Curious minds in the classroom

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CHAPTER 6:

Summary of Findings, Conclusion and Discussion

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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.