 Method

4.2.1.1 *Participants*

The study started as a part of a broader professional development program with fourteen teachers, of whom two withdrew from the program because of pregnancy. The twelve participating teachers came from five schools that showed interest in S&T education, and wanted to incorporate S&T in their school program. Two schools already had some experience in teaching S&T, whereas three schools had almost no experience in it.

The teachers (two male, ten female) had a mean age of 40.3 years, with an age range from 25 to 60 years, and also a wide range of experience (mean level of experience 15. 6 years, ranging from 2 to 37 years). Four teachers already had some experience in teaching S&T, while eight had no such experience. All participants were elementary school teachers working with children in grades 1-4. Children's age varied from four to eight years. All schools were situated in rural areas in the north of the Netherlands, with virtually no children from ethnic or cultural minorities. The teachers were accustomed in teaching all subjects in their class and were coached in how they could best teach S&T. The S&T lessons did not have their priority, and they did not spend much time on teaching S&T.

4.2.1.2 *Design*

The first study lasted one school year, from October until May, in which the try-out version of the VFC-T took place as part of a professional development trajectory for teachers. The professional development involved six team-based theory sessions for each school, where teachers received information about a number of S&T examples, for instance, floating and sinking and the use of cogwheels. In addition, they obtained information about ways of scaffolding (Van Geert & Steenbeek, 2005), and about the teacher's role in children's problem solving. The coaching took place individually. Four or five science classes of each teacher were recorded by the coach, and parts of these recordings, in particular, those concerning the teacher's behavior and the interaction with pupils were extensively discussed with the teacher. The aim of the coaching was to enhance elementary teachers' knowledge and ability to teach science and technology. The coach taught them how to interact with pupils while teaching science, by providing them with tools to enhance their questioning and scaffolding skills. Furthermore, the coach helped to enhance the teachers' intrinsic motivation and well-being, by teaching them to establish a positive spiral of inspiring teachable science moments, in which pupils expressed their enthusiasm and curiosity about S&T. This positively affects teachers' enthusiasm and curiosity, which they can subsequently express in their teaching.

Each teacher prepared an S&T lesson for every coaching session. Coaching took place on the same day. Teacher and coach discussed the video recordings of the lessons, focusing on the teacher's interaction with the children. Attention was paid to S&T talent eliciting remarks of teachers, and the teachers were encouraged to show more of this talent eliciting behavior in their next lessons. The professional development and coaching activities were carried out by three teacher educators, who worked at two teacher training colleges near the schools that participated. The teacher educators all had experience with teacher training and with the coaching of pre-service teachers. They understood the context of the VFC-T, and in several preparatory meetings with the researchers, this context was discussed with them. The first author was present at every coaching session to ensure that all sessions were recorded on video.

4.2.1.3 *Data collection and analysis*

Data were systematically collected through open-ended research methods, such as classroom observations, video recordings of the classroom activities, and video recordings of the coaching sessions with regard to the classroom activities. At the end of the school year and the professional development and coaching program, the twelve participants of the coaching program were interviewed by the researcher using a semi-structured interview technique. In addition, four teachers not participating in the coaching program were interviewed. One aim of the interviews was to examine how the teachers assessed both professional development and coaching in the past period. Another was to examine if the teachers could see any change in their own behavior, as well as in their pupils'. The researchers asked questions about teachers' motivation, their opinion regarding the coaching and the professional development program, and the trajectory's benefits for the teachers and the pupils. The researchers, who participated in the coaching and professional development program, performed the interviews themselves. The length of the interviews ranged from 35 to 75 minutes. All interviews were recorded on tape and transcribed. Afterwards, all teachers' statements were categorized.

4.2.2 Results

4.2.2.1 *Benefits of the VFC-T for the teacher*

When asked about the eventual benefits of the coaching program, ten out of the twelve teachers said that they were very satisfied with the outcomes of the program. They had observed changes in their own teaching, changes in their pupils' attitude, and changes in the interaction in the classroom. Two teachers were not very satisfied, and these were teachers who did not, as a result of organizational problems at their school, receive the coaching section of the program as intended, with proper use of video recordings. Despite this, the trainers received a 7.8 on a scale from 1-10 as an overall mark.

To the question what teachers had actually learned during the VFC-T, and what they were doing differently in their own lessons, the twelve teachers provided a total of 66 answers. These 66 statements could be divided in six categories, as shown in table 2.

Table 2 | *Benefits for teachers*

Category	Number of statements	Examples of teachers' statements
Preparation of the lessons	16	"In advance thinking about what question to use"
Knowledge of S&T	14	"Acquiring more experience in technology lessons"
Interaction during lessons	13	"keep on asking", "keep mouth shut", "use supplementary questions"
Change in oneself	10	"awareness", "flexibility in learning goals in a lesson"
Observing talents in children	8	"to discover talent in children"
Abstract level	5	"give space to pupils", "let pupils look more critical"

The interviews demonstrated that teachers noticed that the interaction in the class had changed. Most answers indicated that teachers themselves talked less, and gave more opportunities for children to discover topics themselves by means of asking the children various kinds of substantive questions. An important learning point for teachers was to discover that they could understand their pupils' way of thinking more. A lesson could be successful even though the whole intended subject matter was not discussed, but instead there had been extensive interaction concerning topics that interested pupils and that compelled them to think. The teaching goal was confined to discussing the entire content of a lesson, but it could also be to evoke interest in children, make them curious, and make them reflect on topics.

Teachers also stated that the coaching sessions made them listen to their pupils more often and with greater interest. Additionally, the coaching sessions resulted in giving the teachers a better understanding of what motivated their pupils. They were very happy with the enthusiasm their pupils showed during S&T lessons. In this way the teachers enjoyed their own classes more.

4.2.2.2 *Benefits of the VFC-T for pupils according to the teachers*

Teachers were asked if they could see any change in behavior and attitude on behalf of their pupils in the classroom. To this question, the teachers provided a total of 43 answers. These 43 statements could be separated in six categories, as shown in table 3. For example, a statement was made seventeen times about change in their pupils' affect. Teachers said they encountered more enthusiasm, initiative and involvement in the classroom.

Table 3 | *Benefits for pupils*

Category	Number of statements	Examples of teachers' statements
Affect	17	"Enthusiasm", "initiative", "involvement"
Cognitive aspects	10	"Pupils are more critical", "learn a lot"
Motivational aspects	2	"Working motivated"
Confidence	11	"Pupils who usually do not attract attention take more part in the classroom activities"
No change observed	3	"Too early to see a change"

According to teachers, pupils enjoyed lessons more, especially when S&T was involved, as can also be concluded from the fact that 17 answers (table 3) had an affective component. Teachers observed that the children who normally gave the right answers were not in the lead, but that other children could also show their skills and take initiative. Reasoning, initiative and enthusiasm are traits that are noticed and appreciated by teachers in the S&T lessons. Three statements referred to the fact that the teacher could not identify changes in the classroom. Two of these answers were given by teachers with whom the coaching program was not executed as intended, due to organizational problems in the school.

4.2.3 Discussion

As a result of the interviews, it becomes clear that most of the teachers felt like they alter their methods of lesson preparation, they know more about S&T, and they interact differently during the lessons. This interaction consists of more listening and more asking supplementary questions. Each teacher saw positive changes, sometimes only in his or her own behavior, sometimes also in the behavior of pupils. Teachers were very happy with the changes they saw in themselves, and the positive effects this had on their pupils' behavior, for instance, the enthusiasm their pupils showed during S&T lessons.

This study has shown that a VFC-T has a positive effect on teacher well-being as this is what teachers themselves report. Nevertheless, interviews, as a research method, have some important limitations, in that participants can show an interview bias. Moreover, interviews only provide qualitative results. Therefore, a second study has been carried out with more emphasis on quantitative results, with the aim of providing data on the real interaction in the classroom, for instance, teacher's questioning. Another aim was to improve the VFC-T, by focusing more on talent eliciting questions, and on making participation in the VFC-T less demanding on the teachers, given their heavy workload.

4.3 Study 2

4.3.1 Method

4.3.1.1 *Participants*

The study started with seven elementary school teachers working with children in grades 1-4 from three different schools. The teachers (one male, six female) had a mean age of 36.4 year, while there was a wide age range from 24 to 56 years old, and also a wide experience range, from 2 to 33 years, with a mean experience of 14 years. The three schools taking part in this study were already incorporating S&T in their school program. All teachers, none of whom had any experience in teaching S&T, participated voluntarily.

4.3.1.2 *Design*

The second study was conducted at three schools for primary education. To improve the design of the coaching program, a literature study was carried out on coaching, scaffolding and questioning. On the basis of this literature study, the VFC-T was improved, and afterwards carried out by the first author in February until April. In comparison with the first coaching format, the new format was based on rigid scheduling, and involved an introduction session of two hours, in which teachers received information about scaffolding (Van Geert & Steenbeek, 2005), questioning (Oliveira, 2010), and the empirical cycle (De Groot, 1961). During this session, teachers learned how scaffolding could take place by asking talent eliciting questions and supplementary questions. Moreover, they learned that questions resulting from the empirical cycle could be used when teaching S&T because these questions are particularly fit for eliciting talented behavior. In the seven weeks following that introduction session, four coaching sessions were scheduled, while the teacher gave a regular S&T lesson, lasting from 20-30 minutes, with a small group of pupils from their class. The lessons were recorded, and coaching took place approximately half an hour after the lesson, and lasted about 30 minutes. Before the coaching session could take place, the coach selected four or five fragments from the video to be discussed. These fragments were selected with a focus on teacher questioning during the interaction with the children. The focus of the coaching session was to enable the teacher to discover, in interaction with the coach, how to change behavior by discussing fragments that were representative of the teacher's behavior.

4.3.1.3 *Variables*

To determine the effect on teachers' questioning, a coding scheme was developed. First, the main verbal statements were coded: 'questions', 'encouragement', 'remarks relating to the content', and 'other remarks' in order to distinguish the different verbal expressions teachers used in class. Second, the variable 'questions' was categorized in terms of the empirical cycle: 'knowledge questions', 'prediction questions', 'research design questions', 'observational questions' and 'questions about the explanation'. Additional categories of questions were: 'supplementary questions', 'other questions relating to the content', and 'other questions'. We expected that there would be a difference between the pre-intervention and the intervention in terms of an increase of teachers' scientific reasoning eliciting questions (from now on TSEQ), such as 'prediction questions', 'research design questions', 'observational questions', and 'questions about the explanation'. We also expected that the teachers would ask more supplementary questions.

4.3.1.4 *Data collection*

Data were systematically collected through classroom observations, video recordings of the classroom activities, and video recordings of the coaching sessions with regard to the classroom activities. Prior to the introduction sessions, two S&T lessons were recorded as a pre-intervention, without coaching afterwards. The video recordings were captured with a digital camcorder, focusing mainly on the teacher, to record the teacher's behavior.

4.3.1.5 *Data analyses*

The first ten minutes of one pre-intervention lesson and two lessons in which coaching took place with four teachers were coded by using The Observer 10.5. To assess the reliability of the coding system, a second observer was trained to code a representative part of the recorded lessons. An inter observer agreement of 74% was found for the variable 'questions' (Kappa =.70). This agreement is substantial, which means that the coding system can be used reliably. The differences between pre-intervention and intervention lessons were analysed using Monte Carlo permutation analyses (Todman & Dugard, 2001). This is a non-parametric permutation test, particularly suitable for small sample sizes as is the case here. The probability that results are caused by chance alone, is estimated by simulating the chance-alone condition. This simulation is done by randomly shuffling all results on a variable during three sessions and with four teachers numerous times (1000 or more). The original result is then compared with the distribution of the results obtained by the random model.

4.3.2 Results

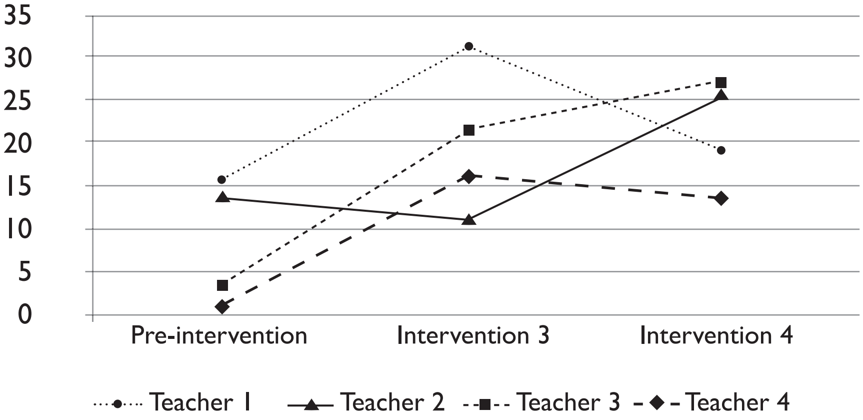
4.3.2.1 *Teacher's scientific reasoning eliciting questions (TSEQ)*

The effect of asking a higher amount of TSEQ and elaborating more on answers can be seen in table 4 and figure 5. The amount of TSEQ asked during part of the lesson increased from 34 in the pre-intervention session with 142% for all teachers together to 82.5, the mean of the intervention sessions (*p*=.04). The amount of increase differed among the teachers, but every teacher benefited from the intervention.

Table 4 | *TSEQ*

Questions empirical cycle	Pre-intervention	Intervention 3	Intervention 4	Mean of interventions
Teacher 1	16	31	19	25
Teacher 2	14	11	26	18.5
Teacher 3	3	21	27	24
Teacher 4	1	16	14	15
Total	34	79	86	82.5

Figure 5 | *TSEQ*



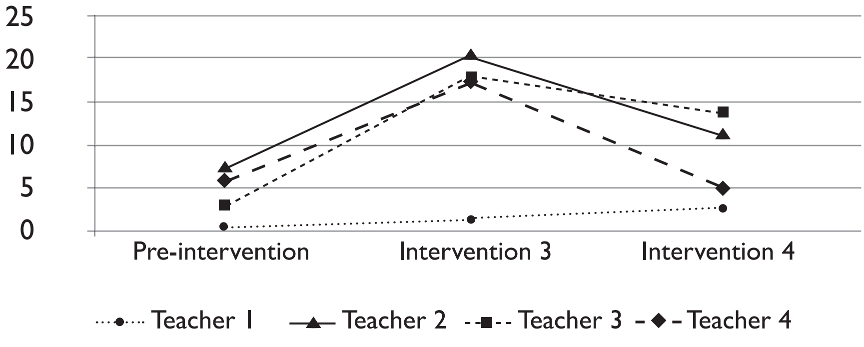
4.3.2.2 *Supplementary questions*

The same effect can be seen with regard to the supplementary questions (table 5 and figure 6). In the pre-intervention lesson, supplementary questions were asked 16 times, while the mean of intervention 3 and 4 was 45.5 questions, an increase of 184%. (*p*=.04). All teachers increased their supplementary questions, although the degree to which their questions increased differed considerably.

Table 5 | *Supplementary questions*

Supplementary questions	Pre-intervention	Intervention 3	Intervention 4	Mean of interventions
Teacher 1	0	1	3	2,0
Teacher 2	7	20	12	16,0
Teacher 3	3	18	14	16,0
Teacher 4	6	18	4	11,5
Total	16	57	34	45,5

Figure 6 | *Supplementary questions*



4.3.3 Discussion

The participating teachers showed a significant improvement in the number of TSEQ, as well as supplementary questions, asked during a lesson. Before they participated in this research, the teachers had virtually never taught S&T in class themselves. During the pre-intervention, it was striking that three of the four teachers had the misconception that pupils had to work independently, without help of the teacher, when attending S&T class. Teachers asked questions, but the questions being asked did not stimulate children's thinking, observing, or sharing their views of the topic, such as the questions used within the empirical cycle. A question during the pre-intervention lesson was, for example: "do you need a drill?", while after the introduction lesson, questions might be: "what do you see happening right now?" or "Why do you think this pencil floats?" When pupils answered these questions, teachers displayed more scaffolding behavior, by asking for explanations for the pupil's answer. In the later lessons, the teachers made more use of supplementary questions, while they rarely did that in the pre-intervention lessons.

During the coaching after each lesson, some teachers indicated that prior to the intervention, they did not expect children this young to be able to answer these questions. They were surprised to see that the S&T lessons taught in this manner made their pupils very enthusiastic. At the last coaching session, all six teachers indicated that they were very satisfied with everything they had learned during the VFC-T. This kind of teaching S&T was new to them, but they thought it would be much easier from then on to teach S&T. The theory about questioning and the empirical cycle was helpful for them, and they enjoyed the interaction with their pupils, as well as the enthusiasm the pupils showed during S&T class. Finally, the teachers reported that the way of questioning was not only helpful in S&T lessons, but that all other lessons could benefit from this new method.

4.4 General discussion

The major question of this study is whether the teachers' well-being increased as a result of better teaching. The answer to this question can be positive: in interviews, teachers mentioned they were very satisfied with the results of the coaching. Each teacher saw positive changes, either in his or her own behavior, or in the behavior of pupils, or in both. Teachers were very happy with the changes they saw in themselves, and the positive effects this had on their pupils' behavior. They learned a lot, and felt more capable of teaching. The amount of positive emotions considerably increased after the coaching, in this particular context of science and technology teaching to young children. The results from study 1 were based on a qualitative method, namely the analysis of interview data. It might be objected that interviews about the effect of interventions lead to biased answers, favoring positive outcomes, although, if the teachers would have been hostile or negative towards the intervention, the expectation would be that their answers would be biased towards negative outcomes. In order to check whether the qualitative results reflect only the teachers' positive biases and are not related to actual changes, we tested the expectations that trained teachers ask more questions that are related to the empirical cycle (Dejonckheere et al., 2009; de Groot, 1961). Furthermore, we expected them to elaborate more on the answers pupils give and to ask more supplementary questions. The results from study 2 showed that the VFC-T has a positive effect on the cognitive quality of the questions the teachers asked.

What is remarkable is that during the last intervention session, almost all teachers showed a considerable decrease in supplementary questions in comparison with the pre-intervention session. An explanation for that could be that during the coaching sessions, emphasis was put on empirical cycle questions teachers could ask, whereas less attention was paid to the supplementary questions that could be used. As can be seen in table 4, those purporting to the empirical cycle did not show this significant drop.

An important question for future research is whether the increase in questioning quality also resulted in an increase in cognitive levels of the answers that the children gave. The qualitative results from study 1 are positive, just as the experience we had in the classroom during study 2. Children gave real substantive answers to the questions being asked, and did not react to these questions by saying "I don't know", or I do not understand that". Although we did not analyse the pupils' answers quantitatively, we think that there is a positive relationship between the teaching behavior and the cognitive performance of the pupils. A follow up study is scheduled to determine the effects of the VFC-T on children's thinking. Additional questions that should be answered in future research are whether the increase in the quality of the questions of the teacher has a durable effect on the teacher, whether it transfers to other teaching situations, and whether it leads to an increase in the quality of pupils' independent reasoning, without the help of the teacher, for instance, when working with peers.

CHAPTER 5:

Primary Science Teaching: Behavior of Teachers and their Pupils during and after a Coaching Program

This chapter is submitted as :
Wetzels, A.F.M., Steenbeek, H.W., & Van Geert, P. L.C. (2015).
Primary science teaching:
behavior of teachers and their pupils during and after a coaching program.
Manuscript submitted for publication.

CHAPTER 5:
Primary Science Teaching: Behavior of Teachers and their Pupils during and after a Coaching Program

5.1 Introduction

5.1.1 The importance of science in school

As the OECD (2008) states: " In today's technology-based societies, understanding fundamental scientific concepts and theories and the ability to structure and solve scientific problems are more important than ever" (p. 16). In current society, public knowledge of science is important for various reasons. First, it is important because science, as such, underlies the technology that everybody is dependent upon. Second, knowledge of science is important because it underlies peoples' decisions regarding socio-scientific issues such as gene manipulation and climate change. Finally, knowledge of science is important because it strengthens the critical attitude of the public towards phenomena like astrology or quack doctors.

These examples show that science is essential for the way society operates as a complex system, now and in the years to come (Nowotny et al., 2001). The implication thereof is that throughout society more science and science related knowledge is needed (Mooney & Kirshenbaum, 2009). Science education from the earliest school years on is an important means to achieve the goal to obtain this knowledge.

Therefore, it is important to stimulate children's science learning potential from preschool on. This potential expresses itself in children at a young age who show that they are already little scientists (Brewer, Chinn, & Samarapungavan, 1998), and have a great interest in science topics (Chouinard, 2007). However, when these children go to school, the great majority of them lose much of this natural talent for science learning (Engel, 2009). That is, children lose their interest in science, their curiosity, as well as their natural way of asking questions and reasoning. As enthusiasm for, and interest in, science can be lost during these early school years, it should be possible for teachers to stimulate these features in young children during school hours. In addition, parents can stimulate this enthusiasm and interest at home, by encouraging their children to express and satisfy their curiosity (Tizard & Hughes, 2002). However, science has not been given much attention in early childhood classrooms (Appleton, 2003; Dickinson et al., 1997; Martin, Mullis, & Foy, 2008; Michaels, Shouse, & Heidi, 2007). In order to help children from a young age on to develop the much needed science knowledge, together with the related scientific reasoning skills, schools should give more attention to science learning from preschool on. In their science lessons, they should focus not only on teaching science content and enabling pupils to learn this content, but also on stimulating other aspects of their pupils' scientific learning behavior, such as their interest in science, their enthusiasm for science, and their expression of scientific reasoning skills, such as those needed in predicting and explaining scientific phenomena.

A common way of teaching science in schools is by means of inquiry learning (Benford & Lawson, 2001; Furtak, 2006; Van Graft & Kemmers, 2007; "What is Enquiry-Based Learning (EBL)?," n.d.). Pupils' inquiry learning is aimed at learning how to think scientifically and independently. According to Dewey (1997), inquiry learning is 'a way of learning science as a process and a way of thinking', which means that it is not primarily focused on science content, i.e., on the knowledge of facts, but on the methods and processes scientists use. It can be used in science lessons to help both teachers and pupils to teach and learn science in interaction with each other. Doing experiments, and predicting and explaining what happens during these experiments (Van Joolingen, De Jong, & Dimitrakopoulou, 2007), helps pupils to think critically and to ask scientific questions. This can then be used to enable them to make sense of their observations in the natural world. Thus, inquiry learning can help to stimulate pupils' scientific reasoning skills. Inquiry learning demands other teaching-learning behavior from both teachers and pupils than what is used in mathematics or English lessons. With inquiry learning, teachers need to learn how to provide adequate support for stimulating pupils' scientific reasoning skills, which requires teachers to behave in a way that they frequently are not accustomed to. This support is visible in the interaction between teacher and pupil, in which pupils can develop the scientific reasoning skills needed for inquiry learning.

Teachers are often not educated in science and inquiry learning, and often lack knowledge of science themselves. As teachers are role models for children, it should be self evident that their behavior in the classroom regarding science education has a clear impact on young children's inquiry skills. An intervention focused not only on teachers' science knowledge, but also on their behavior regarding science lessons in the earliest school years, should therefore be the starting point for enhancing science education in schools.

The aim of this chapter is to study whether a video-feedback coaching intervention for earliest school year teachers can contribute to teachers' behavioral change with respect to stimulating pupils' scientific reasoning skills, and subsequently to the level of pupils' scientific reasoning skills themselves. In this specific form of a professional development trajectory, teachers learn scientific reasoning skills themselves as a way to improve their science teaching behavior, so they can be good role models for their pupils by showing their knowledge for, and interest in, science and scientific reasoning. A multiple case study, using micro genetic measures with regard to change in teachers' and pupils' behavior and their interaction patterns in the classroom during science lessons, is carried out to explore the effects of the intervention on both teachers and pupils.

5.1.2 Knowledge needed when teaching science

Overall, science class in the earliest grades is provided by a teacher, who has not been trained as a specialized science teacher. These teachers usually do not have any experience in teaching science, and do not know enough about science themselves. In addition, they do not know how science can best be taught, and, as a result, they do not feel very confident about their abilities to teach science (Dickinson et al., 1997). Moreover, they often teach science in an authoritarian way or in a way that does not spark enthusiasm and interest in science, i.e., merely using textbooks or worksheets (Dickinson et al., 1997).

The three important types of knowledge needed for teaching science as described in the educational literature (Smith, 1999) are general pedagogical knowledge, science content knowledge, and pedagogical content knowledge, i.e., the way science knowledge is used in classes with the intention to understand and impose meaning and thus the way science can be taught (Hattie, 2003; Smith, 1999).

The first type of knowledge, general pedagogical knowledge, is needed for classroom organization and management, instructional models and classroom discourse (Morine-Dershimer & Kent, 1999; Shulman, 1987). Classroom organization and management stresses the importance of content based instruction, active learning for pupils, as well as the provision of learning activities in line with the pupils' level of thinking (Brophy, 1999; Brophy & Good, 1986). Instructional models include the use of an adequate mix of direct instruction and scaffolding, depending upon the amount of structure a task has for students (Rosenshine & Stevens, 1986). The use of classroom discourse, particularly discourse which uses experience based questions, questions requiring observations and analyses of available data, is known to yield higher student achievements (Otto & Schuck, 1983).

In addition to the general pedagogical knowledge, teachers need to obtain adequate science content knowledge, i.e., an understanding of the basic scientific principles at the level of their pupils, as well as pedagogical content knowledge at that same level. Primary school teachers often claim they lack science content knowledge (Appleton, 2003; Dickinson et al., 1997; Marx & Harris, 2006). There is, however, some discussion in the literature about content knowledge. On the one hand, science content knowledge is deemed necessary to teach science in a proper way; on the other hand, there is a group of researchers who state that the importance of content knowledge (CK) is overrated (Zeidler, 2002), and that teachers need pedagogical content knowledge as a more specific body of knowledge (Ball, Lubienski, & Mewborn, 2001).

The third kind of knowledge is, in fact, a combination of the first and second type of knowledge, namely pedagogical content knowledge. This is knowledge of how to teach specific content in specific contexts; a form of knowledge in action (Mellado, Blanco, & Ruiz, 1998; Shulman, 1987), and consists partially of content knowledge and partially of pedagogical knowledge. It includes teachers' orientation to teaching science, knowledge of science curricula, knowledge of assessment, knowledge of scientific literacy, knowledge of students' understanding of science, knowledge of science content, and knowledge of instructional strategies (Magnusson, Krajcik, & Borko, 1999). In addition to, and partially because of a lack of science content knowledge, teachers do not possess enough pedagogical content knowledge in science, nor the skills to put this knowledge into practice. Because of their lack of content knowledge and pedagogical content knowledge when teaching science, teachers use ineffective teaching methods, such as teacher discussions and explanation, watching science television shows, library results, demonstrations and work sheets (Appleton, 2003; Goodrum et al., 2001), all of which fail to give pupils sufficient opportunities for reasoning scientifically. Teachers need to learn and have experience with effective teaching methods, such as content based instruction, active learning for pupils, as well as providing learning activities in line with pupils' level of thinking (Brophy, 1999; Brophy & Good, 1986) and classroom discourse with the use of thought provoking questions as these are all activities that enhance pupils' scientific reasoning skills.

Pure science content knowledge, therefore, is not fundamental in the science lessons for young children. However, for young pupils' learning to be effective, pedagogical science content knowledge is necessary when focusing on the processes and methods used by scientists and technicians (Van Joolingen et al., 2007) by using inquiry learning. For this reason, teachers need to have insight into the instructional strategies that can be used within inquiry based science education.

5.1.3 Instructional strategies when teaching science

Instructional strategies are techniques teachers use to help pupils become independent, strategic learners. Instructional strategies have - amongst other things - the aim of motivating pupils, of focusing their attention, and of organizing information for understanding and remembering ("Instructional Strategies," 2002). In this article, we focus on three important instructional strategies that comprise a mixture of science content and pedagogical content knowledge, and that together offer teachers clear guidance for implementing inquiry based science teaching. The first strategy is the use of the empirical cycle (De Groot, 1961), which gives teachers and children structure during inquiry learning; the second strategy is asking questions, which provides teachers with a tool to give pupils more room for scientific reasoning; and the third strategy is scaffolding, which gives teachers a good means for supporting pupils' scientific reasoning skills. In the remainder of this section, these three strategies will be discussed.

In his book, 'Methodology: foundations of inference and research in the behavioral sciences', De Groot (1961) describes the empirical cycle as an often used strategy in science and scientific research. De Groot's model includes several important learning activities, such as hypothesizing, observing, explaining and reasoning. The empirical cycles supports inquiry learning by using the following steps: conducting the draft of a research question, formulating a hypothesis concerning the phenomena that are being studied, setting up an experiment to demonstrate the truth or falseness of the hypothesis, observing what happens during the experiment, and finally, drawing a conclusion that validates or modifies the hypothesis. From this last step a new research question can emerge, implying that the cycle is repeated with step one (De Groot, 1961; Dejonckheere et al., 2009).

The second strategy, asking questions, stimulates pupils' curiosity (Goodman & Berntson, 2000), and gives them plenty of opportunities to learn (Wasik et al., 2006), to reason, and to explore (Lee, 2010). However, the questions teachers ask are usually focused on reproduction of knowledge and facts, instead of on enhancing thinking (Engel, 2009; Engelhard & Monsaas, 1988). Asking the right questions includes two main aspects. First, unlike closed questions, open questions do not limit pupils' answers (Hargreaves, 1998; Rivera et al., 2005), but instead elicit more elaborated answers. Secondly, pupil centered questions (e.g. "what do you think what will happen if I pour oil in water") give room to pupils' thinking and reasoning, in contrast to teacher oriented questions, which ask for reproduction of knowledge (e.g. "what is an atom?"(Oliveira, 2010).

The third strategy, scaffolding, gives teachers the opportunity to help pupils until it is no longer needed, and gives pupils the opportunity to work independently, and to receive help only to the extent that it enables them to again work on their own (Mayer, 2004; Palincsar & Brown, 1984). Pupils have a cognitive difference between what they show that they know and what they are potentially capable of (the zone of proximal development (Chaiklin, 2003; Vygotsky, 1978)). This zone can be reached by using scaffolding, i.e., customized help during a task of a pupil who has a higher level of cognitive abilities. This help enables pupils to accomplish tasks they could otherwise not complete themselves.

All three strategies independently have a positive effect on children's scientific reasoning skills. Combining these strategies in a professional development trajectory for teachers aimed at teaching science during the first school years seems, therefore, to be a logical step. In the current study, the three strategies are combined.

5.1.4 Teachers' professional development

The knowledge and skills teachers need in order for them to actually change their behavior should be obtained in a professional development trajectory. That is, knowledge alone is not sufficient in that it will not change behavior in the classroom (Birman et al., 2000). Teachers need time to digest and practice new knowledge. Several studies have shown that there are more elements needed to yield a lasting behavioral change (Desimone, 2009; Garet et al., 2001). The elements needed include sufficient time to learn the new way of working, coherence of the learning activity with their daily work and school policy, focus on the learning process of children, active learning and room to reflect on the learning process, and finally, learning together with teachers from the same school (Birman et al., 2000; Desimone, 2009).

However, a professional development program that focuses on learning new skills and knowledge alone will in general not be effective (Han & Weiss, 2005). Attention must be paid to teachers' intrinsic motivation to change their behavior and to start using the newly learned strategies in the classroom. To enhance intrinsic motivation, three basic concerns that all human beings have, namely the concerns for competence, autonomy and relatedness, need to be addressed (Minnaert et al., 2007; Ryan & Deci, 2000; Steenbeek & Van Geert, 2007, 2013). When all three concerns are adequately met, teachers work intrinsically motivated, and show more enthusiasm, which leads to a higher quality of teaching in the classroom (Kunter et al., 2008).

A professional development trajectory must, therefore, include knowledge about general teaching strategies, the opportunity to practice the learned content and a way to address motivation issues. Such a trajectory in the form of a coaching program can provide teachers with tools to reach behavioral change, and thereby a higher quality of teaching, which in turn will have a positive effect on pupils' scientific reasoning skills. The effects of such a coaching program can be measured in practice by counting the number of scientific reasoning eliciting questions teachers ask and by calculating the level of scientific reasoning skills pupils achieve, as shown in their verbal utterances.

5.1.5 Current study

The study examines the effect of a video coaching program for elementary school teachers of 4-8 year old pupils, (Video Feedback Coaching for Teachers, (VFC-T; Wetzels et al. 2011), which is focused on behavioral change. The study comprises three elements, knowledge about the empirical cycle, asking questions and scaffolding, then, the opportunity to put this knowledge in practice, and, finally, attention to teachers' intrinsic motivation. In this study, we consider the effectiveness of the VFC-T on teachers, and subsequently on the scientific reasoning skills of their pupils, with regard to their classroom discourse, over the duration of the coaching program. Due to limitations of the coaching program and the design of the study, we restrict ourselves to reporting quantitative results regarding verbal utterances during the lessons, by focusing on teachers' use of scientific reasoning eliciting questions and pupils' use of remarks that reflect their scientific reasoning skills.

The study is framed by the following questions:

1. To what extent does the intervention influence teachers' behavior with regard to the use of questions that elicit scientific reasoning eliciting in the classroom?
2. To what extent does the intervention influence pupils' level of scientific reasoning in the classroom, as shown in their verbal utterances?
3 a. What patterns of change can be recognized in individual teacher's trajectories towards increasing the use of questions that elicit scientific reasoning?
   b. What level of coherence is there between the patterns of change in individual teachers' use of questions that elicit scientific reasoning and the level of scientific reasoning of their group of pupils?

During the program, we expect teachers to increase their number of questions that stimulate pupils' scientific reasoning, although the increase will differ for the various teachers (hypothesis 1a). We also expect the number of questions that stimulate pupils' scientific reasoning to increase in the experimental group and not in the control group (hypothesis 1b). Moreover, we expect pupils in the experimental group to show an increase in their level of scientific reasoning during the program (hypothesis 2a), and no increase in the control group (hypothesis 2b). Finally, we expect these results to have a sustainable effect, as will be shown in the post-measurement two months after the program ends (hypothesis 3). A further expectation is that inter-individual variability will occur, in that individual teachers will show different patterns of changes (hypothesis 4a). However, we do expect coherence with regard to the patterns of change visible in individual teachers and their accompanying group of pupils. More specifically, we expect an increase over time in both variables (hypothesis 4b).

5.2 Method

5.2.1 Participants

The study was started after an extensive pilot study, in which the design of the study was developed and tested (Wetzels, Steenbeek, & Van Geert, 2015). Six elementary school teachers, all female, working with children aged 5-8 from two schools in the North of the Netherlands, took part in the intervention (mean age 51, range 35-61, mean experience 23 years, experience range 10-39 years). In addition, a group of five teachers of three schools from the same region, participated as a control group (mean age 39, range 22- 48 years old, mean experience 17 years, experience range 1-27). The teachers of the control group would have the opportunity to follow the intervention program in the next school year. The teachers of the experimental group and the control group were comparable in age and experience, except for one teacher in the control group. In all other aspects (such as experience in teaching science, voluntarily participation), the schools and the teachers were comparable. All participating schools, both experimental and controls, were interested in teaching science, which showed in their participation in "Beta Punt Noord", a partnership of primary education, one academic university, several universities of applied sciences and several businesses in the north of the Netherlands, with the aim of anchoring science and technology in the education program of primary schools. The teachers were asked to choose a group of four to six children, who would be representative for the class as a whole, to participate. All teachers and parents were informed about the use of video recordings, and all gave their written consent for using them for research.

5.2.2 Design

The study, including pre-intervention, coaching and post-intervention lessons, took place over a period of six months (from January until June). After two pre-intervention lessons, during which teachers taught a science lesson which they thought was suitable for their chosen small group of children, an introduction of two hours took place. This introduction was followed by four coaching sessions, during which the teachers taught a science lesson of their own choice, lasting twenty to thirty minutes, with the same group of pupils from their class. The time between the two coaching sessions ranged from one to two weeks. Immediately after each lesson, a coaching session of thirty to sixty minutes took place, using fragments that were selected from the video recording of the lesson of that day. Two months after the last coaching session, two post-intervention lessons were recorded in subsequent weeks. The intervention, including the introduction and all coaching sessions, was performed using an extensive coaching manual (Wetzels et al., 2011) by the first author, who is a psychologist and a trained coach.

5.2.3 Content of the professional development trajectory for teachers

The aim of the coaching was to teach the teachers how to enhance their knowledge and skills of science teaching using instructional strategies as described above (section 1.3.), in order for the pupils to enhance their scientific reasoning skills during the science lessons. The coaching program is focused on teachers' behavioral change, and comprises three elements, knowledge about the empirical cycle, asking questions and scaffolding, then, the opportunity to put this knowledge into practice, and, finally, attention to teachers' intrinsic motivation. Firstly, during the introduction teachers received information about the following strategies: asking questions (Oliveira, 2010), scientific thinking by using the empirical cycle (De Groot, 1961), and scaffolding (Granott et al., 2002; Van de Pol et al., 2010; Van Geert & Steenbeek, 2005). Teachers learned to use open and student centered (Oliveira, 2010) questions during scaffolding, and learned how these questions, in combination with the use of the empirical cycle, can help enhance pupils' scientific reasoning skills. To help incorporate the three strategies, the teachers received flashcards with the empirical cycle described combined with examples of good questioning (appendix A). Secondly, during the coaching session following a lesson, the teachers had the opportunity to put this knowledge into practice and to reflect on their own behavior, with the focus on the use of the three strategies and on the effect that the strategies had on the teacher's behavior, children's thinking and reasoning and the interaction between teacher and pupils. The coach selected four or five fragments, typical for a particular teacher's behavior and interaction with the pupils during the lesson, from the video to be discussed by the teacher and coach. They discussed the video fragments of the lessons, with a focus on the teacher's interaction with the children and the structure, assistance and opportunities the children were provided with during the lesson. Special attention was paid to successful remarks which elicited better interaction with pupils, and which showed the effect the interaction had on pupils' reasoning skills. Teachers were encouraged to show more of this interaction in their next lessons. Thirdly, teachers' intrinsic motivation was stimulated by letting them formulate and work on their own learning goals before the coaching sessions.

5.2.4 Variables

The video-recordings of the lessons (pre-intervention, post-intervention and coaching lessons) were used to objectively determine the effect of the coaching on the actual questioning of the teacher (the variable: 'teacher's scientific reasoning eliciting questioning', from now on TSEQ) and on pupils' scientific reasoning (the variable: 'pupils' level of scientific reasoning, from now on PLS'). With this aim, coding schemes were developed for coding teachers' and pupils' utterances. The teachers' coding scheme was developed using literature that stressed the importance of the empirical cycle and of questioning for science learning (De Groot, 1961; Dejonckheere et al., 2009; Engel & Randall, 2008; Oliveira, 2010), and focused on teachers' scientific reasoning eliciting questioning. The videos were coded in the following order: first, the main verbal statements were coded to distinguish all questions. Secondly, all questions were, as much as possible, classified in terms of the steps of the empirical cycle (table 6) they represent. Follow up questions and other questions were coded in a separate category, not as a category of the empirical cycle. For this study, the sum of all forms of scientific reasoning eliciting questions was used as the main variable. The only exception was that the knowledge questions (code 1) were left out of the calculation because these are not questions that stimulate children's thinking.

Table 6 | *Coding scheme teacher's scientific reasoning eliciting questions (TSEQ)*

code	Question type	Example
1	Knowledge questions	From what material is a pencil made?
2	Prediction questions	What do you think will happen if you throw a pencil into the water?
3	Research design questions	What materials do we need for this experiment?
4	Observational questions	What do you see? What happens?
5	Questions about the explanation	How do you think this is possible?
6	Follow up questions	What do you mean? Can you explain the answer?
7	Other questions	Can you all sit down?

The pupils' coding scheme with regard to their level of reasoning was developed using Skill theory (Fischer & Bidell, 2006), with the aim of analysing children's scientific reasoning skills, i.e., the level of verbal performance of children in scientific tasks. Skill theory describes the developmental cycles of levels and tiers of skills during the human lifespan. In this study, only the levels that children from preschool and grade 1-2 actually use are shown (Fischer & Bidell, 2006). The coding scheme has already been used in a slightly modified way in recent research (Meindertsma et al., 2012; Rappolt-Schlichtmann et al., 2007; Van der Steen, 2014), which showed that the coding scheme could be scored reliably at sentence level. Table 7 shows the levels used, with accompanying examples of pupils' verbal utterances (answers), on that level.

Table 7 | *Coding scheme Pupils' level of scientific reasoning (PLS)*

code	Complexity level	Description	Example
0		No answer is elicited by the teacher	
1	Sensorimotor mapping	A child observes characteristics of an object	This is a blue pencil
2	Sensorimotor systems	Child states a relationship between action and result	The pencil floats because you placed it in the water
3	Single representation	Child refers to one part of the explaining mechanism	The pencil floats because it is small
4	Representational mapping	Child refers to two or more parts of the explaining mechanism	The pencil floats because it is small and light
5	Representational system	Child refers to all explaining mechanisms	The pencil floats because it is light for its size in the water

For this study, the highest level of the pupils' variable PLS was determined for every minute of the lesson. The mean PLS of each lesson was used as the main variable.

5.2.5 Data collection and data analyses

A mixed methods design was used in which both quantitative and qualitative data were gathered (Creswell & Plano Clark, 2011). Both kinds of data were systematically collected through video recordings of the classroom activities, classroom observations, and video recordings of the coaching sessions with regard to the classroom activities. The video recordings were captured with a digital camcorder, focusing mainly on the teacher to record the teacher's behavior.

Because of the labor intensive nature of coding and analysing the data, only the first 15 minutes of the lessons were coded regarding the teachers' variable TSEQ. For the analyses of the children's utterances, the highest level of the pupils' variable PLS was coded for every minute of the lesson. The video coding program, The Observer 10.5 ("The Observer XT," 2011), was used.

The reliability of both coding schemes was assessed by training a second observer to recode 15% of the coded lessons, and to then compare this with the result of the trained observer. An inter observer agreement of 86% was found for the variable 'TSEQ' (Kappa =.85), and 86% (Kappa= .84) for the variable 'PLS', which means that the coding systems can be used reliably.

All differences between pre-intervention, intervention and post-intervention lessons were analysed. That is, the mean of the pre-intervention was compared with the mean of the intervention sessions and with the mean of the post-intervention sessions. The statistical method used is the non-parametric Monte Carlo permutation analyses (Todman & Dugard, 2001) because this test is appropriate for small samples. This test is based on the null hypothesis that no statistical difference exists between pre-intervention, intervention and post-intervention lessons of each teacher. This null hypothesis is tested by randomly permuting the eight lessons per teacher over the eight moments in time. For each random permutation, we calculate the difference between the mean of the pre-intervention and post-intervention lessons as well as the difference between the mean of pre-intervention and intervention lessons. The random permutation has been carried out 1000 times and the distribution of these results was compared with the original results. The number of times that the random permutation produces a difference that is as big or bigger than the observed difference is counted and divided 1000. The result of this division is an estimation of the exact p-value for this small sample.

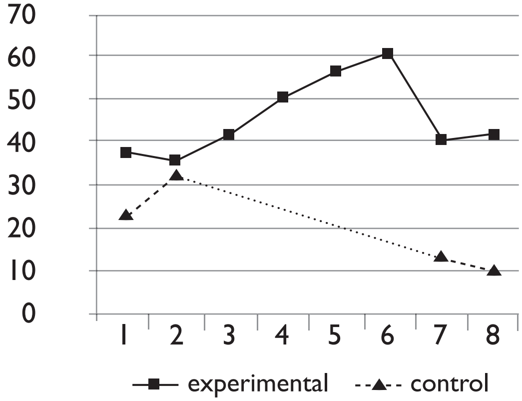
Furthermore, Cohen's d is used to calculate the effect size of the intervention (Cohen, 1988). To gain more insight into the individual trajectories with its specific mutations, the slope of the amount of scientific reasoning eliciting questions is calculated, as well as the slope of the pupils' level of scientific reasoning, in order to compare the increase in empirical cycle questions and the pupils' level of scientific reasoning of each teacher with the performance of the other participating teachers. This time the serial performance variable is examined by using the slope, a linear trend parameter that describes the direction (increase or decrease) and steepness (the strength of the decrease or increase) of the changes in the variables. A level of significance of .05 is used.

To respond to the third hypothesis (with regard to the patterns of change that can be recognized between individual teacher's trajectories), the raw time series of both teachers' amount of scientific reasoning eliciting questions and pupils' level of scientific reasoning were first smoothed, using a Loess smoothing technique, and subsequently normalized, using a linear transformation, so that both teachers' and pupils' measures were put on the same scale, both ranging from 0 to 1 (Jacoby, 2000). Smoothing the raw time series reduces the local variability, e.g. during each measurement point, while still retaining the eventual nonlinearity of the data, i.e., retaining patterns of up- or downward movements across two or more observations. Essentially, a simple regression model is also a form of smoothing, but its disadvantage is that it reduces all variability to a single, overarching trend. The Loess smoothing applied in this article reduces the short-term (micro) variability, but conserves the mid-level (meso) variability.

5.3 Results

5.3.1 Teacher's scientific reasoning eliciting questions (TSEQ)

Figure 7 | *Teacher's scientific reasoning eliciting questions (TSEQ)*



During the coaching sessions, teachers from the experimental condition ask more scientific reasoning eliciting questions than during the pre-intervention lessons, as can be seen in figure 7. This figure shows that the amount of TSEQ for the experimental group increased significantly, from 36.5 for the pre-intervention sessions to 52.3, the mean of the four intervention sessions (p=.02), with a medium effect size (d=0.77). This effect is no longer observable two months later, during the post-intervention lessons. In comparison with the pre-intervention lessons, there is no significant increase observable during the post-intervention lessons (p=.32).

The starting level of TSEQ of the control group is not significantly different from the starting level of the experimental group (p=.16). However, the teachers from the control group show a significant drop in TSEQ from pre-intervention to post-intervention (p< .001), as can be seen in figure 7. During the pre-intervention lessons the teachers, on average, ask 28.5 questions during the first 15 minutes of a lesson, which decreases by 16.5 leaving 12 questions during the post-intervention lessons. When comparing the results of the experimental group with the control group of the pre- and post-intervention conditions, the intervention group remains on the same level, whereas the control group shows a significant drop of 16.5 on average. This difference between the two groups from pre- to post-intervention in the level of TSEQ is significant (*p*=.03). Although the experimental group did not show improvement during the post-intervention, they clearly did not diminish their amount of teacher's scientific reasoning eliciting questions either, as did the control group.

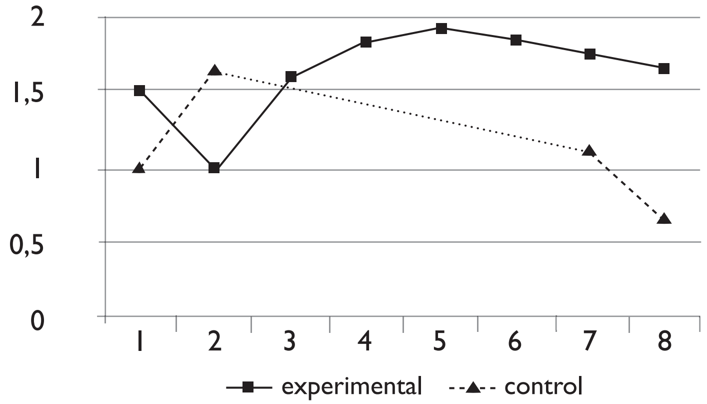
Because not all lessons have the same topic, and because some lessons are more suitable than others for provoking questions, the proportion of the empirical cycle questions to the over all questions was also calculated. This proportion however showed the same pattern as in figure 7, where the absolute amount of empirical cycle questions is shown: a significant increase from pre-intervention to intervention lessons (*p*=.01), no significant increase from pre-intervention to intervention lessons (*p*=.30), and a significant difference between the experimental and the control group (*p*=.01).

Hypothesis 1a can be partly confirmed by these results. The intervention has had a significant effect on the amount of questions asked, but the effect does not seem to last beyond the intervention. However, hypothesis 1b can be confirmed. In comparison with the control group, the experimental group's number of questions stays at the pre-intervention level, whereas the amount of questions of the control group drops to a lower amount. The fact that the experimental group did not drop below the pre-intervention amount gives an indication for a longer lasting effect of the intervention (hypothesis 3).

5.3.2 Pupils' level of scientific reasoning (PLS)

As shown in figure 8, the mean level of pupils' PLS in the experimental condition significantly increased from 1.3 for the pre-intervention lessons to 1.8, for the two post-intervention lessons with a large effect size (*p*=.02; *d*=0.83). This effect was also visible during the intervention lessons. The difference from pre- to post-intervention between the mean of the pre-intervention (1.3) and the mean of the intervention sessions (1.8) is significant with a large effect size (*p*=.002; *d*=0.89). Regarding the control group, a significant decrease of 0.4 occurred, from average 1.3 to average 0.9 (*p*=.05; *d*=1.43).

Figure 8 | *Pupils' level of scientific reasoning (PLS)*



When comparing the experimental group with the control group, the experimental group shows an increase in level of reasoning of .5, whereas the control group shows a decrease of .4. The difference between the two groups is significant as well (p=.01). These results confirm hypothesis 2a and 2b, namely, that the PLS of the experimental group increases, whereas the control group's PLS does not, as well as hypothesis 3, that addresses the longer lasting effect. The pupils show an increase in their level of scientific reasoning during the program, and the experimental group shows an increase, whereas the control group shows a decrease.

5.3.3 Individual teachers' trajectories

5.3.3.1 *Slopes for the change in scientific reasoning eliciting questions for each teacher*

Table 8 | *Slopes for the change in scientific reasoning eliciting questions for teachers A-F*

	Teacher		Teacher		Teacher		Teacher		Teacher		Teacher	
Experimental group	A	*p*	B	*p*	C	*p*	D	*p*	E	*p*	F	*p*
Measurement 1-6	9,13	.03	6,52	.02	7,78	.02	6,04	.05	-0,29	.53	2,31	.38
Measurement 1-8	1,00	.39	0,65	.40	3,53	.06	4,78	.01	-2,17	.73	-0,05	.51

Slopes are calculated for all six teachers (table 8) with regard to their use of TSEQ. First, the slopes over the pre-intervention and the intervention lessons (measurement points 1 to 6), and secondly, over all lessons including the post-intervention lessons (measurement points 1 to 8) were determined. With regard to the slopes of measurement point 1-6, four of the six teachers show a significant positive slope, i.e., they benefitted from the intervention (teacher A, B, C and D, with respectively *p*=.03, *p*=.02, *p*=.02 and *p*=.05). The change in slope of both other teachers (E and F) is not significant i.e., their results cannot be distinguished from a random pattern. The slopes of measurement points 1 to 8 show that only the positive slope of one teacher (D) is significant (*p*=.01),i.e., a significant increase in the number of questions exists. The positive slope of one other teacher (C) approaches the significance level (*p*=.06), which suggests that her slope shows a similar trend. Four teachers show no significant change.

With these results, hypothesis 4a can be confirmed. Inter-individual variability occurs, in that individual teachers will show different patterns of changes.

In summary, three patterns of change can be recognized; the first pattern entails that no behavioral change is visible during the trajectory. This pattern can be seen in the results of two teachers (E and F). The second pattern is that teachers show behavioral change until the last intervention lessons, and then fall back on their initial level, which is the case for three teachers (A,B and C). The third pattern entails behavioral change which endures over the post-intervention lessons (one teacher, D).

5.3.3.2 *Slopes for the change in pupils' level of reasoning for each teacher*

Table 9 | *Slopes for the change in pupils' level of reasoning*

	Teacher		Teacher		Teacher		Teacher		Teacher		Teacher	
Experimental group	A	*p*	B	*p*	C	*p*	D	*p*	E	*p*	F	*p*
Measurement 1-6	0,15	.03	0,42	.02	0,30	.02	0,03	.44	-0,14	.78	0,15	.09
Measurement 1-8	0,05	.19	0,25	.03	0,07	.27	0,11	.17	-0,07	.72	0,09	.10

Table 9 gives an overview of the slopes of the results of the participating teachers' pupils' PLS, again calculated separately during the pre-intervention and the intervention lessons (measurement points 1 to 6), and during all lessons including the post-intervention lessons (measurement points 1 to 8). With regard to measurement points 1 to 6, the group of pupils of three of the six teachers (teacher A, B, and C, *p*=.03, *p*=.02, and *p*=.02 resp.) show a significant positive slope, i.e., they benefited from the intervention. The positive slope of the pupils of teacher F approached the significance level (*p*=.09), which suggests a comparable trend in the change of PLS towards significance. The slope of the other groups of pupils (teachers D and E) is not significant, i.e., the results of these two groups of pupils are not distinguishable from a 0 slope, indicating random fluctuation. A look at the slopes of measurement points 1 to 8 shows that the slope of only one group of pupils (teacher B, *p*=.03) shows a significant positive slope, i.e., a significant increase in their PLS, whereas one other group of pupils (teacher F, *p*=.10) shows a trend towards significance. Four groups of pupils show no significant change over this period.

5.3.3.3 *Coherence in the patterns of change in individual teachers' use of TSEQ and their pupils' PLS.*

Examining the coherence in patterns of change is only meaningful if any coherence exists between individual teachers' use of TSEQ and their pupils' PLS. Therefore, correlations were calculated between the amount of TSEQ and the mean PLS for all teachers and all lessons. The overall correlation was 0.62 and the correlations for the individual teachers varied from 0.54 to 0.83, representing an intermediate coherence between teachers' and pupils' behavior. These correlations are statistically significant (*p*<.001).

Next, in order to examine the level of coherence between the patterns of change in individual teachers' use of TSEQ and their pupils' PLS, a visual inspection of the graphs was carried out. In figure 9, graph A depicts the raw data of teacher A's TSEQ and her pupils' PLS, graph B the raw data of teacher B, etc.

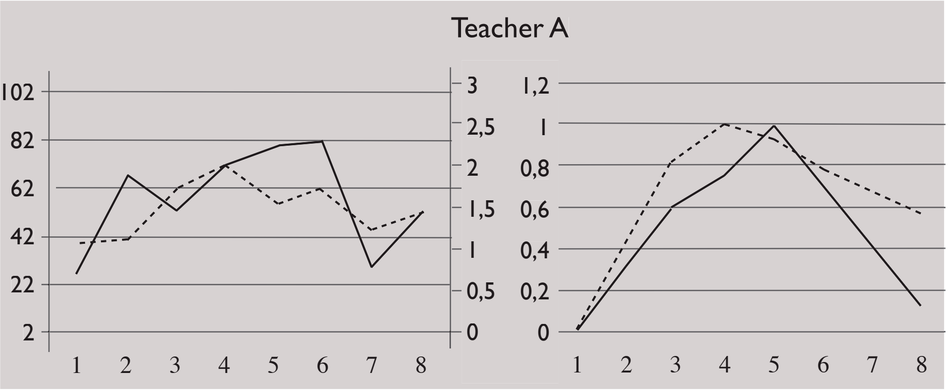
Coherence can be defined in two ways. First, as similarity in the direction of change, as measured between two measurement points, i.e., both variables change in a positive direction or in a negative direction simultaneously, i.e., the direction of change is 'plus plus' or 'minus minus'. 'Plus minus' or 'minus plus' are incoherent changes. TSEQ and PLS can be coherent, in the sense that they move or do not move in the same direction. Figure 9a shows that some coherence can be seen in all teacher/pupils combinations during the whole trajectory, although not in all cases (for instance combination E). Overall, the pupils in the classrooms seem to show more or less the same pattern as their teacher. In one combination, all seven changes in direction that occur are coherent (combination D), in one combination six changes out of seven are coherent (C). Three combinations (A, E and F) show five out of seven coherent changes, whereas one combination shows three out of seven coherent changes (B).

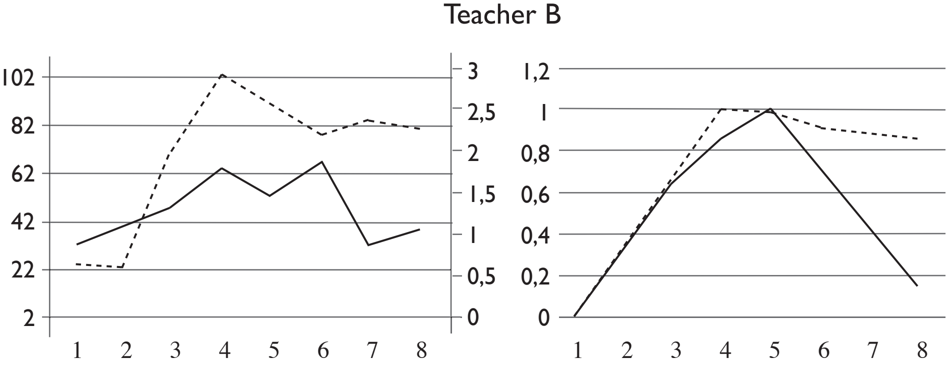
Secondly, coherence can be seen in the patterns teachers and their pupils show. Here, teacher D's pupils show an increase from pre-intervention 1 on, and teacher E's pupils show the same erratic pattern as their teacher. Teacher B's pupils follow her pattern of increase or decrease until coaching lesson 4; during the post-intervention lessons the pupils stay at a high level of reasoning, whereas

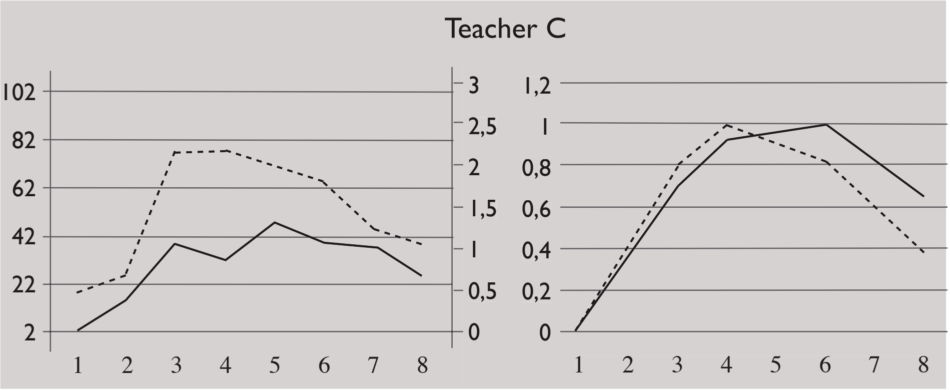
Figure 9a | *Coherence TSEQ and PLS Teacher A-F*
9b | *Coherence TSEQ and PLS Teacher A-F, smoothed and normalized*

9a

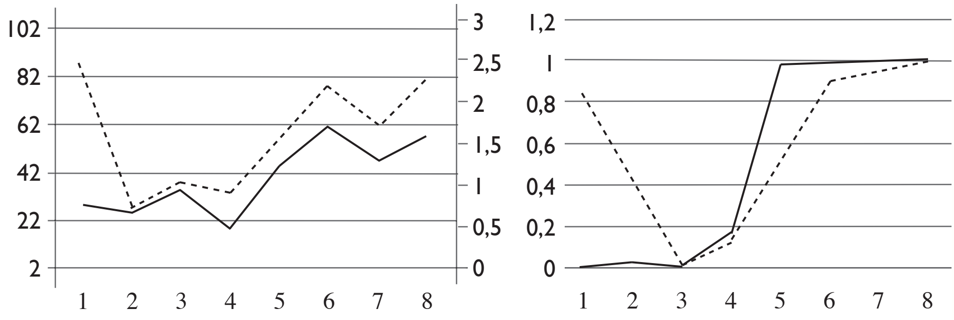
9b


Teacher A

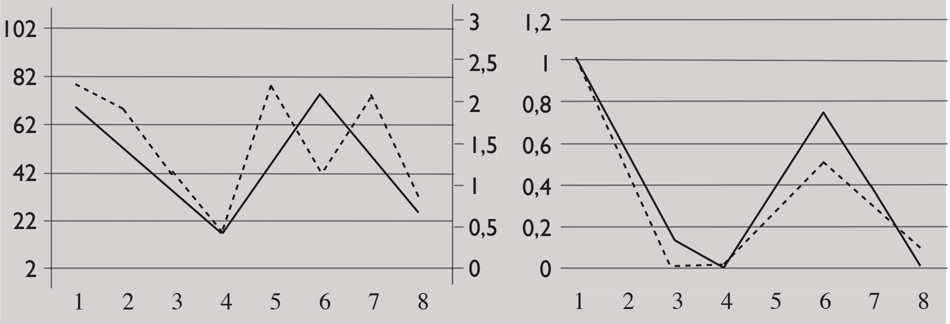

Teacher B


Teacher C

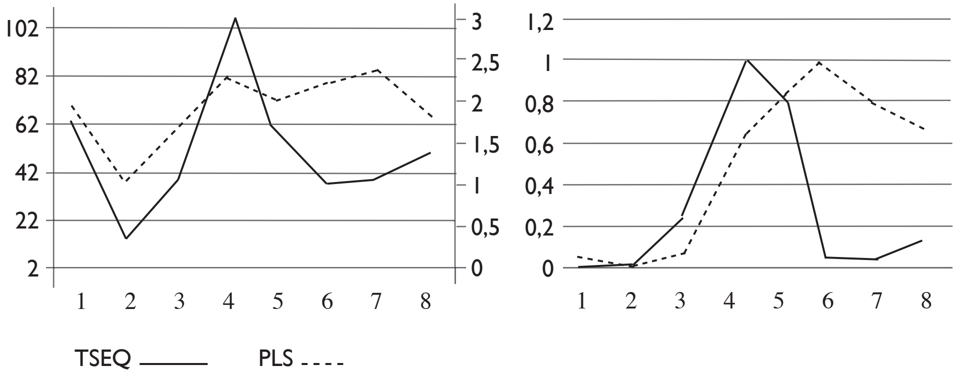
TSEQ ______ PLS ------



Teacher D



Teacher E



Teacher F

teacher B herself declines. Teacher C's pupils follow exactly the same pattern as their teacher: increase during the coaching lessons, decrease during the post-intervention lessons. Teachers A and F and their pupils do not show a clear pattern.

Each way of measuring coherence gives different results. The first way, with regard to coherent changes, shows that teacher D has the most coherent results, whereas the second way, with regard to coherent visible patterns, shows that both teachers C and D have the best coherent pattern. However, both definitions lead to the same conclusion, namely, that inter-individual differences can be observed: the level of coherence differs for the different teacher-pupils combinations.

In order to determine the statistical significance, in addition to the former two coherence measures, the coherence of all teachers together with regard to their TSEQ and their pupils' PLS was calculated by means of a correlation of the slopes for both measurement points 1 to 6 and measurement points 1 to 8. Despite the individual differences, the slopes are coherent with correlations of respectively .64, representing an intermediate coherence and .37, representing a weak coherence. These correlations show that the overall trends in the teachers' questions and the overall trends in the pupils' answers or reasoning are related to one another. This correlation is not statistically significant with p=.27 for the correlation of the slopes for measurement points 1 to 8; however, it approached significance for the correlation of the slopes for measurement points 1 to 6 with p=.07.

To further investigate the coherence in the interaction patterns between the individual teachers and their group of pupils, we reduced the short-term (micro) variability by means of using smoothed, normalized graphs (figure 9b, teachers A-F). A slightly different picture can be observed in comparison with the raw data in figure 9a. The following patterns can be distinguished: two teacher/pupils combinations (C and E) show the same pattern during the whole trajectory. One combination (D) shows the same pattern only after both pre-intervention lessons. The graphs of combinations A and B show that the levels of teacher and pupils stay at approximately the same level during the first six measurement points of the coaching trajectory. Their pupils, however, stay at a higher PLS during measurement point seven and eight, at the same moment that the teachers' TSEQ drops. Combination F shows yet another pattern: the teacher's amount of TSEQ increases only marginally during the trajectory, and decreases again at the end, whereas her pupils' level of reasoning increases. In these latter three cases (A, B, and F) the pupils' PLS stays at a higher level, even if their teachers' TSEQ decreases.

Comparing the patterns found in these smoothed graphs with the averaged results for the separate variables TSEQ and PLS, as shown in figure 7 and 8, it can be seen that the results of the combinations A, B and F are in line with the averaged results of the separate variables. Combination C shows a different pattern: the TSEQ and the PLS show the same pattern during all measurement points 1-8. In these four combinations (A, B, C and F) the pupils' PLS at the end of the trajectory is clearly above the starting level. Combination E shows another pattern: both teacher's TSEQ and pupils' PLS are erratic, and are just slightly in line with each other. Combination D shows a unique pattern as well: the teacher starts at a low level of TSEQ, whereas her pupils' PLS starts at a high level. During the trajectory, the TSEQ and the PLS gradually merge.

Hypothesis 4b cannot be confirmed with these results. We expected an increase over time in both TSEQ and PLS in individual teachers. We can conclude that a form of overall coherence exists with regard to the patterns of change observable in individual teachers and their accompanying group of pupils according to the raw data. The smoothed data show this same coherence, but in addition, they give more information about the patterns that can be found: they show that an increase over time in both variables can only be seen in combination C. Three combinations (A, B and F) show an increase in PLS only; the other combinations (D and E) show no increase at all.

5.4 Conclusion and Discussion

5.4.1 Conclusion

In this study, we investigated the effects of a coaching program (VFC-T) on teachers' scientific reasoning eliciting questions and on their pupils' level of scientific reasoning. We expected teachers to increase their number of questions that stimulate pupils' scientific reasoning results (hypothesis 1a). This expectation was confirmed, as the amount of TSEQ asked by the experimental group increased significantly; from 36.5 for the pre-intervention sessions to 52.3, the mean of the four intervention sessions (p=.018), with a medium effect size (d=0.77). We also expected this increase to have a longer lasting effect, as shown in the post-measurement two months after the program (hypothesis 3). This expectation was not confirmed. During the post-intervention lessons, the TSEQ of the experimental group diminished to about the same amount of questions as were asked during the pre-test lessons.

However, the hypothesis that the results of the experimental group would differ from the results of the control group (hypothesis 1b) was, in a sense, indirectly confirmed: a significant drop in TSEQ could be seen from pre-intervention to post-intervention lessons for the control group. This finding is consistent with declining developmental trends in quality indicators of teaching practices during a school year as a relatively ubiquitous phenomenon, which has been reported in earlier studies using observational measures of teachers behavior (Evertson & Veldman, 1981; Opdenakker, Maulana, & den Brok, 2012; Stroet, 2014). A possible explanation for the phenomenon that the control, as well as the experimental group, showed a decline in comparison to the earlier levels of asking questions could be that the intervention was carried out in March and April, which implicates that the post-intervention lessons were recorded in June, at the end of the school year. During the end of the school year, teachers tend to give more emphasis on social activities, which implies that teachers and students are less focused on high level teaching and high-level intellectual performance than during the rest of the school year. The fact that the level of questions in the experimental group was considerably less affected by this end-of-year phenomenon than the control group could elucidate the results of hypothesis 3, and provides a justification for the long term effectiveness of the intervention. This effectiveness is found in the *difference* between the final levels of reasoning eliciting questions between the experimental and the control group.

Another explanation for the differences between the experimental and the control group could be that an observer effect is present; i.e., the effect that individuals improve or modify an aspect of their behavior in response to their awareness of being observed. In order to partially reduce this effect, we did not communicate to any of the participants which variables would be used to measure the effectiveness of the intervention.

Secondly, we expected pupils in the experimental group to show an increase in the PLS during the program, as well as afterwards, demonstrated by the post-measurement two months after the program (hypothesis 2). This expectation could be confirmed. In addition, it is very clear that the pupils were, in fact, much less influenced by observer effects or end-of-year effects than their teachers, since they do not show a decline towards the end of the year.

Thirdly, the expectation was that the patterns of change in the relationship between teachers and pupils would show considerable inter individual variability (hypothesis 4a). This expectation was clearly confirmed. Three patterns can be recognized, namely, no behavioral change at all, behavioral change until the last intervention lessons, and behavioral change which endures over the post-intervention lessons (Wetzels, Steenbeek, & Van Geert, 2015). Finally, we expected coherence with regard to the patterns of change observable in individual teachers and their accompanying group of pupils (hypothesis 4b). The expectation with regard to the coherence in the patterns of change could be confirmed, first by means of the overall correlation and the correlations for the individual teachers between teachers' use of TSEQ and their pupils' PLS, secondly by means of correlations of the slopes of the teacher-and pupils-variables, and finally, by means of additional coherence measures. As predicted in hypothesis 4a, the patterns of coherence also showed clear inter-individual variability. The dominant pattern that three of the six combinations show, however, is that pupils have learned to reason at a higher level at the end of the coaching trajectory, and have benefited from the way teachers elicit scientific reasoning in the earlier coaching sessions, even though the teachers regress during the final sessions. That is, the intervention seems more sustainable for pupils than for teachers, although the sustainability for teachers depends on whether an end-of-the year or observer effect exists or not.

5.4.2 Limitations and future research

This multiple case study was conducted with a small group of teachers originating from two schools and one coach. The small number of teachers is a direct consequence of the fact that we wanted to answer our research question by means of a labor-intensive, but ecologically valid method, namely, collecting observation data in an authentic situation, and by means of a time serial study of repeated, observed lessons. Because of this methodological choice, the number of participants is, by definition, small. It is clear that the number of observed classes should be increased during further, comparable in-depth studies of authentic teaching situations and reasoning of children.

Furthermore, large inter-individual variability between teachers, as well as intra-individual variability within teachers, were observable in both variables. These results resemble findings in research that focuses on linguistic variables in teacher-pupils interaction (Menninga, van Dijk, Wetzels, Steenbeek, & Van Geert, 2015). Tentative patterns hopefully can be confirmed by future research that focuses on larger scale data, with an emphasis on overall results, as well as individual results, both quantitative and qualitative (Creswell & Plano Clark, 2011). This combination can give more insights regarding the elements that affect the effectiveness of an intervention. For instance, in this study, one teacher/student combination (F) hardly benefited from the intervention. The fact that an intervention is effective at a group level does not imply that it is effective for each individual case in the group. More insight is needed regarding the elements that are responsible for deviant individual results (Barlow & Nock, 2009; Molenaar & Campbell, 2009; Rose et al., 2013).

An important limitation of the current study is that teachers were only coached for four weeks, without any follow-up coaching. It is questionable whether this relatively short coaching period was long enough in order to yield sustainable results; however, long interventions are expensive and sensitive to a lot of attrition. It should be mentioned that other studies (Fabiano et al., 2013; Garet et al., 2001; Han & Weiss, 2005) do suggest that longer lasting trajectories are more effective in this respect. Longitudinal research on the effect of the intervention, with perhaps one or two follow up coaching sessions each year, might reveal that follow up sessions do contribute to the sustainability of an intervention (Dishion & Stormshak, 2007; Guskey & Yoon, 2009; Sandholtz & Ringstaff, 2013).

Another limitation was the way students' performance was measured, namely, only at a group level instead of on both a group level and individually. In addition to studying the level of aggregation of the class, it is of course also very interesting to study the answers at an individual level because ultimately the effect of an intervention must ideally result in an effect in every individual pupil. Focusing on the class level conceals the fact that the intervention might be fine for a rather small subset of students, but entirely miss a number of other students, and possibly even miss the students who could most benefit from the intervention. Regrettably, focusing on individual levels was not possible because of the limited amount of answers of each pupil, and because individual answers in the group could not always be allocated to one specific pupil. The results, therefore, can only be used to measure the effectiveness of the intervention for teachers, individually and on the group level, and not on the level of individual pupils. Therefore, an observational study on the level of individual pupils is a recommendation for the future.

In this study, we limited ourselves to reporting teachers' and pupils' verbal utterances, and more specifically, to teachers' questioning and pupils' level of reasoning. These are not the only variables that can be used to observe changed behavior in the classroom. In more fundamental research, Meindertsma (2014), for instance, uses a variable that specifies the level of openness teachers employ in their utterances, and other researchers examine pupils' nonverbal behavior during reasoning tasks (Goldin-Meadow & Alibali, 2002; Hoekstra, van der Steen, Cox, & Van Geert, n.d.; Thelen & Corbetta, 2002).

We suggest addressing these aforementioned limitations in future research by using a similar real-life design and in-depth study of authentic teacher and pupil behavior, complemented with firstly, an additional number of teacher-pupils combinations, secondly, an increase in the duration of the intervention, and finally an extension of the observed variables including teacher openness and nonverbal reasoning behavior of the pupils.

As is extensively described in chapter 3, a teacher and a school are each complex dynamic systems, which implies that many aspects dynamically determine the effectiveness of an intervention. During the intervention, the coach has to adapt the intervention to the participants' circumstances and specific needs, paying close attention to the diverse ways all the aspects are intertwined and influence each other. In turn, school boards should not treat an intervention as an isolated tool, the effect of which entirely resides in the tool itself. Instead, they should treat an intervention as a tool, the effectiveness of which, is highly dependent on the way this tool is used under the circumstances and concrete contexts, as, for instance, the motivation of the participants. School boards should make efforts to prepare and maintain the local and current context of the intervention, i.e., the school, the teacher and its surroundings, in an optimal way, so that effectiveness can be optimized.

CHAPTER 6:

Summary of Findings, Conclusion and Discussion

CHAPTER 6:
Summary of Findings, Conclusion, and Discussion

The overall aim of this dissertation was twofold. The first aim was to develop and describe a coaching program for teachers in the lower grades of primary education that influences teachers' behavior in order to stimulate pupils' scientific reasoning, taking into account that an intervention takes place in a complex world with various intertwined interacting elements. The second aim was to investigate, in the form of an in-depth study, the effectiveness of the intervention, the extent to which the intervention influenced teachers' well-being, and the extent to which teachers' and students' behaviors changed during the actual science lessons over the course of the intervention.

6.1 Summary of Findings and Conclusions

In chapter 2 we gave an extensive description of the Video Feedback Coaching for Teachers VFC-T and its theoretical foundations. Important elements for the coaching program came from the findings of the Curious Minds project, from the Video Interaction Guidance (VIG) and Video enhanced Reflective Practice (VERP) literature, and from general literature regarding effective educational practices, in particular, and behavioral change, in general. The Curious Minds assumptions were used to develop a coaching program that makes use of video recordings. Practice in the classroom and reflective practice of teacher and coach together were thus combined in the VFC-T. In order to ensure treatment integrity, a training for coaches was also developed. In this training, coaches acquired knowledge and skills needed for correct implementation of the VFC-T. The skills, with regard to working with this knowledge, were practiced by using video-recordings of prior coaching trajectories and coaching trajectories that the coaches carried out themselves.

In chapter 3, we elaborated further on the principles of professional development in general and the VFC-T in particular. A theoretical overview is given of effective aspects of interventions regarding teachers' professionalization. Intervention-, teacher- and context-specific aspects and aspects regarding the implementation of an intervention were first described from a standard viewpoint, after which the issue of effectiveness was re-interpreted in terms of a complexity approach. We concluded that the particular, context-specific intertwinement of all relevant aspects influenced the outcome of an intervention, so that the same intervention had a different progress and outcome in different situations. That is, we defended the view that an intervention is not a fixed protocol imposed on reality. Instead, an intervention is something like a description of a particular set of practices that forms the starting point of a process with a great number of *emergent* idiosyncratic properties that may all contribute to, or counteract, the effectiveness of the process. A multiple case study was used to illustrate this complexity view. In these cases we focused on how the intervention played out at the level of real-time activities of individual teachers in the context of their classrooms and schools. The two participating teachers started with the same intervention-specific and implementation conditions. In each case, we looked at the interplay between all aspects, namely, the intervention-and implementation-specific aspects, but also the teacher- and context-specific aspects. We concluded that the dynamic interplay between the aspects created different outcomes for the two teachers, and that in order to correctly evaluate the effectiveness of a particular intervention, it is important to account for the way in which all aspects are dynamically intertwined over the course of the actual intervention. Moreover, knowledge about how aspects may be dynamically intertwined, and have an influence on each other during the actual intervention process can be used to design more effective interventions, and to implement them more effectively with higher chances that the intervention has a sustainable character.

The studies in chapter 4 were carried out to give an answer to the second research question of this dissertation, namely, to what extent the VFC-T and the accompanying science and technology teaching had an effect on teachers' well- being during their teaching of science and technology. The major question of this study was whether teachers' well-being would increase as a result of the intervention. To obtain an answer to this question, interviews with participating teachers were held. Teachers' experiences were positive: in the interviews (which were held approximately a month after the coaching was finished) teachers mentioned positive changes, either in their own behavior, or in the behavior of pupils, or in both. Teachers found that their own well-being and motivation increased as a result of better preparation of their lessons, their increase of S&T knowledge, and better interaction with their pupils during the lessons. Moreover, they mentioned that they felt their teaching of science and technology had improved as a result of the coaching, in this particular context of science and technology teaching, to young children. The change they saw in their pupils' behaviour referred to the increase in enthusiasm the pupils showed during S&T lessons. As a result, teachers were very happy with the changes they saw in themselves, and the positive effects they saw in their pupils' behavior. The increase in well-being, which was a subjective measurement based on interviews with the participating teachers, was in line with the more objective, quantitative result of a later study, namely, the positive effect on the cognitive quality of the questions teachers asked during the coaching sessions of the VFC-T: teachers asked more questions related to the empirical cycle and more follow up questions.

Chapter 5 gives an extensive answer to the question concerning the results of the VFC-T in terms of teachers' and pupils' changed behavior in the classroom. We conducted an in-depth study, focusing on the actual teaching behavior in the real class context: behavior that is representative of what really happens in terms of real-time ongoing processes. For this reason the effectiveness study has been limited to six teachers and their classes. These six teachers were coached by means of the VFC-T during S&T-lessons, whereas a control group of five teachers performed S&T lessons without the coaching. We first investigated the effects of the VFC-T on the amount of scientific reasoning elicting questions teachers used in the classroom, both during the coaching sessions and two months later. The experimental group increased significantly in their use of scientific reasoning elicting questions during the coaching sessions with a medium effect size of *d*=.77, although two months later this amount dropped to a level similar to that at the start of the trajectory. However, if the long-term effects of the intervention are measured as the difference between the final levels of reasoning eliciting questions between the experimental and the control group, a significant result can be observed because the control group showed a considerably bigger decline two months after the intervention. This quite significant decline for both the experimental and control group seemed to be related to the fact that the post-intervention lessons took place at the end of the school year, in June, at a time during the school year where teachers are focusing on entirely different things than science teaching, for instance, the end-of-year social activities. The fact that the intervention group remained on the pre-intervention level, and was therefore less affected by this end-of-year phenomenon than the control group, which showed a significant decline, provides a justification for the effectiveness of the intervention.

Secondly, we investigated the effects of the VFC-T on the level of reasoning that pupils showed during the science lessons. The experimental group showed an increase in their level of reasoning, both during the coaching sessions and two months later, and this increase was statistically significant in comparison with the control group. Thirdly, we studied teachers' individual patterns of change. Three patterns were found, namely, no behavioral change at all, behavioral change until the last intervention lessons followed by a decline towards the post-intervention lessons, and behavioral change which endures over the post-intervention lessons. Finally, we looked at teachers' individual patterns of change in relationship with their pupils' results. We observed coherence between the patterns of change observable in individual teachers and the patterns of change in the accompanying groups of pupils. Also these patterns of coherence showed clear inter-individual variability, similar to what could be observed in the teachers 'and pupils' individual patterns. However, the forms of coherence show a dominant pattern, namely, first, that the higher level of reasoning resulting from the intervention lasted for two months after the end of the coaching trajectory, and, second, that the pupils benefited from the way teachers elicit scientific reasoning in the earlier coaching sessions, even though the teachers regress during the final sessions as a result of the already mentioned end-of-the-year phenomenon.

6.2 Discussion: Issues with regard to Applied Methodological and Research Aspects

During the project, some important issues arose that might have interesting implications for future research on science & technology teaching in lower grades and teacher education, for the development of interventions aimed at teachers' professional development, and for science teaching in general. In the next sections, issues with regard to the science knowledge necessary for teaching, the sample size, the advantages of the use of video recording, and the way that complexity can be addressed by using mathematical simulation models will be discussed consecutively.

6.2.1 What knowledge do teachers need for science teaching in lower grades?

The first issue concerns the role of science content knowledge and pedagogical content knowledge when teaching science in elementary school in general, and in particular in the lower grades. We argue that the starting point for teachers should not be factual science and technology knowledge, but knowledge of the process of doing science. This as a starting point may lead to a process of acquiring more content-related scientific knowledge. We have addressed this point in the design of the intervention (chapter 2).

Teachers, although they acknowledge the importance of teaching science and technology to their pupils, feel inadequately prepared to do so themselves (Appleton, 1999; Dickinson et al., 1997; Mantzicopoulos et al., 2008). For this reason, in some schools, special science and technology teachers have been appointed. In other schools, teachers give hands-on arts and crafts lessons as an equivalent for science and technology lessons. In both cases, teachers do not actually spend time on teaching science. Additional reasons for the fact that teachers do not teach science and technology are, among others, the fact that they think that learning how to reason scientifically requires a level of understanding that goes far beyond the cognitive abilities of the young pupils, which explains why they as teachers refrain from asking scientific reasoning eliciting questions in the classroom. Yet another reason for not teaching science is their opinion that they do not have enough experience (see also Dickinson et al. (1997). However, the main reason teachers have for not teaching science are based on the assumption that they lack sufficient knowledge themselves. This lack of knowledge concerns two aspects that are clearly different: first, teachers do not feel confident in their knowledge of science, and second, they do not know how to teach science effectively. The first aspect concerns content knowledge, that is, the knowledge about science as a subject. The second aspect concerns the way science can be optimally taught, the pedagogical content knowledge (Shulman, 1987). However, is this true, and should an intervention address both types of knowledge?

As for the first aspect, the sheer volume of science knowledge is enormous, and the amount of scientific knowledge is increasing at an incredible rate (Costa & Liebmann, 1995). The world-famous physicist, Hawking (1998), suggested that if knowledge would keep growing at the current rate, by 2600, if you stacked up the books next to each other, you had to move at 90 miles an hour just to keep up with the end of the line. In addition to the fact that the amount and growth of science knowledge are enormous, many controversies exist in science, for instance, controversies about global warming or ethical discussions about the use of stem-cells. If the scientists themselves cannot agree what true knowledge is, it is even more unlikely that a lay person such as a teacher can decide what scientific knowledge to teach. If such a vast amount of knowledge is available, it seems impossible to know everything. Therefore, it seems inevitable that children in a classroom will ask questions to which teachers do not know the answer. No matter how much a teacher studies science content, it will never be sufficient (Martin, 2009). Based on all this, one may come to the bleak conclusion that teaching science in primary education is a hopeless endeavor. However, we should ask ourselves whether this encyclopedic approach to scientific knowledge-under-construction is appropriate in the context of primary education. In fact, what teachers need is a good basic level of scientific content knowledge, that is to say, knowledge about the fundamental and overarching principles that lie at the basis of scientific knowledge in general, and that, in a sense, constitute the core knowledge of science. This should be the kind of knowledge that provides teachers with sufficient background to ask further questions, and to give their pupils sufficient room for scientific reasoning (Carlsen & Hall, 1997). A prime example of this knowledge is the knowledge of the empirical cycle. The empirical cycle acts both as a key concept for real science and science learning, as well as a means of structuring science teaching, and can help teachers understand science and technology as a coherent, meaningful system (Richland et al., 2012). This key concept can form the basis of lower grade teachers' science knowledge, in addition to fundamental and easy to learn knowledge of, for instance, floating and sinking or air pressure and other relatively easy to use concepts in the classroom.

Darling-Hammond (2000) found that content knowledge is necessary, but not sufficient for teaching science, and the lower the grades being taught, the more important the emphasis on pedagogical content knowledge about how to bring science in practice, i.e., the process of science, should be. For younger children it is likely that their teachers do not need extensive additional factual knowledge about science and technology to teach it well, other than some basic and fundamental principles they already know. What is more important is that teachers know how to teach science, and how children learn science. For children, knowledge of facts and theories is not as important as knowing how to do science, how to reason, how to analyze, and how to observe during science activities. The process of doing science that children need to learn is precisely what teachers need to learn. Moreover, this knowledge can help both teachers and their pupils find answers to questions they do not know the answer to. The empirical cycle can act as the core knowledge about how science is done, that is to say, how science works in practice because this implies a number of teachable scientific skills, namely observing, describing what is observed, asking questions, and reasoning about possible questions and answers.

An example of the use of the empirical cycle, while making use of general available knowledge, is the following: a teacher wants to use the air squirt experiment in a science class in preschool or grade 1. What kind of knowledge does she need? First of all, she should know how to use the empirical cycle to structure the lesson. In addition, the teacher should know the physical principle demonstrated in the air squirt on a basic level, which is that you can compress a volume of gas, but as you compress that volume, its pressure will increase, and as a consequence, it will exert a force on the walls of the container in which the gas is compressed. The teacher's knowledge should at least contain some sort of intuitive understanding of the described principle, and she should at least understand that the principles that govern the air squirt also govern blowing up balloons, or pumping up the tires of a bike or an inflatable bed. Teachers should know addresses of websites which not only provide them with good suggestions for classroom activities, but also which explain the basic physical principles of these activities in simple terms, so that these principles can guide them. An excellent example of such a website in Dutch is www.proefjes.nl.

In short, the starting point for teachers should not be factual science and technology knowledge, but knowledge of the process of doing science. In this way, a process of acquiring more scientific knowledge can start. The other way around, first acquiring scientific knowledge, as is often used in teacher education (VTB, VTB-pro), is less effective because teachers cannot apply the newly learned knowledge in the classroom.

6.2.2 What sample size is appropriate for effectiveness studies?

The second issue is methodological by nature, and addresses the choice for a relatively small sample with regard to both experimental and control group. The design of this study is prompted by the aims of the study: to develop and describe a coaching program for teachers, which influences teacher's behavior, in order to stimulate pupils' scientific reasoning, as well as to assess the effectiveness of this coaching program with regard to teachers' well-being and teachers' and children's behavior in the classroom. The question is what kind of design and what sample size is appropriate for achieving these aims.

In general, research with large samples has shown that representative data can be obtained in order to make generalizations about the population. However, data from large sample research are focused on significant results for the sample as a whole. These data lack depth because these measurements of effectiveness are rarely representative of what really happens in terms of real-time ongoing processes. Small samples make it possible to go more in depth into the data, which makes it possible to focus on the actual trajectories of change on the group level, but also on the level of individuals and individual differences. Moreover, small sample research has the typical advantage of close supervision of the intervention, and ensuring for treatment integrity, both of which are not possible in research with larger samples.

Sample sizes clearly have considerable practical implications: if we had had a sample of, for example, 600 teachers, instead of six , practical limitations would have obliged us to measure the teachers' classroom behavior by, for instance, means of questionnaires, asking teachers how they think they formulate questions. At best, we could have measured their behavior by means of an observational checklist administered during a single science lesson. In small sample research, the measurement of the variables of interest can be done in a much more intensive way, thus providing a much deeper insight into the nature and variability of the teacher's behavior. Moreover, actual behavior can be observed in a naturalistic setting, thereby avoiding the drawbacks of questionnaires, for example, socially desirable responding. In addition, a mixed methods research design (Creswell & Plano Clark, 2011) can be used which has the advantage that it combines quantitative and qualitative methods, and provides a more complete view of the research setting, However, the choice for small or large sample research does not only depend on the methodology that researchers want to use. The choice also depends on the amount of time that a researcher can spend. For instance, a large team of researchers could easily follow the methodology used in this dissertation and in the end still sample 100 or more teachers. That is, in-depth research requires the appropriate, extensive investment of research means, which the typical research project in educational science cannot afford.

Due to the nature of the research described in this dissertation, namely, a design study as well as an effect study, we used small samples for the studies described in chapter 3, 4 and 5. This way, instead of average data, individual data concerning processes, i.e., data about a time series of successive lessons are obtained. This research design allows for customized interventions for individuals because one particular intervention does not work for every individual. Small sample research in education could be used more often, especially when designing new interventions, because it allows for better control of the intervention, and necessary adjustments before a larger sample research design is applied. On the other hand, generalization over a larger group of teachers should be done with caution, as only a small group is included in the study. Moreover, generalization to a particular population of teachers does not mean that the generalized message holds for every individual teacher in the population. Generalization conceals the enormous differences amongst individuals of the same population, e.g. the population of lower grade teachers in the Netherlands.

However, small sample studies have another important aim. According to Opfer & Pedder (2011), small sample studies can be used to determine how teacher learning occurs in a variety of concrete situations with different teachers, schools, and learning activities. In this way, small sample studies can shed more light on the various patterns of teacher learning and on the unique situations of individual teachers or contexts. Small sample studies make it possible to investigate mechanisms of teacher learning with specific attention to the different contexts in which such learning takes place.

6.2.3 Why is it important to use video recordings in research?

The use of video recordings gives the possibility to look at a wide variety of aspects of teaching and learning in a microgenetic way. These aspects can range from involvement or curiosity of children in a classroom (Laevers, Declercq, & Jackaman, 2011; Laevers, 2004), to openness of teachers (Meindertsma, 2014), and to level of reasoning (Meindertsma, 2014; Van der Steen, 2014) or gestures (Hoekstra et al., n.d.). Because the video recordings show the actual teaching learning behaviors as they occur in authentic settings (classrooms), they provide objective and uncompressed information about the events that transpired. For this reason, they provide an optimal objective basis for studying phenomena such as the increase in TSEQ and PLS during the intervention. Since the video recordings capture the entire range of phenomena, they can be used to study a wide variety of properties. For instance, we used our video data to study the teachers' questions and the level of reasoning of children, but the same video data can be used to measure the use of academic language by teachers and pupils (Menninga et al., 2015). In the study just referred to, Menninga et al. studied the ratio of language productivity in the teacher-pupils interaction, hypothesizing that the ratio would change in the course of the intervention. One important result of their study could be observed with regard to language productivity: the proportion of teacher utterances significantly decreased over time and their turns shortened. The pupils' turns, on the other hand, increased in length. Both results had large effect sizes (1.57 for the proportion of teacher utterances, .83 for the turn length of the teachers, and 1.04 for the turn length of the pupils). These results indicate that the teachers gave the pupils more opportunities to elaborate their responses, while at the same time, their use of scientific reasoning eliciting questions diminished. Their study showed the same results as in our own studies, with the addition that results are sustainable not only for pupils two months after the intervention, but also for teachers. This could explain the findings of this dissertation that the pupils' results, with regard to their level of reasoning, stay at a significantly high level after two months. The combination of the study described in chapter 5 of this dissertation, and the study of Menninga et al. (2015) implies that further investigation into the video data, by using different variables by means of different coding schemes could be very helpful to explain results.

An additional advantage of the use of video recordings in in-depth research is that it allows for much more detailed operationalizations of the selected variables because of the wide variety of behavior that can be observed. Furthermore, it enables us to study the selected variables over the course of time, as well as the variability of the variables over the time course. Finally, it enables us to focus on the intertwining of variables and on the changing relationships between two variables over time. A good example of the latter is described in chapter 5, namely, that the time series of levels of reasoning of the pupils and the time series of levels of questioning of the teachers changes over time, with some groups of pupils remaining on a high level while the questioning level of the teacher declines. In a large scale research, such a relationship would most likely have been explained by means of a correlation, or a regression model. This correlation or regression model would have concealed the real complexities of the changing relationships.

6.2.4 Can mathematic simulation models do justice to complexity thinking?

In chapter 3, we described effective aspects of interventions regarding teachers' professionalization, as well as a re-interpretation of the effectiveness of these aspects from a complexity view. The conclusion of chapter 3 is that it is important to recognize that all contextual aspects influence each other intertwiningly, and form positive or negative feedback loops, i.e., various personal, social, and environmental factors may eventually play a role and intertwiningly influence each other and the effective working of an intervention, both during and after the intervention (Adelman & Taylor, 2003; Goldspink, 2007). In therapeutic settings, a setting comparable to professional development settings with regard to important characteristics as, for example, behavioral change, a great deal of client outcome (40%) is attributable to the influence of these kinds of factors, namely factors outside of therapy (Lambert & Barley, 2001), whereas only 15% of the outcome is attributable to an intervention itself. Therefore, according to Van Yperen (2010), these kinds of personal, social, and environmental factors have to be included in an intervention, or even specifically be addressed. This way, the overall effectiveness of an intervention can be enhanced. The question is how the intertwining effects of various personal, social and environmental factors can be accounted for in design and effectiveness studies.

In order to do justice to complexity thinking, and to express the complex relationships within the real world, one possibility is to dive deeper into the data by quantifying all available factors, and by using a mathematical simulation model of interactions that takes these aspects into account (Kunnen, 2012; Steenbeek, 2006; Steenbeek et al, 2013; Van Geert, 2014). Such a model gives a simulation of the changes that occur within the values and relationships of all relevant mutually influencing factors and variables over time. Therefore, it is necessary to not only describe all the relevant factors that influence teachers' professional development trajectory, and thus the variables that we used as results, but also to describe concisely the intertwining relationships between factors and variables. For example, we learn from the literature that collective participation of a group of teachers within a school in an intervention trajectory has a positive influence on a teacher's performance (Batt, 2010; Desimone, 2009; Garet et al., 2001). In a simulation model, collective participation can be used as an independent variable that has an influence on the dependent variable teacher's performance, i.e., teacher's level of scientific reasoning eliciting questions. In order to build a model, knowledge is needed about what levels of collective participations exist (for instance, no collective participation, low collective participation, high collective participation) and to what extent the level of collective participation affects the level of scientific reasoning eliciting questions. A mathematical equation can be used to quantify the influence in the form of a dynamic, iterative process (Van Geert, 2014).

Many forms of mathematical model building exist, and in the behavioral and educational sciences most mathematical models are statistical models, explaining the variance in specific variables on the basis of variance and other variables.

However, these models cannot be used if the conceptual framework is that of a complex dynamic systems. In the latter case, a dynamic model is needed, i.e., a mathematical model of the dynamics of the underlying processes. For the development of such a model and the description of the way variables and factors influence each other, theories within the educational and professional development literature should be used. However, these theories are usually not detailed enough as far as the actual mechanisms of change over the course of time of the intended processes. A dynamic model can be built by asking oneself, as a researcher and expert, fundamental questions about the intertwining relationships of the factors within a model, and how they contribute to the change of the variables over time, eventually leading to actively self-sustaining stable states (called attractors). This may lead to several assumptions that can be mathematically translated into the dynamic model. The model can then be used with the available and new data to test the assumptions, and eventually adjust them. Mathematical model building can be an important tool in research because it requires researchers to think about the minimum set of mechanisms and variables required to get a particular process off the ground, that is, it provides a way to make a model more explicit and complete. Moreover, building a mathematical simulation model allows for "playing with the parameters", i.e., to explore what different scenarios, represented by different parameter sets, mean with regard to the predictions about trajectories made by the dynamic model. The model provides therefore more precise knowledge about the dynamic relationships and the resulting processes in the real world, as well as help with the development of better and more focused interventions.

6.3 Discussion: Recommendations for Research, Science Teaching, and Teacher Education

The results of this in-depth research on the effectiveness of a coaching program aimed to contribute to science education in the primary grades. In the following sections, we first give recommendations for future research on science teaching, we then give recommendations for science teaching in the lower grades, and finally, we give recommendations for teacher education. We conclude with the implications this research can have for the current developments in science teaching in the Netherlands.

6.3.1 Recommendations for research

Although the overall results of the VFC-T are mainly positive, the results with regard to sustainability are ambiguous, and for that reason two serious points of concern can be raised. Firstly, the pupils' results two months after the intervention are sustainable, whereas the teachers' results are not. Secondly, the results with regard to teachers' individual patterns of change show that not all teachers change in the desired direction. In order to improve the VFC-T, the next research questions should ask how much coaching is needed, how long the actual intervention should last, and how the coaching program can be adjusted for individuals. In general, long-term intervention processes in combination with longitudinal in-depth studies are recommended in order to examine the effects of interventions over a longer timeframe and to analyze the individual cases in depth. This in turn offers insight in all relevant aspects from an intervention and how they influence each other from a complexity viewpoint. Our experience with the current research leads us to think that perhaps the length of the coaching program could differ for each teacher, according to their learning curve, with a minimum of three coaching sessions within a relatively short time frame, for instance, four or five weeks. Follow up coaching two, six and twelve months afterwards should be added to promote sustainability of the results. Furthermore, the coach should pay attention to contextual factors, such as collective participation of more teachers of a school and active participation of the school principal, but also to other factors that could interfere with the teachers' learning processes. For that reason, the coach should pay attention to collaboration with the principal and the school team as a whole.

Another important issue for further research is the phenomenon that at the end of the school year the control group showed a decline, and the experimental group did not improve in comparison to the earlier levels of asking questions, the so-called end-of-year effect. This effect is also found in earlier studies using observational measures of teachers behavior (Evertson & Veldman, 1981; Opdenakker et al., 2012). This phenomenon should be kept in mind when executing research during a school year, and, moreover, needs further research itself.

The current research is focused on teaching and learning S&T in the lower grades of primary education. Future research is needed to test the applicability for grades 5-8, but also for special needs education. Provisional exploratory research on these topics shows promising results (Honingh, Steenbeek, & Wetzels, 2012; Van Vondel, Steenbeek, Van Dijk, & Van Geert, n.d.).

6.3.2 Recommendations for science teaching in the lower grades

First, we want to emphasize again that the lower grades are important grades for teaching science and technology. Teachers need to stimulate children's science and technology talent from the earliest school years on because that process of stimulation can encourage young children to develop a lasting, basic understanding of scientific concepts and principles that goes far beyond the level they would develop in other circumstances.

Second, in order to help lower grades teachers to understand science and technology as a coherent, meaningful system, and to give structure to teaching and learning (Richland et al., 2012), teachers and learners need to obtain knowledge of a fundamental science concept, namely, the empirical cycle. In lower grades, this concept, in addition to knowledge of, for instance, floating and sinking or air pressure and other relatively simple to use concepts in the classroom, is considered sufficient. Moreover, teachers need to learn the concepts and associated strategies of questioning and scaffolding, so they can give room and support to their pupils' reasoning skills, as described extensively in chapter 2 where the VFC-T is discussed.

Thirdly, the VFC-T addresses the importance of interaction in the relationship between teacher and pupil. As we saw in chapter 2, a teacher has an important role in this interaction process. Constructivist methods, i.e., discovery learning and inquiry learning that are based on hands-on learning, do not do justice to the importance of the interaction process (Mayer, 2004). Teachers often have the misconception that their role is that of a facilitator of their pupils' hands-on learning processes. In classrooms, it is important for teachers to see that they have a much more important role, namely, co-construction of knowledge, i.e., a cooperative construction of knowledge by a child together with the teacher, in order for their pupils to engage in 'minds on' learning. The teacher must take the responsibility or lead in guiding the process, by using strategies such as questioning and scaffolding. The importance of high-quality, focused interaction between teacher and pupil cannot be stressed enough.

6.3.3 Recommendations for teacher education

The video feedback coaching trajectory is an effective and efficient way to change teacher behavior if teachers start such coaching trajectory with the explicit personal aim to improve their level of teaching science and technology. However, as we have seen in the preceding sections, teachers' behavioral change is not easily established. According to Loucks-Horsley et al. (2010), three to five years are needed for teachers to fully implement new ways of working in daily practice. This leads us to the recommendation for educational practice that suggests that professionalization should be carried out in the form of a long-term program of teacher support. It seems that an effective way for this would be to start with a short intervention, as the VFC-T, based on the teacher's own improvement goals, which would then be followed by regular checkup sessions and follow up sessions over the course of a couple of years. The intervention should be embedded in the school in such a way that collective participation of more teachers of a school is stimulated, as well as active participation of the school principal.

Finally, however well designed an intervention is, the intervention should be carried out in consideration of complex dynamic systems, such as schools and teachers, with many intertwiningly influencing contextual factors. Therefore, school boards should not treat an intervention as an isolated causal influence with an intrinsic effectiveness. Instead, they should treat it as a tool of which the effectiveness depends on its use in concrete situations and with idiosyncratic participants. Schools should make efforts to optimize the influencing contextual factors as much as possible so that effectiveness can be enhanced.

6.3.4 Current developments in the Netherlands

The VFC-T is in line with Dutch developments with regard to teaching science and technology. The Dutch Technology Pact 2020 (*Nationaal Techniekpact 2020*, 2013) was established as a joint initiative of central government, the organized business community, the trade unions, the education community, and the regions with the aim of increasing the number of technology graduates by the year 2020, in order to meet the growing demand for skilled technologists. Education providers, employers, workers, young people, the top sectors, and regional and central governments have therefore agreed upon a national Technology Pact. One line of action is relevant for this dissertation, namely, that more students need to choose a study in the field of technology. Therefore, teachers need to be educated in teaching science and technology for children at a young age because a negative attitude towards science can already develop in preschool (Jarvis & Pell, 2005). A program like the VFC-T can help teachers to give children positive experiences with, and basic knowledge of, science because it is easy to implement and does not require large investments in time and material.

In addition, participation in the VFC-T is also possible by means of e-learning. Recently, a web-based training program has been designed for working with excellent pupils in primary education (Wetzels, Steenbeek, & Fraiquin, 2014). Teachers can use the VFC-T, as described in chapter 2, including the use of video feedback, independent of a coach, for instance, together with a coworker. The e-learning program will be extended with an online coaching possibility in the fall of 2015.

The VFC-T is especially designed for use in schools with more or less experienced teachers. An important development is that in the next few years, the Teacher Training College, of the Hanze University of Applied sciences in Groningen, will implement Curious Mind in their curriculum. This way, teachers in training will get acquainted with the Curious Mind way of working in classrooms already in their education.

In conclusion, the results of this dissertation have demonstrated the importance of interaction in the relationship between teacher and pupil and the importance of strategies teachers should adopt in order to fulfill their role in the interaction process. The results have also demonstrated the importance of a coaching program with use of video enhanced reflective practice in order to improve teachers' practice of teaching and pupils' scientific reasoning.

References

Adelman, H.S., & Taylor, L. (2003). On sustainability of project innovations as systemic change. *Journal of Educational and Psychological Consultation*, *14*, 1-25. doi: 10.1207/S1532768XJEPC1401

Alfieri, L., Brooks, P.J., Aldrich, N.J., & Tenenbaum, H.R. (2011). Does discovery-based instruction enhance learning? *Journal of Educational Psychology*, *103*, 1-18. doi: 10.1037/a0021017

Appleton, K.M. (1999). Why teach primary science? Influences on beginning teachers' practices. *International Journal of Science Education, 21*, 37-41. doi: 10.1080/095006999290769

Appleton, K.M. (2003). Toward an understanding of science teaching practice. *Research in Science Education*, *18*, 1-25. doi: 10.1023/A:1023666618800

Armour, K.M., & Yelling, M.R. (2004). Continuing professional development for experienced physical education teachers: Towards effective provision. *Sport, Education and Society*, *9*, 95-114. doi: 10.1080/1357332042000175836

Ball, D.L., Lubienski, S., & Mewborn, D. (2001). Research on teaching mathematics: The unsolved problem of teachers' mathematical knowledge. In V. Richardson (Ed.), *Handbook of research on teaching* (4th ed., pp. 433-456). New York: Macmillan.

Bandura, A. (1971). *Social learning theory*. New York: General Learning Press.

Bandura, A. (1976). Self-reinforcement: Theoretical and methodological considerations. *Behaviorism*, *4*, 135-155.

Bandura, A., & Cervone, D. (1983). Self-evaluative and self-efficacy mechanisms governing the motivational effects of goal systems. *Journal of Personality and Social Psychology*, *45*, 1017-1028.

Barber, M., & Moursched, M. (2007). *How the world's best-performing school systems come out on Top.* McKinsey and Co. London.

Barlow, D.H., & Nock, M.K. (2009). Why can't we be more idiographic in our research? *Perspectives on Psychological Science*, *4*, 19-21. doi: 10.1111/j.1745-6924.2009.01088.x

Barth, R.S. (2004). L*earning by heart*. San Francisco: Jossey-Bass.

Batt, E.G. (2010). Cognitive coaching: A critical phase in professional development to implement sheltered instruction. *Teaching and Teacher Education*, *26*, 997-1005. doi: 10.1016/j.tate.2009.10.042

Baumeister, R.F., Bratslavsky, E., Finkenauer, C., & Vohs, K.D. (2001). Bad is stronger than good. *Review of General Psychology*, *5*, 323-370. doi: 10.1037//1089-2680.5.4.323

Benford, R., & Lawson, A.E. (2001). *Relationships between effective inquiry use and the development of scientific reasoning skills in college biology lab*. Tempe.

Bentley, M.L. (1995). Making the most of the teachable moment: Carpe diem. *Science Activities*, *32*, 23-27. doi: 10.1080/00368121.1995.10113190

Berlyne, D.E. (1966). Curiosity and exploration. *Science*, *153*, 25-33.

Berlyne, D.E. (1970). Novelty, complexity, and hedonic value. *Perception and Psychophysics*, *8*, 279-286.

Berman, P., McLaughlin, M.W.A., Bass, G., Pauly, E., & Zallman, G. (1977). *Federal programs supporting educational change, vol VII: Factors affecting implementation and continuation*. Santa Monica, CA: The Rand Corporation. Retrieved from http://www.osti.gov/servlets/purl/1025774

Binkley, M., Erstad, O., Herman, J., Raizen, S., Ripley, M., Miller-Ricci, M., & Rumble, M. (2012). Defining twenty-first century skills. In P. Griffin, B. Care, & E. McGaw (Eds.), *Assessment and teaching of 21st century skills* (pp. 17-66). New York: Springer.

Birman, B.F., Desimone, L., Porter, A.C., & Garet, M.S. (2000). Designing professional development that works. *Educational Leadership*, *57*, 28-33.

Bleicher, R.E. (2004). Revisiting the STEBI-B: Measuring self-efficacy in preservice elementary teachers. *School Science and Mathematics*, *104*, 383-391. doi: 10.1111/j.1949-8594.2004.tb18004.x

Boelhouwer, M.D. (2013).*Tussen weerstand en weerbaarheid en andere recepten*. University of Groningen.

Boomstra, N. (2014). *Read all about it!* University of Groningen.

Borko, H., Jacobs, J., Eiteljorg, E., & Pittman, M.E. (2008). Video as a tool for fostering productive discussions in mathematics professional development. *Teaching and Teacher Education*, *24*, 417-436. doi: 10.1016/j.tate.2006.11.012

Borko, H., Koellner, K., Jacobs, J., & Seago, N. (2011). Using video representations of teaching in practice-based professional development programs. *ZDM Mathematiocs Education*, *43*, 175-187. doi: 10.1007/s11858-010-0302-5

Bradburn, N.M. (1969). *The structure of psychological well-being*. Oxford, England: Aldine.

Brewer, W. F., Chinn, C.A., & Samarapungavan, A. (1998). Explanation in scientists and children. *Minds and Machines*, *8*, 119-136.
doi: 10.1023/A:1008242619231

Brief, A.P., & Aldag, R.J. (1977). The intrinsic-extrinsic dichotomy: Toward conceptual clarity. *Academy of Management Review*, *2*, 496-500.

Brophy, J.E. (1999). Teaching. *International Academy of Education & International Bureau of Education.* Retrieved from http://unesdoc.unesco.org/images/0012/001254/125450e.pdf

Brophy, J., & Good, T.L. (1986). Teacher behavior and student achievement. In M.C. Wittrock (Ed.), *Handbook of research on teaching* (3rd ed., pp. 328-375). New York: Macmillan.

Bruner, J.S. (1961). The art of discovery. *Harvard Educational Review*, *31*, 21-32.

Cacioppo, J.T., Gardner, W.L., & Berntson, G.G. (1999). The affect system has parallel and integrative processing components: Form follows function. *Journal of Personality and Social Psychology*, *76*, 839-855. doi: 10.1037/0022-3514.76.5.839

Carey, S., & Spelke, E. (1996). Science and core knowledge. *Philosophy of Science*, *63*, 515. doi: 10.1086/289971

Carlsen, W.S., & Hall, K. (1997). Never ask a question if you don't know the answer: The tension in teaching between modeling scientific argument and maintaining law and order. *Journal of Classroom Interaction*, *32*, 14-23.

Carver, C.S., & Scheier, M.F. (1998). *On the self-regulation of behavior*. New York: Cambridge University Press.

Chaiklin, S. (2003). The zone of proximal development in Vygotsky's analysis of learning and instruction. In A. Kozulin, B. Gindis, V. Ageyev, & S. Miller (Eds.), *Vygotsky's educational theory and practice in cultural context* (pp. 39-64). Cambridge: Cambridge University.

Chouinard, M.M. (2007). *Children's questions*. Boston: Wiley-Blackwell.

Coburn, C.E. (2003). Rethinking scale: Moving beyond numbers to deep and lasting change. *Educational Researcher*, *32*(6), 3-12
doi: 10.3102/0013189X032006003

Cohen, D.K., & Hill, H.C. (2000). Instructional policy and classroom perfomance: The mathematics reform in California. *Teachers College Record*, *102*, 294-343.
doi: 10.1111/0161-4681.00057

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.

Conezio, K., & French, L. (2002). Science in the preschool classroom. Capitalizing on children's fascination with the everyday world to foster. *Young Children*, *57*, 1-5.

Costa, A., & Liebmann, A. (1995). Process is as important as content. *Educational Leadership*, *52*(6), 23-24.

Creswell, J.W., & Plano Clark, V.L. (2011). *Designing and conducting mixed methods research* (2nd ed.). Thousand Oaks, CA: Sage Publications.

Cunningham, R.T. (1987). What kind of question is that? In W. W. Wilen (Ed.), *Questions, questioning techniques and effective teaching*. Washington D.C.: National Education Association.

Darling-Hammond, L. (2000). Teacher quality and student achievement: A review of state policy evidence. *Education Policy Analysis Archives*, *8*, 1-44. doi: 10.1038/sj.clp

Day, C. (1999). *Developing teachers. The challenge of lifelong learning*. New York: Taylor & Francis Inc.

De Groot, A.D. (1961). *Methodologie: Grondslagen van onderzoek en denken in de gedragswetenschappen*. 's Gravenhage: Mouton & Co.

Deci, E.L., & Ryan, R.M. (Eds.) (2002). *Handbook of self-determination research*. Rochester (NY): The University of Rochester Press.

Dejonckheere, P.J.N., Van De Keere, K., & Mestdagh, N. (2009). Training the scientific thinking circle in pre- and primary school children. *The Journal of Educational Research*, *103*, 1-16. doi: 10.1080/00220670903228595

Desimone, L.M. (2009). Improving impact studies of teachers' professional development: Toward better conceptualizations and measures. *Educational Researcher*, *38*, 181-199. doi: 10.3102/0013189X08331140

Dewey, J. (1938). *Experience and education*. New York: Collier Books.

Dewey, J. (1997). *How we think*. New York: Dover Publications.

Dickinson, V.L., Burns, J., Hage, E.R., & Locker, K.M. (1997). Becoming better primary science teachers: A description of our journey. *Journal of Science Teacher Education*, *8*, 295-311. doi: 10.1023.A:1009451102335

Diener, E. (1984). Subjective well-being. *Psychological Bulletin*, *95*, 542-575.

Dinham, S., & Scott, C. (2004). International patterns of teacher satisfaction and motivation in Australia, England, New Zealand, United States of America, Cyprus and Malta: The role of context and the "third domain." *Paper presented at the British Educational Research Association Annual Conference, University of Manchester, 16-18 September 2004.*

Dishion, T., & Stormshak, E. (2007). *Intervening in children's lives. An ecological, family-centered approach to mental health care*. Washington: American Psychological Association.

Durlak, J.A., & DuPre, E.P. (2008). Implementation matters: A review of research on the influence of implementation on program outcomes and the factors affecting implementation. *American Journal of Community Psychology*, *41*, 327-50. doi: 10.1007/s10464-008-9165-0

Edwards, C., Gandini, L., & Forman, G. (Eds.) (1993). *The hundred languages of children: The Reggio Emilia approach to early childhood education*. Norwood, NJ: Ablex.

Eindrapportage Expertisecentrum TK. (2010).

Engel, S. (2006). Open Pandora's box: Curiosity in the classroom. The Sarah Lawrence Child Development Institute Occasional Papers.

Engel, S. (2009). Is curiosity vanishing? J*ournal of American Academy of Child and Adolescent Psychiatry*, *48*, 777-779. doi: 10.1097/CHI.0b013e3181aa03b0

Engel, S., & Randall, K. (2008). How teachers respond to chilren's inquiry. *American Educational Research Journal*, *46*, 183-202. doi: 10.3102/0002831208323274

Engelhard, G., & Monsaas, J.A. (1988). Grade level, gender, and school-related curiosity in urban elementary schools. *Journal of Educational Research*, *82*, 22-26. doi: 10.1080/00220671.1988.10885860

Evans, L. (2002). What is teacher development? *Oxford Review of Education*, *28*, 123-137. doi: 10.1080/03054980120113670

Evertson, C.M., & Veldman, D.J. (1981). Changes over time in process measures of classroom behavior. *Journal of Educational Psychology*, *73*, 156-163.

Fabiano, G.A., Vujnovic, R.K., Waschbusch, D.A., Yu, J., Mashtare, T., Pariseau, M.E., Pelham, W.E., Parham, B.R., Smalls, K.J. (2013). A comparison of workshop training versus intensive, experiential training for improving behavior support skills in early educators. *Early Childhood Research Quarterly*, *28*, 450-460. doi: 10.1016/j.ecresq.2012.12.001

Ferguson, R.F. (1991). Paying for public education: New evidence on how and why money matters. *Harvard Journal on Legislation*, *28*, 465-498.

Fischer, K.W., & Bidell, T.R. (2006). Dynamic development of action and thought. In R.M. Lerner & W. Damon (Eds.), *Theoretical models of human development. Handbook of child psychology* (pp. 313-399). New York: Wiley.

Fishbach, A., Eyal, T., & Finkelstein, S.R. (2010). How positive and negative feedback motivate goal pursuit. *Social and Personality Psychology Compass, 4*, 517-530. doi: 10.1111/j.1751-9004.2010.00285.x

Fogel, A. (2009). What is a transaction? In A. Sameroff (Ed.), *The transactional model of development: how children and contexts shape each other* (pp. 271-280). Washington, DC: American Psychological Association.

Fredrickson, B.L. (2009). *Positivity*. New York, NY US: Crown Publishers.

Fredrickson, B.L. (2013). Updated thinking on positivity ratios. *The American Psychologist*, *68*, 814-22. doi: 10.1037/a0033584

Frenken, K. (2006). *Innovation, evolution and complexity theory*. Cheltenham (UK): Edward Elgar Publishing Limited.

Frijda, N.H. (1986). *The emotions*. Cambridge University Press. Retrieved from http://www.oxfordscholarship.com/oso/public/content/philosophy/0199253048/toc.html

Fukking, R. (2005). Effectonderzoek naar Video Interactie Begeleiding. SCO-Kohnstamm Instituut.

Fullan, M. (2007). *The new meaning of educational change*. New York, NY US: Teachers College Press.

Furtak, E.M. (2006). The problem with answers: An exploration of guided scientific inquiry teaching. *Science Education, 90*, 453-467. doi: 10.1002/sce.20130

Gall, M.D. (1970). The use of questions in teaching. *Review of Educational Research*, *40*, 707-721. doi: 10.3102/00346543040005707

Garet, M.S., Porter, A.C., Desimone, L., Birman, B.F., & Yoon, K.S. (2001). What makes professional development effective? Results from a national sample of teachers. *American Educational Research Journaleducational Research Journal*, *38*, 915. doi: 10.3102/00028312038004915

Gearing, R.E., El-Bassel, N., Ghesquiere, A., Baldwin, S., Gillies, J., & Ngeow, E. (2011). Major ingredients of fidelity: A review and scientific guide to improving quality of intervention research implementation. *Clinical Psychology Review*, *31*, 79-88. doi: 10.1016/j.cpr.2010.09.007

Geerts, W., Steenbeek, H.W., Van der Werff, A., & Van Geert., P.L.C. (n.d.). The influence of video cases on the acquisition of situated knowledge by pre-service secondary school teachers. Manuscript in preparation.

Gelman, R., & Brenneman, K. (2004). Science learning pathways for young children. *Early Childhood Research Quarterly*, *19*, 150-158.
doi: 10.1016/j.ecresq.2004.01.009

Goldenberg, C., & Gallimore, R. (1991). Changing teaching takes more than a one-shot workshop. *Educational Leadership*, *49*, 69-72.

Goldin-Meadow, S., & Alibali, M. (2002). Looking at the hands through time: A microgenetic perspective on learning and instruction. In N. Granott & J. Parziale (Eds.), *Microdevelopment : Transition Processes in Development and Learning* (pp. 80-105). New York: Cambridge University Press.

Goldspink, C. (2007). Transforming education: Evidential support for a complex systems approach. *E:CO*, 9, 77-92.

Goodman, L., & Berntson, G. (2000). The art of asking questions. *The American Biology Teacher*, *62*, 473. doi: 10.1662/0002-7685(2000)062[0473:TAOAQ]2.0.CO;2

Goodrum, D., Hackling, M., & Rennie, L. (2001). *The status and quality of teaching and learning of science in Australian schools. Department of Education, Training and Youth Affairs*. Canberra.

Goodwin, C.J. (2003). *Research in psychology: Methods and design*. New York: John Wiley & Sons, Inc.

Gottfredson, D.C., & Gottfredson, G.D. (2002). Quality of school-based prevention programs: Results from a national survey. *Journal of Research in Crime and Delinquency*, *39*, 3-35.

Granott, N., Fischer, K.W., & Parziale, J. (2002). Bridging to the unknown: A transition mechanism in learning and development. In N. Granott & J. Parziale (Eds.), *Microdevelopment: Transition processes in development and learning* (pp. 131-156). Cambridge: Cambridge University Press.

Granott, N., & Parziale, J. (2002). *Microdevelopment: Transition processes in development and learning. Cambridge: Cambridge University Press.*

Greenfield, D.B., Jirout, J., Dominguez, X., Greenberg, A., Maier, M., & Fuccillo, J. (2009). Science in the preschool classroom : A programmatic research agenda to improve science readiness. *Early Education and Development*, *20*, 37-41.
doi: 10.1080/10409280802595441

Grigg, J., Kelly, K.A., Gamoran, A., & Borman, G.D. (2012). Effects of two scientific inquiry professional development interventions on teaching practice. *Educational Evaluation and Policy Analysis*, *35*, 38-56. doi: 10.3102/0162373712461851

Guanglu, Z. (2012). On the recursion between teaching and learning. *Complicity: An International Journal of Complexity and Education*, *9*, 90-97.

Guerin, L. (2015). *Participation Revisited: an old idea made new. Group problem solving as educational approach for citizenship education.*

Guskey, T.R. (2003). What makes professional development effective ? *Phi Delta Kappan*, *84*, 748-750. doi: 10.3102/00028312038004915

Guskey, T.R., & Yoon, K.S. (2009). What works in professional development? *Phi Delta Kappan*, *90*, 495-500. doi: 10.2307/20446159

Han, S.S., & Weiss, B. (2005). Sustainability of teacher implementation of school-based mental health programs. *Journal of Abnormal Child Psychology*, *33*, 665-79. doi: 10.1007/s10802-005-7646-2

Hargreaves, A. (1998). The emotions of teaching and educational change. In A. Hargreaves, A. Liebermann, M. Fullan, & D. Hopkins (Eds.), *International handbook of educational change* (pp. 558-575). Dordrecht: Kluwer Academic Publishers.

Harrop, A., & Swinson, J. (2003). Teachers' questions in the infant, junior and secondary school. *Educational Studies*, *29*, 49-57. doi: 10.1080/03055690220000042480

Harwell, S.H. (2003). *Teacher professional development: It's not an event, it's a process.* Waco, Texas: CORD.

Hattie, J. (2003). *Teachers make a difference: What is the research evidence ? Australian Council for Educational Research Annual Conference on Building Teacher Quality.*

Hattie, J.A.C. (2009). *Visisble learning. A synthesis of over 800 meta-analyses relating to achievement*. New York, US: Routledge.

Hawking, S. (1998). Second White House Millennium Evening Lecture. Retrieved March 16, 2015, from https://www.youtube.com/watch?v=9Mo6wwX55dA

Hestenes, L.L., Cassidy, D.J., & Niemeyer, J. (2004). A microanalysis of teachers' verbalizations in inclusive classrooms. *Early Education and Development*, *15*(1), 37-41. doi: 10.1207/s15566935eed1501

Hetherington, L. (2013). Complexity thinking and methodology: The potential of "complex case study" for educational research. *Complicity: An International Journal of Complexity and Education*, *10*, 71-85.

Hodson, D. (2003). Time for action: Science education for an alternative future. *International Journal of Science Education*, *25*, 645-670. doi: 10.1080/09500690305021

Hoekstra, L.,Van der Steen, S., Cox, R., & Van Geert, P. (n.d.). Speech, gesture and acting during the construction of children's understanding of scientific concepts: A microgenetic analysis.

Honingh, E., Steenbeek, H.W., & Wetzels, A.F.M. (2012). Van "Juf, ik heb wat ontdekt!" tot 'Huh, hoe kan dat?'. *Didactief*, *42*(5).

Howard-Jones, P.A., & Demetriou, S. (2009). Uncertainty and engagement with learning games. *Instructional Science*, *37*, 519-536. doi: 10.1007/s11251-008-9073-6

Howe, M.J.A., Davidson, J.W., & Sloboda, J.A. (1998). Innate talents: Reality or myth? *Behavioral and Brain Sciences*, *21*, 399-442. doi: 10.1017/S0140525X9800123X

http://www.haus-der-kleinen-forscher.de/en/. (n.d.). Retrieved April 7, 2015, from http://www.haus-der-kleinen-forscher.de/en/

Hyun, E., & Marshall, J. (2003). Teachable-moment-oriented curriculum practice in early childhood education. *Journal of Curriculum Studies*, *35*, 111-127. doi: 10.1080/00220270210125583

Imperley, H., Wilson, A., Barrar, H., & Fung, I. (2007).*Teacher professional learning and development. Wellington*, New Zealand.

Instructional Strategies. (2002). Retrieved April 7, 2015, from https://education.alberta.ca/media/352984/is.pdf

Jacoby, W.G. (2000). Loess: a nonparametric, graphical tool for depicting relationships between variables. *Electoral Studies*, *19*, 577-613. doi: 10.1016/S0261- 3794(99)00028-1

Jarvis, T., & Pell, A. (2004). Primary teachers' changing attitudes ancognition during a two-year science in-service programme and their effect on pupils. *International Journal of Science Education*, *26*, 1787-181 doi: 10.1080/0950069042000243763

Jarvis, T., & Pell, A. (2005). Factors influencing elementary school children's attitudes toward science before, during, and after a visit to the UK National Space Centre. *Journal of Research in Science Teaching*, *42*, 53-83. doi: 10.1002/tea.20045

Jirout, J., & Klahr, D. (2012). Children's scientific curiosity: In search of an operational definition of an elusive concept. *Developmental Review*, *32*, 125-160. doi: 10.1016/j.dr.2012.04.002

Jonassen, D. (1991). Objectivism vs. constructivism. *Educational Technology Research and Development*, *39*, 5-14. doi: 10.1007/BF02296434

Jörg, T. (2011). *New thinking in complexity for the social sciences and humanities: A generative, transdisciplinary approach*. New York, NY: Springer.

Keiny, S. (1994). Constructivism and teachers' professional development. *Teaching and Teacher Education*, *10*, 157-167.

Kennedy, H., Landor, M., & Todd, L. (Eds.). (2011). *Video Interaction Guidance: a relationship-based intervention to promote attunement, empathy and well-being.* London: Jessica Kingsley Publishers.

Kennedy, H., Landor, M., & Todd, L. (Eds.). (2015). *Video Enhanced Reflective Practice: Professional development through attuned interactions*. London: Jessica Kingsley Publishers.

Kirschner, P.A., Sweller, J., & Clark, R.E. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist*, *41*, 75-86. doi: 10.1207/s15326985ep4102_1

Klahr, D., Zimmerman, C., & Jirout, J. (2011). Educational interventions to advance children's scientific thinking. *Science*, *333*, 971-976. doi: 10.1126/science.1204528

Kluger, A.N., & DeNisi, A. (1996). The effects of feedback interventions on performance: A historical review, a meta-analysis, and a preliminary feedback intervention theory. *Psychological Bulletin*, *119*, 254-284. doi: 10.1037/0033-2909.119.2.254

Koestner, R. (2008). Reaching one's personal goals: A motivational perspective focused on autonomy. *Canadian Psychology/Psychologie Canadienne*, *49*, 60-67. doi: 10.1037/0708-5591.49.1.60

Kumpulainen, K., Hmelo-Silver, C.E., & Cesar, M. (2009). *Investigating classroom interaction; Methodologies in action*. Rotterdam: Sense Publishers.

Kumpulainen, K., & Wray, D. (2002). *Classroom interaction and social learning*. London: Routledge.

Kunnen, S. (2012). Toy models and the search for mechanisms. In S. Kunnen (Ed.), *A dynamic systems approach to adolescent development* (pp. 93-98). East Sussex: Psychology Press.

Kunter, M., Tsai, Y., Klusmann, U., Brunner, M., Krauss, S., & Baumert, J. (2008). Students' and mathematics teachers' perceptions of teacher enthusiasm and instruction. *Learning and Instruction*, *18*, 468-482. doi: 10.1016/j.learninstruc.2008.06.008

Laevers, F. (2004). Experiential education: Effective learning through well-being and involvement. In *OECD Starting strong: curricula and pedagogies in early childhood education and care: five curriculum outlines*. Paris: OECD, 5-7.

Laevers, F., Declercq, B., & Jackaman, S. (2011). *Observing involvement in children from 6 to 12 years (DVD)*. Leuven: Cego Publishers NV.

Lambert, M.J., & Barley, D. (2001). Research summary on the therapeutic relationship and psychotherapy outcome. *Psychotherapy: Theory, Research, Practice, Training*, *38*, 357-361. doi: 10.1037//0033-3204.38.4.357

Lambert, R.G., McCarthy, C., O'Donnell, M., & Wang, M. (2009). Measuring elementary teacher stress and coping in the classroom: Validity evidence for the classroom appraisal of resources and demands. *Psychology in the Schools*, *46*, 973-988.

Lee, Y. (2010). *Blended teacher supports for promoting open ended questioning in pre-k science activities*. University of Virginia.

Lee, Y., Kinzie, M.B., & Whittaker, J.V. (2012). Impact of online support for teachers' open-ended questioning in pre-k science activities. *Teaching and Teacher Education*, *28*, 568-577. doi: 10.1016/j.tate.2012.01.002

Lehmann, A.C., & Gruber, H. (2006). Music. In K.A. Ericsson, N. Charness, P.J. Feltovich, & R.R. Hoffman (Eds.), *The Cambridge handbook of expertise and expert performance* (pp. 457-470). New York, NY, US: Cambridge University Press.

Lewis, M. (2002). Interacting time scales in personality (and cognitive) development: Intentions, emotions, and emergent forms. In N. Granott & J. Parziale (Eds.), *Microdevelopment: transition processes in development and learning* (pp. 183-212). New York: Cambridge University Press.

Locke, E.A., & Latham, G.P. (2006). New directions in goal-setting theory. *Current Directions in Psychological Science*, *15*, 265-268.
doi: 10.1111/j.1467-8721.2006.00449.x

Loewenstein, G. (1994). The psychology of curiosity: A review and reinterpretation. *Psychological Bulletin*, *116*, 75-98. doi: 10.1037/0033-2909.116.1.75

Loucks-Horsley, S., Stiles, K.E., Mundry, S., Love, N., & Hewson, P.W. (2010). *Designing professional development for teachers of science and mathematics.* Thousand Oaks, CA: Corwin.

Loughran, J.J. (2002). Effective reflective practice: In search of meaning in learning about teaching. *Journal of Teacher Education*, *53*, 33-43.
doi: 10.1177/0022487102053001004

Magnusson, S., Krajcik, J., & Borko, H. (1999). Nature, sources, and development of pedagogical content knowledge for science teaching. In J. Gess-Newsome & N.G. Lederman (Eds.), *Examining pedagogical content knowledge* (pp. 95-132). London: Kluwer Academic Publishers.

Mantzicopoulos, P., Patrick, H., & Samarapungavan, A. (2008). Young children's motivational beliefs about learning science. *Early Childhood Research Quarterly*, *23*, 378-394. doi: 10.1016/j.ecresq.2008.04.001

Martin, D. (2009). *Elementary science methods: A constructivist approach, volume 3*. Belmont: Wadsworth Cengage Learning. Retrieved from https://books.google.nl/books?id=UxmIPW-VYRIC&printsec=frontcover&source=gbs_ge_summary_r&cad=0#v=onepage&q&f=false

Martin, M.O., Mullis, I.V. ., & Foy, P. (2008). *TIMSS 2007 International Science Report: Findings from IEA's trends in international mathematics and science study at the fourth and eighth Grades*. Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Lynch School of Education, Boston College.

Marx, R.W., & Harris, C.J. (2006). No child left behind and science education: Opportunities, challenges, and risks. *The Elementary School Journal*, *106*, 467-478.

Mattanah, J., Pratt, M., Cowan, P., & Cowan, C. (2005). Authoritative parenting, parental scaffolding of long-division mathematics, and children's academic competence in fourth grade. *Journal of Applied Developmental Psychology*, *26*, 85-106. doi: 10.1016/j.appdev.2004.10.007

Maurer, T.J., Weiss, E.M., & Barbeite, F.G. (2003). A model of involvement in work-related learning and development activity: The effects of individual, situational, motivational, and age variables. *Journal of Applied Psychology, 88*, 707-724. doi: 10.1037/0021-9010.88.4.707

Mayer, R.E. (2004). Should there be a three-strikes rule against pure discovery learning? The case for guided methods of instruction. *The American Psychologist*, *59*(1), 14-9. doi: 10.1037/0003-066X.59.1.14

Meindertsma, H. (2014). *Predictions and explanations*. University of Groningen.

Meindertsma, H.B., Van Dijk, M.W.G., Steenbeek, H.W., & Van Geert, P.L.C. (2012). Application of Skill Theory to compare scientific reasoning of young children in different tasks. *Netherlands Journal of Psychology*, *67*, 9-19.

Mellado, V., Blanco, L.J., & Ruiz, C. (1998). A framework for learning to teach science in initial primary teacher education. *Journal of Science Teacher Education*, *9*, 195-219.

Menninga, A., Van Dijk, M.W.G., Wetzels, A.F.M., Steenbeek, H.W., & Van Geert, P.L.C. (n.d.). Academic language in science and technology lessons in kindergarten; an intervention study. Manuscript submitted for publication.

Michaels, S., Shouse, A.W., & Schweingruber, H.A., (2007). *Ready, set, science!: Putting research to work in k-8 science classrooms.*Washington D.C.: National Academies Press

Minnaert, A., Boekaerts, M., & De Brabander, C. (2007). Autonomy, competence, and social relatedness in task interest within project-based education. *Psychological Reports*, *101*, 574-586. doi: 10.2466/PR0.101.2.574.586

Molenaar, P.C.M., & Campbell, C.G. (2009). The new person-specific paradigm in psychology. *Current Directions in Psychological Science*, *18*, 112-117. doi: 10.1111/j.1467-8721.2009.01619.x

Moon, J. (2001). *PDP Working Paper 4: Reflection in higher education learning.* LTSN Generic Centre. Exeter.

Mooney, C., & Kirshenbaum, S. (2009). *Unscientific America: How scientific illiteracy threatens our future*. New York: Basic Books.

Morine-Dershimer, G., & Kent, T. (1999). The complex nature and sources of teachers' pedagogical content knowledge. In J. Gess-Newsome & N.G. Lederman (Eds.), *Examining pedagogical content knowledge* (pp. 21-50). Dordrecht, The Netherlands: Kluwer.

Murphy, P.K. (2007). The eye of the beholder: The interplay of social and cognitive components in change. *Educational Psychologist*, *42*, 41-53. doi: 10.1080/00461520709336917

Myhill, D., & Warren, P. (2005). Scaffolds or straitjackets? Critical moments in classroom discourse. *Educational Review*, *57*, 55-69. doi: 10.1080/0013191042000274187

Nationaal Techniekpact 2020. (2013). Retrieved from http://techniekpact.nl/nationaal-techniekpact-2020/

Noell, G.H., & Gansle, K.A. (2009). Moving from good ideas in educational systems change to sustainable program implementation: Coming to terms with some of the realities. *Psychology in the Schools*, *46*, 78-89. doi: 10.1002/pits.20355

Noell, G.H., Gresham, F.M., & Gansle, K.A. (2002). Does treatment integrity matter? A preliminary investigation of instructional implementation and mathematics performance. *Journal of Behavioral Education*, *11*(1), 51-67.

Noell, G.H., Witt, J.C., Gilbertson, D.N., Ranier, D.D., & Freeland, J.T. (1997). Increasing teacher intervention implementation in general education settings through consultation and performance feedback. *School Psychology Quarterly*, *12*, 77-88. doi: 10.1037/h0088949

Nowotny, H., Scott, P., & Gibbons, M. (2001). *Re-thinking science: Knowledge and the public in an age of uncertainty.* Cambridge: Polite Press.

OECD. (2008). “Introduction.” In *PISA 2006: science competencies for tomorrow’s world: Volume 1: Analysis*. OECD Publishing.
doi: dx.doi.org/10.1787/9789264040014-2-en

Oh, P.S. (2005). Discursive roles of the teacher during class sessions for students presenting their science investigations. *International Journal of Science Education*, *27*, 1825-1851. doi: 10.1080/09500690500239714

Oliveira, A.W. (2010). Improving teacher questioning in science inquiry discussions through professional development. *Journal of Research in Science Teaching*, *47*, 422-453. doi: 10.1002/tea.20345

Opdenakker, M.C., Maulana, R., & Den Brok, P. (2012). Teacher–student interpersonal relationships and academic motivation within one school year: Developmental changes and linkage. *School Effectiveness and School Improvement*, *23*, 95-119. doi: 10.1080/09243453.2011.619198

Opfer, V.D., & Pedder, D. (2011). Conceptualizing teacher professional learning. *Review of Educational Research*, *81*, 376-407. doi: 10.3102/0034654311413609

Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International Journal of Science Education*, 25, 1049-1079. doi: 10.1080/0950069032000032199

Otto, P.B., & Schuck, R.F. (1983). The effect of a teacher questioning strategy training program on teaching behavior, student achievement, and retention. *Journal of Research in Science Teaching*, *20*, 521-528. doi: 10.1002/tea.3660200603

Palincsar, A.S., & Brown, A.L. (1984). Reciprocal teaching of comprehension-fostering and comprehension-monitoring activities. *Cognition and Instruction*, *1*, 117-175.

Palmer, D.H. (2002). Factors contributing to attitude exchange amongst preservice elementary teachers. *Science Education*, *86*, 122-138. doi: 10.1002/sce.10007

Parker, W.C., & Hess, D. (2001). Teaching with and for discussion. *Teaching and Teacher Education*, *17*, 273-289.

Parkinson, J., Hendley, D., Tanner, H., & Stables, A. (1998). Pupils’ attitudes to science in key stage 3 of the national curriculum: A study of pupils in South Wales. *Research in Science & Technological Education*, *16*, 165-176.
doi: 10.1080/0263514980160206

Paterson, C., & Chapman, J. (2013). Enhancing skills of critical reflection to evidence learning in professional practice. *Physical Therapy in Sport*, *14*, 133-138.
doi: 10.1016/j.ptsp.2013.03.004

Perepletchikova, F., & Kazdin, A.E. (2005). Treatment integrity and therapeutic change: Issues and research recommendations. *Clincal Psychology: Science and Practice*, *12*, 365-383. doi: 10.1093/clipsy/bpi045

Pettelier, L.G., & Sharp, E.C. (2009). Administrative pressures and teachers' interpersonal behaviour in the classroom. *Theory and Research in Education*, *7*, 174-183. doi: 10.1177/1477878509104322 The

Piaget, J. (1970). *Science of education and psychology of the child*. New York: Oxford University Press.

Pintrich, P.R. (2000). The role of goal orientation in self regulated learning. In M. Boekaerts, P.R. Pintrich, & M. Zeidner (Eds.), *Handbook of selfregulation* (pp. 451-502). San Diego: Academic Press.

Post, A. (2009). *TalentenKracht: Sprankelen tussen wetenschap en de praktijk*. Retrieved from http://www.talentenkracht.nl//docs/Publicaties/200911-tkbrochure_def.pdf

Pressley, M., Graham, S., & Harris, K. (2006). The state of educational intervention research as viewed through the lens of literacy intervention. *The British Journal of Educational Psychology*, *76*, 1-19. doi: 10.1348/000709905X66035

Rappolt-Schlichtmann, G., Tenenbaum, H.R., Koepke, M.F., & Fischer, K.W. (2007). Transient and robust knowledge: Contextual support and the dynamics of children's reasoning about density. *Mind, Brain and Education*, *1*, 98-108.

Richland, L.E., Stigler, J.W., & Holyoak, K.J. (2012). Teaching the Conceptual Structure of Mathematics. *Educational Psychologist*, *47*, 189-203. doi: 10.1080/00461520.2012.667065

Rivera, C. De, Girolametto, L., Greenberg, J., & Weitzman, E. (2005). Children's responses to educators' questions in day care play groups. *American Journal of Speech-Language Pathology*, *14*, 14-26. doi: 10.1044/1058-0360(2005/004

Roehrig, G.H., & Luft, J.A. (2004). Constraints experienced by beginning secondary science teachers in implementing scientific inquiry lessons. *International Journal of Science Education*, *26*, 3-24. doi: 10.1080/0950069022000070261

Rosaen, C.L., Schram, P., & Herbel-Eisenmann, B. (2002). Using hypermedia technology to explore connections among mathematics, language, and literacy in teacher education. *Contemporary Issues in Technology and Teacher Education*, *2*, 297-326.

Rose, D.J., & Church, R.J. (1998). Learning to teach: The acquisition and maintenance of teaching skills. J*ournal of Behavioral Education*, *8*, 5-35.

Rose, L.T., Rouhani, P., & Fischer, K.W. (2013). The science of the individual. *Mind, Brain, and Education*, *7*, 152-158. doi: 10.1111/mbe.12021

Rosenshine, B., & Stevens, R. (1986). Teaching functions. In M. C. Wittrock (Ed.), *Handbook of research on teaching* (3rd ed., pp. 376-391). New York: Macmillan.

Roth, W.M. (1996). Teacher questioning in an open-inquiry learning environment: Interactions of context, content, and student responses. *Journal of Research in Science Teaching*, *33*, 709-736.
doi: 10.1002/(SICI)1098-2736(199609)33:7<709::AID-TEA2>3.0.CO;2-R

Rowe, K. (2003). The importance of teacher quality as a key determinant of students' experiences and outcomes of schooling. Retrieved from http://research.acer.edu.au/cgi/viewcontent.cgi?article=1001&context=research_conference_2003

Rutherford, F.J. (1964). The role of inquiry in science teaching. *Journal of Research in Science Teaching*, *2*, 80-84.

Ryan, R.M., & Deci, E.L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist*, *55*, 68-78. doi: 10.1037/0003-066x.55.1.68

Sandholtz, J.H., & Ringstaff, C. (2013). Assessing the impact of teacher professional development on science instruction in the early elementary grades in rural US schools. *Professional Development in Education*, *39*, 678-697.
doi: 10.1080/19415257.2012.751044

Sarama, J., & Clements, D. (2009). Teaching math in the primary grades: The learning trajectories approach. *Young Children*, *64,* 63-65.
doi: 10.1111/j.1750-8606.2009.00095.x

Schmidt, H.G. (1983). Problem-based learning: rationale and description. *Medical Education*, *17*, 11-16.

Schunk, D.H. (2005). Self-Regulated Learning : The educational legacy of Paul R. Pintrich. *Educational Psychologist*, *40*, 85-94. doi: 10.1207/s15326985ep4002

Schwartz, M. (2009). Cognitive development and learning: Analyzing the building of skills in classrooms. *Mind, Brain, and Education*, *3*, 198-208.
doi:10.1111/j.1751-228X.2009.01070.x

Seago, N. (2004). Using videos as an object of inquiry for mathematics teaching and learning. In J. Brophy (Ed.), *Using video in teacher education* (pp. 259-286). Oxford: Elsevier.

Seidel, T., Stürmer, K., Blomberg, G., Koberg, M., & Schwindt, K. (2010). Teacher learning from analysis of videotaped classroom situations: Does it make a difference whether teachers observe their own teaching or that of others? *Teaching and Teacher Education*, *27*, 259-267. doi: 10.1016/j.tate.2010.08.009

Shulman, L.S. (1987). Knowledge and teaching: foundations of the new reform. *Harvard Educational Review*, *57*, 1-21.

Simonton, D.K. (1999). Talent and its development: An emergenic and epigenetic model. *Psychological Review*, *106*, 435-457. doi: 10.1037//0033-295X.106.3.435

Simonton, D.K. (2001). Talent development as a multidimensional, multiplicative and dynamic process. *Current Directions in Psychological Science*, *10*, 39-43. doi: 10.1111/1467-8721.00110

Smith, D.C. (1999). Pedagogical content knowledge in elementary science. In J. Gess-Newsome & N. G. Lederman (Eds.), *Examining pedagogical content knowledge*. Dordrecht, The Netherlands.

Smith, L., & Thelen, E. (2003). Development as a dynamic system. *Trends in Cognitive Sciences*, *7*, 343-348. doi: 10.1016/S1364-6613(03)00156-6

Sorsana, C. (2008). Introduction: Developmental co-construction of cognition. *European Journal of Developmental Psychology*, *5*, 537-543.
doi: 10.1080/13546800701851179

Start Science Sooner. (2010). *Scientific American*, *302*(3), 28.
doi: 10.1038/scientificamerican0310-28

Steenbeek, H.W. (2006). *Modeling dyadic child-peer interactions: Sociometric status, emotional expressions, and instrumental actions during play*. University of Groningen.

Steenbeek, H.W., & Uittenbogaard, W. (2009). Bèta-talenten van jonge kinderen in kaart. *Panama-Post. Reken-Wiskundeonderwijs: Onderzoek, Ontwikkeling, Praktijk*, *28*, 89-100.

Steenbeek, H.W., & Van Geert, P.L.C. (2007). A theory and dynamic model of dyadic interaction: concerns, appraisals, and contagiousness in a developmental context. *Developmental Review*, *27*, 1-40. doi: 10.1016/j.dr.2006.06.002

Steenbeek, H.W., & Van Geert, P.L.C. (2008). An empirical validation of a dynamic systems model of interaction: Do children of different sociometric statuses differ in their dyadic play? *Developmental Science*, *11*, 253-281.
doi: 10.1111/j.1467-7687.2007.00655.x

Steenbeek, H.W., & Van Geert, P.L.C. (2009a). *Ogen hebben, ogen geven, ogen krijgen.* Groningen.

Steenbeek, H.W., & Van Geert, P.L.C. (2009b). *Pilot Expertisecentrum Talenten-Kracht*. Groningen.

Steenbeek, H.W., & Van Geert, P.L.C. (2013). The emergence of learning-teaching trajectories in education: A complex dynamic systems approach. *Nonlinear Dynamics, Psychology, and Life Sciences*, *17*, 233-67.

Steenbeek, H.W., Van Geert, P.L.C., Hageman, N., Meissner, R., Van Vondel, S., Broekhof, K., & Cohen de Lara, H. (2011). "Having eyes, giving eyes, receiving eyes." In M. J. De Vries, H. Van Keulen, S. Peters, & J. Walma van der Molen (Eds.), *Professional development for primary teachers in science and technology* (pp. 63-79). Rotterdam: Sense Publishers.

Steenbeek, H.W., Van Geert, P.L.C., & Van Dijk, M. (2011). The dynamics of children's science and technology talents: A conceptual framework for early science education. *Netherlands Journal of Psychology*, *66*, 96-109.

Strathie, S., Strathie, C., & Kennedy, H. (2011). Video Enhanced Reflective Practice. In H. Kennedy, M. Landor, & L. Todd (Eds.), *Video Interaction Guidance* (pp. 170-180). London: Jessica Kingsley Publishers.

Stroet, K. (2014). *Studying motivation in classrooms. Effects of teaching practices on early adolescents' motivation*. University of Groningen.

Sugden, N.A. (2010). *Relationships among teacher workload, performance, and well-being.* Walden University.

Susskind, E. (1979). Encouraging teachers to encourage children's curiosity: A pivotal competence. J*ournal of Clinical Child Psychology, 8*, 101-106.

Tharp, R., & Gallimore, R. (1988). *Rousing minds to life: Teaching, learning and schooling in social context*. Cambridge: Cambridge University Press.

The Observer XT. (2011). Noldus Information Technology.

Thelen, E., & Corbetta, D. (2002). Microdevelopment and dynamic systems: Applications to infant motor development. In N. Granott & J. Parziale (Eds.), *Microdevelopment: Transition processes in development and learning.*

Tizard, B., & Hughes, M. (2002). *Young children learning* (2nd ed.). Oxford: Blackwell Publishing Ltd.

Todman, J.B., & Dugard, P. (2001). *Single-case and small-n experimental designs: a practical guide to randomization tests*. Mahwah (NJ): Erlbaum.

Van Aalderen-Smeets, S.I., Walma van der Molen, J.H., & Asma, L.J.F. (2012). Primary teachers' attitudes toward science: A new theoretical framework. *Science Education*, *96*, 158-182. doi: 10.1002/sce.20467

Van Benthem, J., Dijkgraaf, R., & De Lange, J. (2005). *Talentenkracht*. Retrieved from http://jdlange.nl/wp-content/uploads/2012/01/TK-2005.pdf

Van de Pol, J., Volman, M., & Beishuizen, J. (2010). Scaffolding in teacher–student interaction: A decade of research. *Educational Psychology Review*, *22*, 271-296. doi: 10.1007/s10648-010-9127-6

Van den Heijkant, C., Quak, G., Van Swet, J., Vloet, K., De Vos, M., & Van der Wegen, R. (2004). *School Video Interactie Begeleiding*. Antwerpen-Apeldoorn: Garant.

Van der Steen, S. (2014). *"How does it work?" A longitudinal microgenetic study on the development of young children's understanding of scientific concepts*. University of Groningen.

Van Dijk, M., Van Geert, P.L.C., & Steenbeek, H.W. (2010). De Talententuin. Een nieuwe benadering van W&T talent.*TK-magazine*. The Hague: PBT.

Van Geert, P.L.C. (1998). A dynamic systems model of basic developmental mechanisms: Piaget, Vygotsky, and beyond. *Psychological Review*, *105*, 634-677. doi: 10.1037/0033- 295X.105.4.634-677

Van Geert, P.L.C. (2009). Nonlinear complex dynamical systems in developmental psychology. In S.J. Guastello, M. Koopmans, & D. Pincus (Eds.), *Chaos and complexity in psychology; the theory of nonlinear dynamical systems* (pp. 242-281). Cambridge: Cambridge University Press.

Van Geert, P.L.C. (2011). *An overview of the research program of the curious minds consortium 2011*.

Van Geert, P.L.C. (2011). *Talent and excellence for science and technology in young children: A review of the literature*. Groningen.

Van Geert, P.L.C. (2014). Dynamic modeling for development and education: From concepts to numbers. *Mind, Brain, and Education*, *8*, 57-73.

Van Geert, P.L.C., & Steenbeek, H.W. (2005). The dynamics of scaffolding. *New Ideas in Psychology*, *23*, 115-128. doi: 10.1016/j.newideapsych.2006.05.003

Van Geert, P.L.C., & Steenbeek, H.W. (2007). *Waar ligt de kracht?*

Van Geert, P.L.C., & Steenbeek, H.W. (2010). Networks as complex dynamic systems: Applications to clinical and developmental psychology and psychopathology. *Behavioral and Brain Sciences*, *33*, 174-175.

Van Geert, P.L.C., & Steenbeek, H.W. (2014). The good, the bad and the ugly? The dynamic interplay between educational practice, policy and research. *Complicity: An International Journal of Complexity and Education*, *11*, 22-39.

Van Graft, M., & Kemmers, P. (2007). *Onderzoekend en ontwerpend leren in natuur en techniek. (Inquiry and design based learning in science and technology)*. Den Haag: Platform Beta Techniek.

Van Joolingen, W.R., De Jong, T., & Dimitrakopoulou, A. (2007). Issues in computer supported inquiry learning in science. *Journal of Computer Assisted Learning*, *23*, 111-119. doi: 10.1111/j.1365-2729.2006.00216.x

Van Orden, G.C., Holden, J.G., & Turvey, M.T. (2003). Self-organization of cognitive performance. *Journal of Experimental Psychology*, *132*(3), 331-50. doi: 10.1037/0096-3445.132.3.331

Van Veen, K., Zwart, R., Meirink, J., & Verloop, N. (2010). Professionele ontwikkeling van leraren: Een reviewstudie naar effectieve kenmerken van professionaliseringsinterventies van leraren. Iclon/Expertisecentrum Leren van Docenten.

Van Vondel, S., Steenbeek, H.W., Van Dijk, M., & Van Geert, P.L.C. (n.d.). "Looking at" educational interventions: surplus value of using a complexity approach to assess the effectiveness of an intervention during S&T-education. Manuscript in preparation.

Van Yperen, T. (2010). 55 Vragen over effectiviteit. Nederlands Jeugdinstituut.

Vygotsky, L.S. (1978). Mind in society: *The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Wade, R.K. (1984). What makes a difference in inservice teacher education? A meta-analysis of research. *Educational Leadership*, *42*, 48.

Walma van der Molen, J. (2008). De belangstelling voor wetenschap en techniek in het basisonderwijs. In D. Fourarge & A. de Grip (Eds.), *Technotopics III Essays over onderwijs en arbeidsmarkt voor bètatechnici* (pp. 13-22). The Hague: Platform Bèta Techniek.

Wasik, B.A., Bond, M.A., & Hindman, A. (2006). The Effects of a Language and Literacy Intervention on Head Start Children and Teachers. *Journal of Educational Psychology*, *98*, 63-74. doi: 10.1037/0022-0663.98.1.63

Wetzels, A.F.M., Steenbeek, H.W., & Fraiquin, M. (2011). *TalentenKracht in de klas: Een coachingsprogramma voor leerkrachten van groep 1-4.*

Wetzels, A.F.M., Steenbeek, H.W., & Fraiquin, M. (2014). Talent creert Talent. Een e-learning module voor het werken met excellente leerlingen. Retrieved from http/www.onderwijsnu.nl/ elearningmodules/ talent_creert_talent.

Wetzels, A.F.M., Steenbeek, H.W., & Van Geert, P.L.C. (n.d.). Primary science teaching: behavior of teachers and their pupils during and after a coaching program. Manuscript submitted for publication.

Wetzels, A.F.M., Steenbeek, H.W., & Van Geert, P.L.C. (n.d.). The effect of a coaching program on teachers' well-being in science and technology lessons in primary education. Manuscript submitted for publication.

What is Enquiry-Based Learning (EBL)? (n.d.). Centre for Excellence in Enquiry-Based Learning. University of Manchester. Retrieved April 7, 2015, from http://www.ceebl.manchester.ac.uk/ebl/

Wilen, W.W. (1987). *Questions, questioning techniques, and effective teaching*. Washington D.C.: National Education Association.

Wood, D., Bruner, J.S., & Ross, G. (1976). The role of tutoring in problem solving. *Journal of Child Psychology and Psychiatry, and Allied Disciplines, 17*(2), 89-100.

Zeidler, D.L. (2002). Dancing with maggots and saints: Visions for subject matter knowledge, pedagogical knowledge, and pedagogical content knowledge in science teacher education reform. *Journal of Science Teacher Education, 13*, 27-42.

Appendix A

Empirical cycle
1 Ask a question
 - What will happen if I pour oil into water?

2 Hypothesize
 - I think oil will float on water

3 Research design
 - How can I study this? What do I need to explore this?

4 Observation
 - What do you see? What are those bubbles?

5 Drawing conclusions
 - Did your hypothesis prove to be right or wrong? What can be the reason?

Nederlandse samenvatting

Hoofdstuk1:

Inleiding

In dit proefschrift is het ontwerp beschreven van een interventie voor professionele ontwikkeling van leerkrachten om wetenschap en technologie lessen te geven in groep 1-4 van het primair onderwijs. Tevens zijn de resultaten beschreven van de effectstudie naar de resultaten van de interventie.

Wetenschap en technologie (W&T) is een onderschat maar belangrijk onderwerp in het primair onderwijs, ook in groep 1-4. Vaak wordt gezegd dat kinderen in deze leeftijdsgroep al kleine onderzoekers zijn, en van nature nieuwsgierig. Jonge kinderen tonen deze nieuwsgierigheid voor alles wat er in hun omgeving gebeurt, zoals iedere ouder kan bevestigen. Jonge kinderen houden ervan om alles wat ze tegenkomen te onderzoeken, te bekijken en aan te raken. Als kinderen naar school gaan, lijkt deze nieuwsgierigheid langzaamaan te verdwijnen (Engel & Randall, 2008; Engelhard & Monsaas, 1988). In groep 7 en 8 tonen veel kinderen nauwelijks nog nieuwsgierigheid naar gebeurtenissen in de natuur om hen heen. Omdat zij wilde onderzoeken of deze teruggang in nieuwsgierigheid te maken had met school, heeft Engel (2006) het gedrag van leerkrachten in de klas geobserveerd gedurende verschillende lessen. Zij constateerde dat leerkrachten bij vrijwel alle lessen over het algemeen enkel kennis checkten of kinderen aanmaanden bij de les te blijven, en daardoor dus nauwelijks nieuwsgierigheid stimuleerden. Een voorbeeld:

> De leerkracht had in de klas een activiteit opgezet om kinderen te laten zien hoe de Egyptenaren als eerste het wiel hadden uitgevonden. Ze gaf leerlingen een houten plank, een aantal houten wielen, een aantal blokken die getransporteerd moesten worden op de houten plank en een touw met een meetapparaatje dat wanneer het was vastgemaakt aan de houten plank, de afstand en tijd kon meten gedurende welke de plank zich verplaatste als eraan getrokken werd. De kinderen kregen ook een werkblad waarop ze konden vastleggen hoe gemakkelijk het was om de houten plank te verplaatsen als er een aantal wielen werden toegevoegd of afgehaald. De kinderen waren met veel plezier aan het werk en het lokaal gonsde van de activiteit. De leerkracht liep door het lokaal en gaf tips en suggesties met betrekking tot de beste manier om de plank te verplaatsen, zodat de kinderen het werkblad in konden vullen. Regelmatig spoorde ze de kinderen aan om vooral het werkblad in te vullen. Op een gegeven moment begon een kind te experimenteren met het materiaal door op een onverwachte manier aan het touw te trekken, door de wielen anders te bewegen en door verschillende andere voorwerpen op de plank te zetten. De leerkracht gaf hierop

> het commentaar: "Kinderen, jullie krijgen straks tijd om te experimenteren in de pauze. Nu zijn we eerst bezig met wetenschap en technologie." (Engel, 2006, p.7)

Het lijkt erop dat leerkrachten nauwelijks vragen stellen in de klas, waardoor ze kinderen niet stimuleren tot nieuwsgierigheid en onderzoek. Leerkrachten hebben echter een heel belangrijke rol bij het ontwikkelen van nieuwsgierigheid en daarmee voor interesse in wetenschap en technologie.

Naast een belangrijke rol bij het ontwikkelen van nieuwsgierigheid hebben leerkrachten ook een belangrijke rol bij de ontwikkeling van kennis. Kinderen ontwikkelen intuïtieve theorieën over hun omgeving op grond van een combinatie van aangeboren basiskennis en hun dagelijkse ervaringen (Carey & Spelke, 1996; Van Geert, 2011). Deze intuïtieve theorieën komen echter niet altijd overeen met de wetenschappelijke werkelijkheid. Leerkrachten hebben een belangrijke rol als het er om gaat de misconcepties van hun leerlingen te vervangen door reële W&T kennis. Het vervangen van intuïtieve kennis bij kinderen door juiste concepten vereist meer kennis en vaardigheden van leerkrachten dan enkel kennis van die concepten. Professionalisering van leerkrachten is een noodzakelijk middel om de kwaliteit van het lesgeven op het gebied van W&T te verbeteren met als uiteindelijk doel het niveau van kennis en redeneren van leerlingen te verhogen.

Kennis van W&T speelt in de maatschappij een belangrijke rol. Uiteraard is bekend dat de maatschappij steeds meer mensen nodig heeft die opgeleid zijn in W&T omdat de wereld steeds meer afhankelijk is geworden van W&T (*Nationaal Techniekpact 2020*, 2013; Wise, 1985). Daarnaast speelt echter mee dat het maatschappelijke debat ook steeds meer over effecten van W&T gaat. Discussies over genmanipulatie, het broeikaseffect en andere ethische en maatschappelijke onderwerpen gaan iedereen aan, hetgeen betekent dat iedereen een bepaald niveau aan kennis nodig heeft. Daarbij is niet zozeer gespecialiseerde kennis van belang, maar veeleer een basiskennis met betrekking tot wetenschappelijke concepten en met betrekking tot hoe de wetenschap en de wetenschapper werken. Dergelijke kennis is noodzakelijk voor burgers om deel te kunnen nemen aan het maatschappelijke debat.

Aandacht voor W&T in het onderwijs kan dan ook niet vroeg genoeg beginnen ("Start Science Sooner," 2010). In 2006 is in Nederland het project TalentenKracht gestart met als doel talenten van jonge kinderen op het gebied van wetenschap en technologie te onderzoeken (Van Benthem et al., 2005; Steenbeek et al., 2011). Eén van de zeven samenwerkende universiteiten binnen dit programma is de Rijksuniversiteit Groningen, en wel specifiek de afdeling ontwikkelingspsychologie, behorend bij de faculteit GMW. Dit TalentenKracht centrum in Groningen heeft inmiddels een aantal fundamentele en toegepaste onderzoeksprojecten uitgevoerd op het gebied van W&T en jonge kinderen. Dit proefschrift beschrijft de resultaten van een ontwerp- en effectstudie van een coaching programma voor leerkrachten, genaamd Video Feedback Coaching voor leerkrachten (VFC-T). Het programma is er op gericht leerkrachten in de onderbouw van het primair onderwijs op te leiden om lessen (W&T) te geven die het wetenschappelijk redeneren van de leerlingen stimuleren. Omdat een coaching programma niet plaatsvindt in een vacuüm heeft het ontwerp mede plaatsgevonden vanuit een complexiteitsbenadering. Er is rekening gehouden met het feit dat een dergelijk programma uitgevoerd wordt in een complexe wereld en een complexe schoolomgeving, waarbij diverse contextvariabelen invloed hebben op de uitvoering van het programma. Verder worden de resultaten beschreven van een onderzoek naar de effecten van de VFC-T op het welbevinden van leerkrachten en op de veranderingen in gedrag van leerkrachten en leerlingen in de klas.

Achtereenvolgens komen in dit hoofdstuk aan bod: het ontwerp van de VFC-T (hoofdstuk 2), het effect van professionele ontwikkeling van leerkrachten vanuit een complexiteitsstandpunt (hoofdstuk 3), de resultaten van het effectonderzoek naar de VFC-T op het gebied van welbevinden van leerkrachten (hoofdstuk 4) en de resultaten van het effectonderzoek naar de VFC-T in termen van veranderd gedrag van leerkrachten en leerlingen in de klas (hoofdstuk 5).

Hoofdstuk 2:
De beschrijving van de VFC-T

De VFC-T is gebaseerd op een aantal algemene principes op het gebied van talent en talentontwikkeling, op het gebied van gedragsverandering en op een aantal specifieke punten die belangrijk zijn voor het leren en onderwijzen van W&T.

Voor wat betreft talent en talentontwikkeling wordt rekening gehouden met een aantal belangrijke aannames op het gebied van W&T talent die geformuleerd zijn binnen het project TalentenKracht (Steenbeek & Van Geert, 2009). De eerste aanname is *dat ieder kind talentvol is en zijn of haar talenten kan ontwikkelen in interactie en co-constructie met de omgeving*. Dit houdt in dat ieder kind de potentie heeft om talentvol W&T-gedrag te laten zien, dat wil zeggen nieuwsgierigheid, belangstelling, onderzoeksvaardigheden, redeneren, logisch denken en probleemoplossend vermogen (Van Benthem et al., 2005; Van Geert, 2011). Dit gedrag kan zich ontwikkelen door een positieve interactie met de omgeving, waaronder de leerkracht, waarbij kind en omgeving elkaar wederzijds positief beïnvloeden. De tweede aanname is dat *kinderen van nature nieuwsgierig* zijn naar hun omgeving.

De derde aanname is dat *ouders en leerkrachten talentvol gedrag van kinderen kunnen zien*, dit kunnen plaatsen in een ontwikkelingsperspectief en daarnaar kunnen handelen met als doel de verdere ontwikkeling van talent bij kinderen. De vierde aanname is dat het belangrijk is dat de *leerkracht zich ontwikkelt tot talent-expert*, wat inhoudt dat de leerkracht talentvol gedrag van kinderen kan zien, dit talentvol gedrag kan plaatsen in een ontwikkelingsperspectief en ernaar kan handelen. De laatste aanname is *dat casus-gestuurd leren (case-based learning) de beste manier is om leerkrachten (maar ook ouders en opvoeders) "ogen te geven"*, dat wil zeggen te leren zien in een kader van W&T ontwikkeling.

Om op een goede manier W&T in groep 1-4 in de dagelijkse lespraktijk te kunnen geven zijn een drietal onderwerpen essentieel voor leerkrachten om te beheersen. Leerkrachten hebben allereerst kennis nodig van een fundamenteel concept dat helpt W&T als een coherent betekenisvol systeem te zien, en dat hen helpt structuur aan hun lessen te geven (Richland, Stigler, & Holyoak, 2012). De empirische cyclus (De Groot, 1961) voldoet daaraan, omdat het model in de wetenschappelijke praktijk toegepast wordt en omdat de vijf stappen (van onderzoeksvraag tot conclusie) helpen structuur aan te brengen bij het nadenken over W&T-onderwerpen in de klas. Vervolgens hebben leerkrachten kennis nodig over het gebruik van vragen die leerlingen ruimte geven om te redeneren en om na te denken (Oliveira, 2010). Tenslotte hebben leerkrachten kennis nodig over en inzicht in hoe ze de juiste hoeveelheid ondersteuning kunnen geven. Scaffolding is een geschikte strategie daarvoor omdat deze werkwijze leerlingen in staat stelt een hoger niveau te bereiken dan ze zonder hulp hadden kunnen doen (Wood, Bruner, & Ross, 1976). Daartoe biedt de leerkracht hulp net boven het niveau dat de leerling alleen kan bereiken, en bouwt die hulp pas af als de leerling zelfstandig verder kan.

Leerkrachten kunnen de voornoemde strategieën tot zich nemen, maar het bewerkstelligen van een daadwerkelijke gedragsverandering vereist meer. Bij het ontwerp van de VFC-T is er uitdrukkelijk uitgegaan van een aantal principes van gedragsverandering om de kans te vergroten dat gedragsverandering ook daadwerkelijk plaatsvindt. Er is aandacht voor onder andere het feit dat leerkrachten eerder geneigd zijn tot gedragsverandering als een interventie is gericht op concrete lessen (Harwell, 2003) en als de intrinsieke motivatie gestimuleerd wordt door op een juiste manier concerns als competentie, sociale relaties en autonomie bij leerkrachten aan te spreken (Minnaert, Boekaerts, & de Brabander, 2007; Steenbeek & Van Geert, 2007). Ook is het belangrijk gebruik te maken van modelling (Bandura, 1971), reflectie (Paterson & Chapman, 2013) en videobeelden (Seidel, Stürmer, Blomberg, Koberg, & Schwindt, 2010).

De VFC-T is als volgt opgezet: leerkrachten krijgen een theorieles, met informatie over wetenschap en technologietalent van jonge kinderen en over de empirische cyclus, vragen stellen en scaffolding. Op basis daarvan stellen leerkrachten hun eigen leerdoelen op voor de komende coaching sessies. In de daaropvolgende vier tot zes weken volgen vier coaching sessies in de klas van de leerkracht. De leerkracht voert daarvoor steeds een W&T les van 20-30 minuten naar eigen keuze uit met een klein groepje leerlingen. De les wordt opgenomen op video door de coach. Direct na de les bespreekt de coach de les met de leerkracht aan de hand van de leerdoelen en een mix van videobeelden die voornamelijk inhoudelijk goed gedrag laten zien naast een enkel leerpunt. Deze bespreking duurt ongeveer 30-45 minuten.

Omdat de effectiviteit van een interventie niet alleen afhangt van de kwaliteit van de interventie zelf, maar ook van de manier waarop de interventie wordt uitgevoerd, is het belangrijk dat coaches goed opgeleid worden. Daartoe is een training voor coaches ontwikkeld ("Train de Trainer") waarin op basis van de VFC-T handleiding voor coaches (Wetzels, Steenbeek, & Fraiquin) gedurende vier bijeenkomsten van twee uur de coaches opgeleid worden.

Hoofdstuk 3:

Het effect van professionele ontwikkeling van leerkrachten vanuit een complexiteitsstandpunt

In hoofdstuk drie is een theoretisch overzicht gegeven van effectieve aspecten van professionele ontwikkeling voor leerkrachten. Interventie- , leerkracht- en contextspecifieke aspecten, alsmede aspecten met betrekking tot de implementatie zijn eerst beschreven vanuit een traditioneel gezichtspunt, waarna de effectiviteit van deze aspecten is geherinterpreteerd in termen van een complexiteitsbenadering van ontwikkeling en leren. Een belangrijke conclusie is dat de uitkomst van een interventie beïnvloed wordt door de context waarin de interventie plaatsvindt en de wijze waarop alle relevante aspecten op elkaar inwerken. Daarbij wordt de uitkomst van de interventie dusdanig beïnvloed dat dezelfde interventie een verschillende voortgang en uitkomst kan laten zien in verschillende situaties, bij verschillende individuele leerkrachten. Een interventie is dus geen vast protocol dat de werkelijkheid op een vaste wijze beïnvloedt, maar meer de beschrijving van een bepaald samenstel van handelingen dat het startpunt vormt van een proces met een groot aantal idiosyncratische eigenschappen die allemaal in meer of mindere mate positief of negatief bijdragen aan de effectiviteit van het proces, bij deze specifieke individuele persoon/ leerkracht. Een gevalsstudie (case study) illustreert dit complexiteitsstandpunt door te laten zien hoe de VFC-T uitwerkt op resultaatniveau bij twee leerkrachten in de context van hun klas en hun school. Beide leerkrachten hadden hetzelfde startpunt op het gebied van interventiespecifieke aspecten (ze volgden dezelfde interventie) en aspecten met betrekking tot de implementatie (ze hadden dezelfde coach). De verschillen in de leerkracht- en contextaspecten (bijvoorbeeld een directeur die anders omging met de interventie), en de manier waarop de verschillende aspecten elkaar beïnvloeden, laten een idiosyncratisch proces zien, waarin de interventie bij beide leerkrachten verschillende uitkomsten toont. Dit betekent dat een coach zich bewust moet zijn van dit samenspel en van de manier waarop dit de reactie van de leerkracht beïnvloedt. Bovendien is het , om op correcte wijze de effectiviteit van een bepaalde interventie te kunnen evalueren, noodzakelijk om duidelijk te maken op welke wijze alle aspecten met elkaar samenhangen en elkaar beïnvloeden gedurende de interventie. De kennis over deze samenhang en de wijze van beïnvloeden kan zowel gebruikt worden om effectievere interventies te ontwerpen alsook om interventies beter te implementeren, hetgeen kan leiden tot betere resultaten ook op langere termijn.

Hoofdstuk 4:

Het effect van de VFC-T op het welbevinden van leerkrachten

Het onderzoek in hoofdstuk 4 geeft resultaten van een eerste effectonderzoek van de VFC-T. Allereerst is door middel van interviews met deelnemende leerkrachten onderzocht wat de invloed van de VFC-T op het welbevinden van leerkrachten is. De ervaringen van de leerkrachten waren positief: een maand na afloop van de coaching gaven ze aan dat hun plezier in de W&T lessen toegenomen was en dat ze gemotiveerder waren om W&T-lessen te geven. Ze zagen bij zichzelf veranderingen zoals een betere voorbereiding van de les, een toename in W&T-kennis en meer en betere interactie met de leerlingen gedurende de les. Bovendien vonden zij zichzelf na de coaching beter toegerust om lessen W&T te geven. Daarnaast waren de leerkrachten blij te zien dat hun leerlingen veel enthousiasme en betrokkenheid toonden tijdens de lessen. Deze kwalitatieve resultaten van de leerkrachten op basis van de interviews waren in lijn met kwantitatieve resultaten van dezelfde leerkrachten: de coachingsessies hadden tot gevolg dat leerkrachten significant meer vragen gingen stellen gebaseerd op de empirische cyclus.

Hoofdstuk 5:

Het effect van de VFC-T op het gedrag van leerkrachten en leerlingen in de klas

Een uitgebreid vervolgonderzoek, beschreven in hoofdstuk 5, met andere scholen en leerkrachten, geeft antwoord op de vraag wat de effecten van de VFC-T zijn in termen van veranderd gedrag van leerkrachten en leerlingen in de klas. Daarvoor is een diepte-onderzoek uitgevoerd bij zes leerkrachten, met een focus op het daadwerkelijk gedrag van leerkracht en leerling in de normale klasse-situatie. Deze zes leerkrachten werden gecoacht volgens de VFC-T , terwijl er een controlegroep van vijf leerkrachten was in dezelfde periode zonder coaching. De resultaten zijn gemeten bij de leerkrachten op basis van het aantal gestelde vragen die wetenschappelijk redeneren van leerlingen uitlokken (TSEQ), bij de leerlingen op basis van het niveau van redeneren (PLS), beide zowel gedurende de coaching als twee maanden later. De resultaten laten zien dat bij leerkrachten een toename te zien was ten opzichte van de voormetingen van TSEQ gedurende de periode van coaching. Twee maanden later, bij de nameting, was het niveau van TSEQ gezakt tot het niveau van de voormetingen. Opvallend was dat bij de controlegroep er een significante daling te zien was tijdens de nameting ten opzichte van de voormeting. Als het resultaat op langere termijn gemeten wordt als het verschil tussen de experimentele en de controle groep, kan gesteld worden dat er ook op de langere termijn een significant resultaat is waar te nemen. Een mogelijke verklaring voor de afname van TSEQ bij beide groepen kan zijn dat de nametingen plaats hebben gevonden in juni, een periode waarin leerkrachten wellicht meer aandacht hebben voor andere, sociale, activiteiten dan de lessen W&T. Een dergelijk resultaat is ook in ander onderzoek gevonden (Opdenakker, Maulana, & den Brok, 2012; Stroet, 2014). De resultaten op leerlingniveau laten zien dat het niveau van redeneren (uitgedrukt in PLS) van de leerlingen zowel tijdens de coaching als bij de nametingen significant hoger was dan tijdens de voormetingen, ook in vergelijking met de controlegroep.

In een vervolgstap is onderzocht of de gevonden resultaten zichtbaar waren bij alle leerkrachten van de experimentele groep. Dit bleek niet het geval. In de individuele verandertrajecten van leerkrachten zijn drie verschillende patronen te herkennen in TSEQ: geen toename gedurende het hele traject, enkel een toename gedurende het coaching traject en een toename die ook nog te zien is bij de nameting. Vervolgens is gekeken naar de coherentie tussen de resultaten van een leerkracht en de bijbehorende groep leerlingen. Hierin was een grote interindividuele variabiliteit te onderkennen. Het dominante patroon was echter dat het niveau van PLS van leerlingen twee maanden na afloop van het coaching traject van de leerkracht hoger was dan bij de voormetingen, terwijl de leerkrachten wel een toename vertonen gedurende het coaching traject, maar daarna in hun niveau van TSEQ terugvallen. Leerlingen lijken dan nog steeds te profiteren van het eerdere gedrag van hun leerkrachten.

Hoofdstuk 6:
Aanbevelingen voor vervolgonderzoek

In dit onderzoek is gebruik gemaakt van een kleine groep leerkrachten die intensief gevolgd zijn. Deze keuze is ingegeven door het doel van het onderzoek. Het doel was het ontwerpen en beschrijven van een interventie voor professionele ontwikkeling van leerkrachten die het gedrag van leerkrachten en leerlingen beïnvloedt. Daarnaast werd het effect van de interventie gemeten op het welbevinden van leerkrachten en het gedrag van leerkrachten en leerlingen in de klas. Over het algemeen leidt onderzoek met een grote steekproef tot representatieve data die generaliseerbaar zijn naar de hele populatie. Deze data geven echter enkel gemiddelde waarden, en geven minder informatie over wat er gebeurt op individueel niveau. Een klein aantal deelnemers geeft de mogelijkheid te kijken naar wat er werkelijk gebeurt in de klas, en op die manier meer diepgaand de processen in een klas te onderzoeken, met daarbij oog voor individuele verschillen tussen leerkrachten.

Onderzoek met een kleine steekproef is daardoor bij uitstek geschikt bij ontwerpstudies, omdat dit onderzoek meer inzicht geeft in achtergronden, in plaats van enkel resultaten. Daardoor kan na afloop van de effectstudie het ontwerp gericht verbeterd worden. Het nadeel blijft dat de generaliseerbaarheid naar de populatie met voorzichtigheid moet worden gedaan.

De resultaten van dit onderzoek zijn over het algemeen positief. Een aantal punten vallen echter op. Ten eerste geven de resultaten voor wat betreft de langere termijn een gemengd beeld. De resultaten van leerkrachten lijken na twee maanden teruggezakt te zijn naar het niveau van voor de interventie, al geldt dat niet voor de resultaten van de leerlingen. Daarnaast tonen de resultaten van de individuele leerkrachten aan dat niet alle leerkrachten positieve gedragsveranderingen tonen. Om de VFC-T te verbeteren zal in toekomstig onderzoek nagegaan moeten worden hoeveel coaching nodig is, hoelang de interventie moet duren en hoe het programma aan individuele leerkrachten kan worden aangepast. Een interventie over een langere periode gecombineerd met longitudinaal diepgaand onderzoek kan meer inzicht geven in de relevante aspecten die nodig zijn voor verbetering.

Aanbevelingen voor de lessen W&T in groep 1-4

W&T lessen in de onderbouw van het primair onderwijs zijn belangrijk. Leerkrachten hebben een belangrijke rol in het stimuleren van het talent voor W&T van jonge kinderen. Om dit goed te kunnen doen is het belangrijk dat de leerkrachten W&T kunnen zien als een coherent betekenisvol geheel en op basis daarvan structuur geven aan de lessen W&T (Richland et al., 2012). Het gebruik van de empirische cyclus, in aanvulling op de al aanwezige kennis van leerkrachten van zaken als drijven en zinken, luchtdruk en andere relatief eenvoudige concepten is voldoende om op een adequate manier W&T lessen te geven. Daarnaast is het belangrijk dat leerkrachten gebruik maken van het stellen van de juiste vragen om leerlingen ruimte te geven om te redeneren, en van scaffolding om hen te ondersteunen. Bovendien maken leerkrachten, door gebruik te maken van de empirische cyclus, een begin met het zelf verwerven van meer W&T kennis. Dit lijkt een effectievere methode dan te starten met het verwerven van W&T kennis, de methode die vaak wordt gebruikt bij de opleiding van leerkrachten. Daarbij ontbreekt vaak de kennis over hoe de concepten in de klas te gebruiken.

In aanvulling daarop kan het belang van interactie in de relatie tussen leerkracht en leerling tijdens de W&T lessen niet genoeg benadrukt worden (Mayer, 2004). Leerkrachten hebben vaak de onjuiste veronderstelling dat hun rol in de klas het faciliteren van de " hands on" leeractiviteiten van de leerlingen is. Leerkrachten dienen echter te onderkennen dat ze een veel belangrijkere rol hebben. Zij hebben een belangrijke rol in de co-constructie van kennis, dat wil zeggen de gezamenlijke constructie van kennis van een kind samen met henzelf als leerkracht, waarbij de leerlingen gestimuleerd worden tot "minds-on" leren. Leerkrachten kunnen de verantwoordelijkheid daarvoor nemen door strategieën als vragen stellen en scaffolding op juiste momenten in de klas toe te passen.

Aanbevelingen voor de professionalisering van leerkrachten

VFC-T is een effectieve manier voor leerkrachten om hen te helpen hun gedrag in de klas te veranderen, mits contextuele factoren daaraan positief bijdragen. Daartoe voorziet de VFC-T leerkrachten van voldoende kennis om de lessen W&T te geven, maar ook van de mogelijkheid om te oefenen met nieuw gedrag in de klas en daarop te reflecteren met een coach. De resultaten gedurende de coaching periode zijn positief voor leerkrachten en leerlingen, de resultaten op langere termijn zijn wel positief voor de leerlingen maar niet voor de leerkrachten. Daarnaast is het zo dat niet elke leerkracht verbetering toont. Uit ander onderzoek komt naar voren dat er een termijn van drie tot vijf jaar nodig is voor leerkrachten om een nieuwe manier van werken in de dagelijkse praktijk volledig toe te passen (Loucks-Horsley, Stiles, Mundry, Love, & Hewson, 2010). Deze beide zaken leiden tot de aanbeveling om leerkrachtprofessionalisering plaats te laten vinden in een langetermijnperspectief van coaching en reflectie.

Daarnaast is het van belang rekening te houden met het feit dat een interventie, hoe goed ontworpen ook, wordt uitgevoerd in een complex dynamisch systeem als een school of een klas, met veel elkaar beïnvloedende factoren. Een schoolleiding dient derhalve een interventie niet als een op zichzelf staand effectief middel te behandelen, maar te beseffen dat de effectiviteit ervan mede afhankelijk is van diverse concrete contextuele factoren. Het is aan de schoolleiding om samen met een coach deze contextuele factoren zoveel mogelijk positief te beïnvloeden om de effectiviteit van een interventie te vergroten.

Tenslotte

Dit proefschrift beschrijft het belang van interactie in de relatie tussen leerkracht en leerling en het belang van de verschillende strategieën die leerkrachten kunnen toepassen om hun rol in dit interactieproces te kunnen vervullen. De VFC-T ondersteunt het interactieproces tijdens W&T lessen aan de hand van coaching en reflectie aan de hand van video.

De VFC-T sluit aan bij recente ontwikkelingen in Nederland met betrekking tot W&T in het onderwijs. Het Nederlandse Techniekpact 2020 is een gezamenlijk initiatief van rijksoverheid, het georganiseerde bedrijfsleven, de vakbonden, het onderwijsveld en de regio's met als doel om het aantal afgestudeerden in W&T tot het jaar 2020 te vergroten om aan de groeiende behoefte aan technisch personeel te voldoen. Een van de speerpunten van het Techniekpact 2020 is dat meer kinderen een opleiding in de techniek gaan volgen. De VFC-T kan helpen om al op jonge leeftijd kinderen enthousiast te maken voor die richting.

De VFC-T en de daaraan ten grondslag liggende theorie wordt inmiddels op een aantal plaatsen ingezet. Naast deelname aan reguliere coaching-trajecten, onder andere via het Wetenschapsknooppunt Noord-Nederland, is deelname mogelijk door middel van een recent ontworpen e-learning programma (Wetzels, Steenbeek, & Fraiquin, 2014). Leerkrachten kunnen op die manier onafhankelijk van een coach gebruik maken van de VFC-T, waarbij gerichte reflectie op eigen videobeelden zelfstandig plaats kan vinden of samen met een collega. In het najaar van 2015 zal de e-learning worden uitgebreid met een online coach mogelijkheid.

De VFC-T is ontworpen voor gebruik door min of meer ervaren leerkrachten die al voor de klas staan. Een belangrijke ontwikkeling is dat de Pabo Hanzehogeschool Groningen de komende jaren TalentenKracht steeds meer in het curriculum gaat verwerken. Op die manier zullen leerkrachten gedurende hun opleiding al in aanraking komen met het werken volgens TalentenKracht principes.

Dankwoord

Het schrijven van dit proefschrift was een traject, waarvan ik aan de start niet kon bedenken hoe het er uit zou zien en zelfs of ik het zou kunnen. De afgelopen jaren zijn leerzaam geweest, maar het is ook een leuke tijd geworden, waar ik met veel plezier aan terugdenk. Veel mensen hebben aan deze periode ieder op hun eigen wijze bijgedragen en die wil ik dan ook bedanken.

Beste Paul, vanaf ons eerste contact aan de telefoon, jij in Groningen en ik op Bonaire, heb je me enthousiast gemaakt voor het TalentenKracht-onderzoek. Wat was ik blij met je mailtje om 8 uur 's morgens waarin je me vertelde dat jij en Henderien voor mij gekozen hadden om als aio bij het Expertisecentrum TalentenKracht onderzoek te doen. Nog blijer was ik met het vertrouwen dat je me gaf toen we het onderzoek een andere richting gaven. Dat is jouw kracht, mensen vertrouwen geven, en vervolgens ondersteunen met jouw enorme kennis en creativiteit. Paul, dank je wel voor dit alles. Ik ben heel blij dat ik deze jaren met jou heb mogen werken.

Lieve Henderien, wat heb ik een geluk gehad dat jij mijn begeleider bent geweest. Ik kan nog nagenieten van de inhoudelijke discussies op het gebied van coachen, leren, leerkrachten en leerlingen. Deze discussies hebben de basis gevormd van het proefschrift zoals het uiteindelijk geworden is. Je hebt me veel geleerd op het gebied van observatie-onderzoek en de analyses die daarbij horen, je hebt me geholpen bij het nemen van allerlei beslissingen en je bent een grote steun voor me geweest bij het schrijfwerk. Maar bovenal waardeer ik de zakelijke en persoonlijke gesprekken, die nog wel eens door elkaar wilden lopen, en die ertoe hebben geleid dat we samen onder andere de Train-de-Trainerscursus hebben ontworpen en www.coachinginhetonderwijs.nl hebben opgezet. Hopelijk blijven we nog lang met elkaar samenwerken.

Verder wil ik graag Alexander Minnaert, Julliette Walma van der Molen en Ferre Laevers bedanken voor hun deelname aan de leescommissie.

Dit onderzoek had niet plaats kunnen vinden zonder de inzet van leerkrachten en leerlingen van een groot aantal scholen. Dank je wel, OBS Beukenlaan in Winschoten, OBS 't Vrieske Honk in Vriescheloo, de Benedictusschool in Heiloo, OBS Jan Bierma in Aduard, OBS Goeman Borgesius in Oldehove, CBS De Betrouwen in Bakkeveen, CBS De Paedwizer in Beetsterzwaag, CBS De Opdracht in Ureterp, Sint Michaëlschool in Wolvega, OBS Joseph Haydn in Groningen, De Westerschool in Wildervank en Schuilingsoord in Zuidlaren.
Marianne Fraquin, bedankt voor je hulp bij het leggen van contacten met de scholen.

Verder wil ik graag Jolien, Rick, Cynthia, Eva, Renate, Mara en Lisette bedanken. Jullie hebben in het kader van je mastertheseonderzoek een bijdrage geleverd aan de dataverzameling, de ontwikkeling van codeersystemen en aan het coderen.

Ik heb een heel fijne tijd gehad bij Ontwikkelingspsychologie. Ik had me geen betere collega's kunnen voorstellen. Dank jullie wel voor de gezelligheid, jullie belangstelling, de gesprekken en de input tijdens researchbesprekingen en aio-overleggen. De congressen in Berkeley, Seattle, Antwerpen, Leuven en Munchen, die ik met collega's bezocht heb, waren niet alleen leerzaam maar ook erg gezellig.
Ik wil een paar mensen nog extra noemen. Marijn, bedankt voor je tijd en je steun op momenten dat ik het even niet meer zag zitten. Je had gelijk, wensen die je doet aan de Stille Oceaan komen altijd uit! Heidi en Marieke V., dank je wel voor het luisteren en het er zijn. Elisa, zonder jou zou ik dit project niet eens zijn gaan doen. Bedankt voor de leuke tijd in het Muntingh, ik heb heel veel van je geleerd. Marieke B., fijn dat jij samen met Elisa kamer 3.16 hebt vormgegeven. Na twee weken samen op een kamer is 3.16 een begrip geworden voor ons drie. Dank je wel voor alle gesprekken en gezelligheid. Marieke B. en Elisa, de gezellige avonden samen om weer eens iets te vieren zal ik niet vergeten. Hopelijk komen er nog veel van die gelegenheden!

Naast al diegenen die figuurlijk met me mee zijn gelopen in dit traject, zijn er nog een aantal mensen die dat letterlijk hebben gedaan. Tijdens lange en soms erg lange duurlopen hebben mijn hardloopmaatjes van de HoogeZandlopers met me meegeleefd. Het lopen met jullie liet me altijd weer zien dat fysieke inspanning het allerbeste is om te ontspannen in een drukke tijd.

Familie en vrienden, ik wil jullie bedanken voor jullie vertrouwen, steun en belangstelling. Niet alleen tijdens dit promotietraject, maar ook in alle jaren daarvoor! Momenten die in mijn geheugen gegrift staan zijn de avond van mijn afstuderen als accountant in 1988 samen met mijn familie, en het etentje met vrienden voor mijn verjaardag in 2004, de start van een nieuwe carrière. Buurman Martin, ik wil ook jou bedanken. Je gitaar had niet op een beter moment kunnen komen. De laatste schrijfmaanden was dat de ideale afleiding!

Willemijn en Marga, ik ben er trots op dat jullie mijn paranimfen willen zijn. We hebben het al lang geleden afgesproken, en nu is het eindelijk zover. Dank jullie wel!

Lieve Henk, jij was degene die me met één simpele vraag in februari 2005 op het spoor zette om mijn droom om psychologie te studeren te gaan realiseren. Ook daarna heb je me geholpen, en niet alleen met de praktische dingen. Je hebt meegedroomd, meegedacht en me vooral altijd het vertrouwen gegeven dat het gaat lukken.
Wat moet ik zonder jou?

Publications

International publications

Birbeck, J., Williams, K., Celebi, M., and Wetzels, A.F.M. (2015). *Connect, Reflect and Grow - VERP development in the early years*. In Video Enhanced Reflective Practice: Professional Development through Attuned Interactions Edited by H. Kennedy, M. Landor and L. Todd.

Wetzels, A.F.M., Steenbeek, H.W., & Van Geert, P.L.C. (manuscript accepted, pending revision). *A complexity approach to investigating the effectiveness of an intervention for lower grade teachers on teaching science.*

Wetzels, A.F.M., Steenbeek, H.W., & Van Geert, P.L.C. (manuscript accepted, pending revision)) *The Effect of a Coaching Program on Teachers' Well-being in Science and Technology Lessons in Primary Education*.

Wetzels, A.F.M., Steenbeek, H.W., & Van Geert, P.L.C. (manuscript accepted, pending revision) *Primary science teaching: the effect of a coaching program on the behavior of teachers and their pupils.*

Menninga, A., Van Dijk, M.W.G., Wetzels, A.F.M., Steenbeek, H.W., & Van Geert, P. L.C. (manuscript submitted for publication). *Academic Language in Science and Technology Lessons in Kindergarten; an Intervention Study.*

Dutch publications

Wetzels, A.F.M., & Steenbeek, H.W. (2015). Wetenschap en Techniektalent; het creëren van een positieve talentspiraal van leerlingen en docenten samen. *Bij de Les, 11*, 36.

Wetzels, A.F.M., Steenbeek, H.W., & Fraiquin, M. (2014). *Talent creert Talent. Een e-learning module voor het werken met excellente leerlingen.* http/www.onderwijsnu.nl/ elearningmodules/ talent_creert_talent

Wetzels, A.F.M., Steenbeek, H.W., Wierdsma, M., & Fraiquin, M. (2015). *Online coaching. Een e-learning module met online coachomgeving.*

Wetzels, A.F.M (2013). Wetenschap en Techniek in de onderbouw: het talent is er al! *Bètapunt Noord Magazine, 2.*

Hoekstra L., De Koning, B., & Wetzels, A.F.M. (2013). Hoe kunnen leerkrachten excellente kinderen ondersteunen tijdens Wetenschap & Techniek-lessen? *Bètapunt Noord Magazine, 2.*

Steenbeek H.W. & Wetzels, A.F.M. (2013.) *Ouders ogen geven: werkmap voor leerkrachten groep 1-2.*

Wetzels, A.F.M (2012). De wetenschappelijke methode: een tool voor leerkrachten. *Bètapunt Noord Magazine, 1.*

Honingh, E, Steenbeek, H.W. & Wetzels, A.F.M. (2012.) Van 'Juf, ik heb wat ontdekt!' tot 'Huh, hoe kan dat?' *Didactief, 42, 5*