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Curious minds in the classroom

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CHAPTER 2:

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

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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 Ben- them 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.

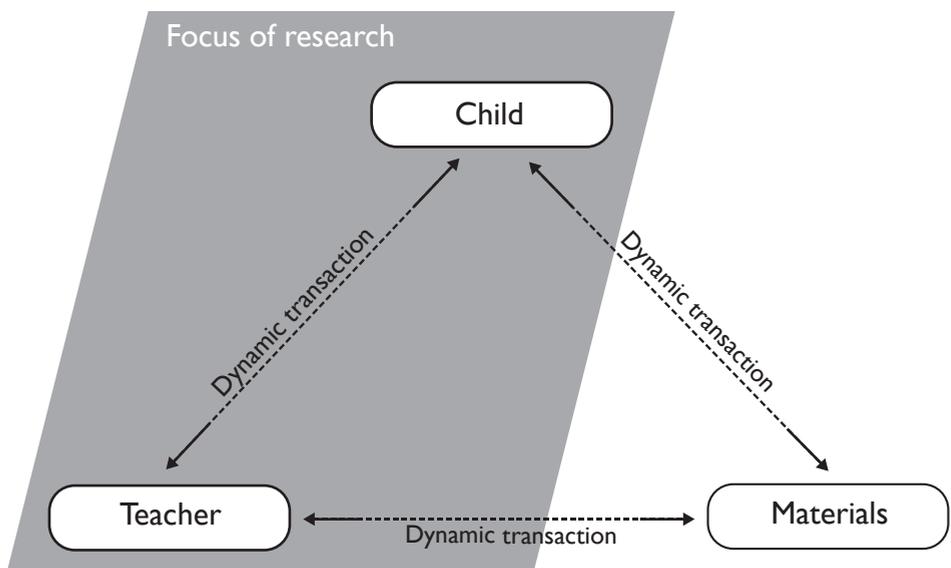
Static vs. dynamic: Science talent is only one of many talents children can have. When speaking about talent in general, the most frequently used definition of talent is a static one, a person's ability to excel in a certain area, a giftedness (Howe, Davidson, & Sloboda, 1998). However, this research 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 focu-

ses 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 un-

structured 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 (Wilén, 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 (Wilén, 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.

