Chapter 8

Summary and discussion
8.1 Aim of this dissertation

The aim of this dissertation was to explore the nature and the use of (academic) language in an ecologically authentic environment – that is, small group science activities in early elementary school – and to evaluate an intervention. This intervention, which was called ‘Language as a Tool for learning science’ (LaT) aimed at improving the language use of teachers and students in these real-time interactions during science activities. Language is a key factor in the development of reasoning skills, in particular during the transition from the home or preschool setting to formal schooling (kindergarten and first grade of elementary school). The context of science activities is particularly important for advancing language learning. The intertwined developmental processes of language learning and reasoning – as taking place in real-time teacher-student interaction – were studied over the course of the intervention. This dissertation integrated fundamental scientific insights and educational practice by applying the framework of complex dynamic systems on designing, implementing and evaluating an intervention. This was done by using a combination of traditional group-based (global) and individual process-based (dynamic) methodologies, which provided a rich source of information on the teaching-learning processes during the LaT intervention. Because of the practical relevance of this type of research, a group of novice teachers – which were student teachers in their final year of teacher education – was included to see whether the intervention could be implemented during teacher education.

8.2 Summary of results

8.2.1 Part I

In the first two studies, the focus is on forms of (academic) language use as it occurs in small group science activities. These studies provide insights into the preconditions for the LaT intervention.

Chapter 2

Chapter 2 was based on data of the Curious Minds in the Classroom (CMC) intervention, which was developed and implemented by Wetzels (2015). This intervention was the first to use video feedback coaching to stimulate students’ reasoning skills in the Curious Minds project. Previous analyses indicated that in the course of the CMC, teachers’ open-ended questions increased and that students’ reasoning increased in complexity (Wetzels, 2015). Since many studies indicate that language learning is essential to science learning and that it also provides great opportunities for language learning (e.g. Conezio & French, 2002; French & Peterson, 2009; Glass & Oliveira, 2014; Wellington & Osborne, 2001), the aim of Chapter 2 was to gain insight into the language use of teachers and students over the course of eight science lessons that were part of the CMC intervention. The video recordings of ten kindergarten teachers’ science lessons ($N_{\text{intervention}} = 5$, $N_{\text{control}} = 5$) were transcribed and analyzed. The results were compared with those of a control group.
The results revealed a change in the verbal interaction between teachers and students in the intervention condition: the proportion student utterances – and the length of these utterances – increased. This increase in verbal contributions of the students creates more language-learning opportunities, which is the first step towards refining the students’ language skills to a more academic register. The results on the qualitative measures of (academic) language use showed that the students increased in lexical sophistication and causal connectives after the intervention but not in the diversity of their language use. The teachers’ language also increased in sophistication, but less pronounced. There were no changes in teacher language regarding lexical diversity or causal connectives.

As there were no indications of changes in language use in the control group, it may be assumed that the increases in the intervention group may, at least partly, be related to the increased questioning skills of the teachers after the CMC intervention. This is also strengthened by the fact that there was only weak support for change in lexical sophistication and no indications of change for lexical diversity or causal connectives of the teachers. The teacher input showed no or very few signs that teachers employed modelling strategies to improve students’ language skills. Teaching science seems to not automatically imply using academic language. Wong Fillmore and Snow (2002) already emphasized that teachers have little awareness of the important role they have in acquainting students with academic language. The most optimal kindergarten science intervention would, therefore, include both stimulating questioning strategies and modelling academic language. The conclusion of this chapter is that in practice, it is important to raise teachers’ awareness of the need to stimulate (academic) language-learning opportunities. Science lessons represent an appropriate context in which to acquaint students with academic language (Conezio & French, 2002; French, 2004; Peterson & French, 2008; Samarapungavan et al., 2008). However, using and eliciting more academic language should be an explicit goal for teachers if the language use in science lessons is to be further improved (Schleppegrell, 2001; Wong Fillmore & Snow, 2002).

Chapter 3
Chapter 3 focused on the nature of language use in early elementary science activities. Language learning is bidirectional in nature (Bronfenbrenner & Morris, 2006; Sameroff & MacKenzie, 2003; Van Dijk & Van Geert, 2011; Van Dijk et al., 2013; Van Geert, Steenbeek, & Van Dijk, 2011), which means that language can be seen as an ordered, coupled, and meaningful sequence of utterances of the individual in a specific interactional context (e.g. teacher-student discourse during science activities). Typically, the utterances of the interaction partners are not independent, but are co-constructed and coordinated, to create meaning and understanding. Both teacher and students adapt their individual utterances to each other, and the probability increases that certain combinations of utterances will recur within and across multiple interactions, creating more predictable patterns of language use. The aim of this study was to investigate those bidirectional relations involving the complexity of language use in teacher–student interactions. Insight into these dynamics is important because, ultimately, the
intended intervention is aimed at changing (optimizing) the patterns of interaction between teachers and students. Our aim was to determine whether there was a bidirectional relation in language interaction and, if such a relation existed, to better understand its properties, including potential differences between experienced teachers and novice teachers. In addition, it was explored whether open-ended teacher questions evoked complex and lexically dense language use in students. Observational methods were used to capture the language use unfolding in real time, which is essential for understanding the underlying dynamics of the interaction (Bakeman & Quera, 2011). Twenty-two experienced and eight novice teachers participated in this study. Their verbal interactions with students during two science activities were transcribed and coded for syntactic complexity, lexical density of content-specific words, and open-ended teacher questions.

The findings of the sequential analyses specifically emphasized the relevance of modeling complex language in interaction with students and eliciting complex language from students by asking open-ended questions. Despite our teachers' lack of experience in teaching science, there were indications of mutual adaptation when it comes to complex and lexically dense language in the teacher–student interaction during these early science lessons. More specifically, there was evidence for bidirectional temporal relations between the complexity and density of teachers' and students' language. This means that both teachers and students were sensitive to each other's use of complex and dense language. Complex and dense language use of students was most evident at moments in which the teacher used complex and dense language and encouraged the students to give elaborate answers by asking open-ended questions. The findings indicated stronger bidirectional relations for the experienced teachers in the sense that their use of complex and lexically dense language was more contingent on their students' use of complex and dense language. Still, in both groups, there were large differences between individual teacher-student pairs regarding the extent to which teachers and students adapted to each other's language use. Insights into the underlying dynamics and structure of the language interaction during science lessons are of great importance in the context of language learning. The study in chapter 3 has contributed to the knowledge about the dynamics in the real-time teacher–student dialogue: it emphasized the value of investigating immediate, moment-by-moment sequences in teacher and student language. In addition, the results suggested that open-ended questions can be seen as a driving mechanism in the context of language learning within early elementary science education, as teachers' use of open-ended questions evoked more complex and dense student responses. An implication for teachers is that they should be encouraged to pose open-ended questions – as opposed to closed questions, which often elicit only a single word – so that students are stimulated to give more elaborate and linguistically complex responses.

8.2.2 Part II
The first part of this dissertation has demonstrated the preconditions regarding language use in the context of early elementary science activities. In the second part of this dissertation, the
effectiveness of a newly developed video feedback coaching intervention particularly focusing on improving language learning during science was evaluated. The intervention, which was called Language as a Tool for learning science (LaT), was an expansion of the CMC intervention of Wetzels. The LaT intervention was comparable to the CMC intervention in that it also focused on enhancing and expanding teachers’ open-ended questioning skills, scaffolding strategies, and introducing the empirical cycle as means to improve the quality of the interaction. The surplus value of the LaT intervention was that it also focused on language learning during science activities. Participants in the intervention were introduced to the importance of language (learning) during science activities, and they were provided with information and tools on evoking and modelling complex language from students. All of these strategies were integrated within the method of video feedback coaching, which has proven to be very effective in educational settings. Moreover, video feedback coaching is particularly suitable to provide insight – to teachers – into the real-time interactional processes. If professional development for teachers in early elementary science education is important when it comes to existing teaching practices, it may be even more important in teacher education (McKenzie, Santiago, Sliwka, Hiroyuki, 2005). From existing literature (e.g. Clotfelter, Ladd, & Vigdor, 2007; Hattie, 2003; Harris & Sass, 2007; Heritage & Heritage, 2013; Kane, Rocko, & Staiger, 2006; Ladd, 2008; Randi & Corno, 2005; Rivkin, Hanushek, & Kain, 2005), it becomes clear that experienced teachers are likely to have relatively stable, effective and adaptive teaching skills, whereas novice teachers seem to be in a stage of their career in which they are much more capable of improving. This raised the question whether and how both types of teachers may benefit from professional development in science education. A comparison between the two groups of participants will therefore provide important information for educational practice, policymakers, and teacher education programs. In Chapters 4, 5, and 6, the effectiveness of the LaT intervention on teaching practices of experienced teachers was compared with those of novices. The effectiveness of the LaT intervention was evaluated from different perspectives. The first two chapters (Chapter 4 and 5) focused on global measures (macro level) as indicators of eventual effectiveness, and the last two chapters (Chapter 6 and 7) addressed more dynamic measures (micro level) in order to detect possible changes in the underlying dynamics.

Chapter 4
In Chapter 4, the effects of the intervention were evaluated in terms of global teacher and student behavioral indicators, taking the form of group averages and other aggregated measures per session. The aim was to investigate the effectiveness of the LaT intervention for two types of teachers, namely experienced teachers and novices, and the impact of the intervention on students’ verbal reasoning expressions and language use. The results of this study were consistent with the hypothesis that both teachers and students benefit from the LaT intervention. On average, teachers started to pose more open-ended questions, while students’ reasoning also increased, and both teachers’ and students’ language use increased in syntactic complexity and – to a lesser extent – lexical sophistication. Another important finding was that
students used more complex sentences to express predictions and explanations. The comparison between experienced and novice teachers indicated that there was almost no difference in the way these groups benefitted from the intervention. These results provide support for the premise that language learning can be fostered by an intervention focused on improving the quality of teacher-student interactions (Barber & Mourshed, 2007). The findings also illustrate the possibilities of combining science and language learning in early elementary classrooms (e.g., French & Peterson, 2008; Gelman & Brenneman, 2004; Samarapungavan et al., 2008; Snow, 2014; Spycher, 2009; Wellington & Osborne, 2001). They also contribute to the insight into effective forms of professional development for teachers in early elementary education. The positive impact of the intervention points to the importance of creating and stimulating language-learning opportunities during science education. It illustrates that science and language learning can be integrated in early elementary grades. Nevertheless, this integration is challenging for teachers, and that is why professional guidance is required. The improvements of the language and cognitive level are global aspects of the quality of the interaction. Further in-depth studies are needed to gain more insights into possible changes in the dynamics of interaction.

Chapter 5
Chapter 5 is an evaluation of the LaT intervention in terms of attitudes towards teaching science in addition to the effectiveness of the intervention on behavior (Chapter 4). However, considering teachers’ attitudes and beliefs is of fundamental importance during any intervention, since positive feelings and feelings of control towards teaching science contribute to teachers’ willingness to change their behavior (Garet, et al., 2001; Desimone, 2009; Haney, Czerniak, & Lumpe, 1996; Van Aalderen-Smeets & Walma Van der Molen, 2013). Many studies report on negative attitudes and beliefs of elementary teachers towards teaching science (e.g., Appleton, 2003; Eshach, 2003; Greenfield et al., 2009). Although studies suggest that changing teachers’ attitudes can be accomplished through professional development focusing on inquiry-based courses, making this change happen is still a major challenge. The goal of this study was, therefore, to investigate whether the LaT intervention also had an impact on teachers’ attitudes towards science. The theoretical framework of Van Aalderen-Smeets and Walma Van der Molen (2013), and the Dimensions of Attitude toward Science (DAS), was used to investigate teachers’ attitudes. Previous studies have showed that this instrument is reliable and valid. In this study, all participants that took part in the previous study were included ($N_{\text{exp_intervention}} = 11$, $N_{\text{exp_control}} = 6$, $N_{\text{nov_intervention}} = 8$). The teachers completed the DAS questionnaire before (pre-intervention measure) and after the intervention (post-intervention measure).

The findings of this study indicated large differences in initial attitudes between experienced teachers in the intervention and control condition as well as between experienced and novice teachers. Secondly, there was evidence for the hypotheses that the attitudes of teachers in the intervention conditions – both experienced and novices – changed in a positive way after the intervention. The attitudes of both types of teachers changed on the sub
dimensions of enjoyment, anxiety, self-efficacy, and context dependency. For the experienced teachers, there also was a positive change regarding perceived difficulty, and for the novices a change in perceived relevance. It was also hypothesized that the novices may show more improvement compared to the experienced teachers. There only was evidence that this was the case for self-efficacy and perceived relevance. With regard to the control group, contrary to our expectations, they showed positive changes in attitudes on the sub dimensions of enjoyment and anxiety, perceived difficulty, and context-dependency as well. The expected inter-individual differences were made visible in the scatterplots of changes in attitudes; and the resulting graphs showed that the difference within groups sometimes were just as large as the variation between groups. A correspondence analysis revealed that the overall structure of the teacher attitudes remained fairly similar from pre- to post-intervention. The structure of the attitudes was also similar for novice and experienced teachers.

In sum, the findings of this study indicate that teaching experience plays a role in the attitudes teachers have towards teaching science. Teaching experience also seems to be of influence on the possibility to change these attitudes, in that the novice teachers showed the most improvement. The unexpected changes in attitudes of the control teachers were not reflected in changes in their actual teaching behavior (see Chapter 4). There are several possible factors that may have contributed to the changes in the control group. The first explanation relates to the fact that teachers were asked to reflect on their attitudes in the form of the questionnaire. The second explanation may be that teachers immediately experienced the enthusiasm of their students when engaging in science activities. Science activities were very uncommon and maybe even inexistent for the intervention as well as the control group. Asking these teachers to give science lessons – and asking about their experiences in the form of a questionnaire – is in itself a form of intervention. Thirdly, the activities took place in small teaching groups compared to the whole classroom setting. The attitude of teachers might be different depending on whether teachers teach in small groups or in the whole classroom. Lastly, there was one individual in the control group who clearly differed (extreme scores) from the other individuals in this group. The changes in the control group may also be partly due to the extreme scores of this individual. Overall, maybe one of the most interesting conclusions that can be drawn from this study is that the individual differences within the groups greatly outweigh the differences between the group averages.

Chapter 6
The aim of the study described in this chapter was to examine the dynamics of language use in real-time teacher-student interactions and to analyze in detail whether this dynamics changes in the course of the LaT intervention. This dynamics concerns the temporal structure of the interaction with regard to syntactic complexity. Coordination of the syntactic complexity in the teacher-student interaction is the focus of the current study. Coordination is defined as the on-going and (un)intentional process of mutual interpersonal adaptation (e.g. Garrod & Pickering, 2009). This means that within an on-going interaction, input as well as (effective) contingent responses of both
teachers and students shape their language toward syntactic coordination (Dale & Spivey, 2006): while interacting, teacher and students are inclined to produce utterances that correspond — regarding syntactic complexity — to those being heard (e.g. Branigan et al., 2000; Dale & Spivey, 2006). This process of mutual dependency among relatively independent components derived from two (sub)systems is often referred to as coupling. In one of the previous studies, the existence of transactional relations — which are the mutual influences in interaction, also known as bidirectional relations — was confirmed regarding syntactic complexity in the context of science lessons (see Chapter 3). The contribution of this study was to investigate syntactic coordination, which is defined as using sentences of the same syntactic category (no sentence, simple sentence, complex sentence), over multiple utterances within one session and across the course of an intervention.

The goal was to quantify the relative strength and direction of coordination between teacher and students regarding syntactic complexity, and investigate whether this coordination process changed during an intervention in early science lessons. In order to quantify the interactions, Cross Recurrence Quantification Analysis (CRQA) was used. This technique in particular quantifies recurrent patterns across all possible timescales, and, therefore, includes in its analysis matches of all utterances across the entire interaction. This method aims to quantify the coordination and reveals global structures and temporal patterns of language within real-time teacher-student interactions, and whether these patterns move toward syntactic coordination. In this study, all eight lessons of seven female experienced kindergarten teachers that participated in the LaT intervention were included. The verbal interactions were accurately transcribed and coded for syntactic complexity.

The results showed changes in the proportion of recurrent points, which meant in case of simple sentences that teachers and students became more loosely coupled over time, whereas in case of complex sentences teachers and students showed increasing coordination. This indicates a more flexible interaction and a stronger coupling between teachers’ and students’ complex sentences. In the light of the intervention under investigation this is an important result. This means that teachers and students can learn to use more complex language and coordinate their language complexity better in order to co-construct science discourse. The influence of both teachers and students was equally strong at the start of the intervention, but changed towards more asymmetry in the coupling in the way that students became somewhat more leading in the interaction. However, the effect size of this result was small. Since the intervention aimed at stimulating students to talk and elaborate on their responses, the slight changes towards more ‘influence’ of students – in a dynamic way – on the syntactic coordination are an interesting and supportive result. The application of CRQA provided new insights and contributes to better understanding of the dynamics of syntactic coordination.

**Chapter 7**

In Chapter 7, the aim was to explore the changes in patterns of interaction over the course of the LaT intervention and to study whether there are differences between teacher-student interactions of teachers with different teaching experience (experienced teachers versus
novices). The study in Chapter 4 revealed that both types of teachers benefitted from the intervention in terms of global measures such as questioning, reasoning, and using language. One of the most notable differences between experienced and novice teachers concerns novices’ issues with classroom management skills (Wolff, Van den Bogert, Jarodzka, & Boshuizen, 2015). However, our knowledge about the actual task-related teaching-learning processes (the real-time dynamics) in these different groups is limited, and we also know only very little about how these processes change in the long run. For this reason, the quality and the structure of the coordination were explored of the teacher-student interactions in terms of sequential verbal behaviors. In order to do this, the changes in real-time teacher-student interactions over time were explored by applying the method of State Space Grids (SSG). Using this technique a state space is constructed of ordinal data of teacher and students, which provides information about the teacher-student interaction over time. This information concerns knowledge about the quality and the temporal structure of the interaction. In other words, it reveals qualitative descriptions of the patterns of interaction in terms of coupled behaviors of teachers and students as well as general (whole grid) and specific (region) measures of real-time variability in these patterns of interaction. The contribution of this study is to detect possible changes in the dynamics in interaction over the course of the LaT intervention. As a first step, the real-time teacher-student interactions were explored focusing on how teachers and students co-construct science discourse during the short-term timescale of a single lesson and whether and how this co-construction process changed over the course of the LaT (i.e. on the long-term timescale of the intervention). As a second step it was explored whether the processes of co-construction process of teachers with different teaching experience – experienced versus novices – differed over the course of the LaT. Six lessons of two groups of teachers were included in this study: student teachers in their last year of teacher education (novices) and teachers with six or more years of teaching experience (experienced teachers). The video recordings were transcribed and the task-related utterances were coded for teachers’ questioning behavior (0 = no question, 1 = closed-ended question, 2 = open-ended question) and students’ reasoning (0 = no reasoning, 1 = observation, 2 = prediction, 3 = explanation).

The results suggested that the quality of the interaction after the intervention changed in comparison to the quality before the intervention. In regular science education, without intervention, the teacher-student interaction took the form of a relatively rigid pattern of non-optimal interactions (no co-construction). The system was drawn repeatedly towards this type of interaction, in which it rested over extended periods and to which it returned quickly. The results further showed that the elements that were introduced during the intervention are powerful enough to change these patterns of interaction as well as to support the teacher-student system to employ a richer repertoire of teacher-student interactions. The active co-construction quadrant, which is more optimal in terms of intervention goals, was visited more often. The strength of the initial state (no co-construction) decreased, which means that the percentage of interactions in this quadrant decreased and that the behavior of teachers and students returned less quickly to this state. In the end, these changes might lead to more ‘active co-construction’
during science lessons, but the ‘no co-construction’ state was still the preferred state of the teacher-student system. With regard to the structure of the interaction, the variability of the interaction in general was rather high. Over the course of the intervention, the interaction increased in variability, which reveals changes in the dynamics of the interaction. This variability may be seen as an indicator of a process of change (Bassano & Van Geert, 2009; Van Geert & Van Dijk, 2002) or as an indication of more flexible patterns of interaction. A comparison of the interaction patterns in both groups of teachers revealed that there are almost no differences in the content-related teaching-learning processes between experienced teachers and novices. It may be that the differences in interaction are more determined by, for instance, classroom management and that both groups can successfully benefit from the LaT intervention.

8.3 Discussion questions
In this section, six discussion questions will be answered based on the insights resulting from the empirical studies in this dissertation.

• **How is language used to co-construct science discourse?**
The results showed that the co-construction of science discourse entails a bidirectional process of teachers and students. The complexity of the language they use works as a positive upward spiral, in which the complexity of the teacher prompts the complexity of the students, and the complexity of the students serves as a starting point for the next contribution of the teacher. Positive student outcomes in terms of reasoning and language use are most evident at moments in which the teacher uses complex and dense language, and encourages students to give elaborate answers by asking open-ended questions. In this process of co-constructing science discourse, open-ended questions can be seen as a driving mechanism to stimulate reasoning and language learning.

• **How does the process of co-constructing science discourse change during the LaT intervention?**
Over the course of the intervention, global measures indicated increased use of teacher and student skills/variables – such as teacher questioning, student reasoning, and language complexity and sophistication – which are contributing factors to the co-construction of science discourse. The complex dynamic systems approach inspired us to study the micro-dynamics – rather than the variables in isolation – of these real-time teacher-student interactions. Based on our results, the conclusion is that the interactional dynamics changed during the intervention supporting the co-construction of science discourse. This implies that the elements of the intervention are powerful enough to change the patterns of interaction during the co-construction of science discourse. The State Space Grid analyses revealed that the quality and the structure of the (patterns of) interaction changed in the way that there were more and longer instances of co-construction. This means that in these moments, which occurred more often in
later stages of the intervention, teachers asked more open-ended questions and students expressed more reasoning. At the same time, the interaction became more variable – in terms of a richer repertoire of different teacher-student interactions – on the longer-term (over the sessions). The latter may be interpreted as an indication of a process of change (Bassano & Van Geert, 2009; Van Geert & Van Dijk, 2002) or as increased flexibility of the interaction. The process of co-constructing complex science discourse also entails coordination between teacher and students in a way that enables students to sufficiently understand and contribute to the conversation (Clark, 1996; Garrod & Pickering, 2004; Mercer, 1995). Language can be seen as an ordered, coupled and meaningful sequence of utterances of the individual in a specific interactional context (e.g. teacher-student discourse during science lesson). Typically, the utterances of the interaction partners are not independent, but are coordinated, to create meaning and understanding. Detailed micro-level analyses (using Cross Recurrence Quantification Analysis) of the complexity of the language during the intervention revealed that the structure of the conversations changed. Teachers and students started using more complex language over the sessions, the use of these constructions was more coordinated, and at the same time are flexible. In line with other studies, teachers and students – in order to successfully contribute to the conversation – align their language complexity to ultimately create mutual understanding (Brown-Schmidt & Tanenhaus, 2008; Pickering & Garrot, 2004). This means that both teacher and students adapt their individual utterances to each other, and this increases the probability that certain combinations of utterances will recur within and across multiple interactions, creating more predictable patterns of language use.

• What about students’ learning gains after the intervention?

The focus of this dissertation was on (language) learning in the context of complex, intertwined interactions during science lessons. The inevitable question after the implementation of educational interventions is: what are the learning gains of students? From our point of view, the learning gains of students cannot be attributed – in part or in whole – to a particular teaching strategy. In learning, there is no core mechanism such as linear long-term cause-and-effect to assess the impact of an intervention. Learning takes place in social interaction, and so learning is influenced by multiple factors whose relative contribution changes dynamically in relation to the other components and new factors may enter or leave the network of dynamic relationships as a consequence of the preceding dynamic relationships. This is what makes the teaching-learning processes such a complex, intertwined system. The students’ learning outcomes in such a complex system are hard to capture by using traditional educational testing, or even traditional research methodologies. Learning gains in this dissertation are not measured by means of standardized educational testing, but rather in terms of changes in behavior over time. Although these measures do not capture future knowledge and skill development, they do give insight into the occurrence of certain (desired or optimal) forms of behavior in this specific setting. The most important findings of this dissertation related to learning gains are those that indicate changes in the types and patterns of interaction. As the quality of interaction is often
said to be of influence to changes in learning (Barber & Mourshed, 2007), more optimal ways of interaction – such as those resulting from the LaT intervention – will constitute beneficial teaching-learning processes in the (near) future. One of the main goals of the LaT intervention was to introduce teachers and students to the fundamentals of acquiring new (scientific) knowledge and introduce them to the language that is required to verbalize this process. Changes in this basic attitude towards encountering science activities will contribute to future experiences in this context, ultimately resulting in positive learning gains of students.

• **What is the surplus value of LaT intervention?**

The LaT intervention was one in a line of several video feedback coaching interventions that were designed at the Curious Minds research group of the University of Groningen. The main goal of these interventions was to enhance and expand teachers' questioning and scaffolding strategies in order to stimulate students’ reasoning skills. The interventions were successfully implemented in a diversity of educational settings: regular lower grade elementary classrooms (Wetzels, 2015), regular upper grade elementary classrooms (Van Vondel, 2016), special educational needs classrooms (Honingh), excellent or gifted children in upper grade classrooms (Veenstra-De Koning), and in out-of-school science activities (Geveke, 2016). All these interventions resulted in positive changes in terms of teachers' questioning behavior and students' reasoning skills. However, none of these studies included the language that was used to ‘do’ the learning and teaching of science. The findings of Chapters 4, 6, and 7 indicate that the LaT intervention, of which the basic principles were similar to the previous interventions but with a specific and explicit focus on language learning, yields very promising results. The results with regard to questioning behavior and student reasoning are comparable to the results of the previous interventions. The surplus value of the LaT intervention is that it explicitly aimed at effects on language use. An exploration of language measures on data of the basic intervention of Wetzels (Chapter 2) showed some interesting changes in language use of students, which may be related to the increase in open-ended teacher questions. However, there were little indications that teachers increased in academic language use themselves. After the LaT intervention (Chapter 4), which also focused on language modeling strategies for teachers, both teachers and students increased in complexity and sophistication of language use. Teachers were more aware of the importance of language learning (opportunities) during science education, and they learned to employ strategies to model complex language and evoke more and more complex language from students. Because of the linguistic demands of science education, even in early elementary classrooms, it is important to include opportunities for language learning into an intervention. The LaT intervention showed that it is possible to integrate language learning and science learning, even in a relatively short period of time. So, although the original CMC intervention by Wetzels was not aimed at improving language use, there were indications that language use also benefited (Chapter 2). The intervention that was designed and evaluated in this dissertation has shown that if there is an explicit focus on language use in combination with scientific thinking, the effects on language are stronger and
deeper. Stimulating scientific reasoning of students is not only a matter of scientific reasoning skills as such, but is a matter of a smart combination of the use of scientific language and cognitive reasoning skills.

• **What are the conditions for successful implementation of the LaT intervention?**

In the context of an intervention targeting science education – which is a new subject to teach for many teachers – the role of theoretical knowledge of the teacher cannot be ignored. With this intervention, the aim was to demonstrate that the basic principles of stimulating scientific reasoning in students could be taught to teachers. The students who participated in this study – although only four to six years old – showed that they can learn to understand and apply the basic process of scientific reasoning following the steps of the empirical cycle, albeit with the help and support of their teacher. The LaT intervention is clearly a first step – and not the end goal – towards successful science education. Unquestionably, for true deep understanding of the underlying principles – and being able to support this understanding in students – some general background knowledge of physics is important. Teachers should have practical knowledge of a wide variety of interesting scientific phenomena (which they can easily get from a wide variety of good Internet sources focusing on science in the classroom), should have a basic understanding of a small number of truly fundamental scientific principles (such as the use of the empirical cycle as a guiding principle of scientific research and thinking), and should be willing to consult a variety of sources (e.g. on the Internet, together with their class) if they have a question about scientific explanations or physics knowledge. The most important aspect in stimulating students’ development of reasoning and language skills seems to relate to the teachers’ sensitivity to the individual learning opportunities and potentials of students. Teachers can actively contribute to optimizing the process of co-constructing science discourse when they adapt their input – for instance, the type of questions they ask or the language the use – to the specific needs of their students. The student responses reflect the fit between the teacher input and the student response, which helps teachers to tailor their input to their students’ abilities. In this way, teaching science – and doing it while also creating language-learning opportunities – requires a fine balance between challenging students and adapting to their (potential) abilities.

Another important issue concerning successful implementation is that teachers should be familiar with the phenomenon of academic language, and the opportunities for language learning that arise during science activities. Existing research showed that many teachers are not aware of the importance of academic language (Wong Fillmore & Snow, 2002). It is still relatively unknown among teachers that it is of great importance to introduce children to his academic register from a young age onwards. Moreover, many teachers believe that this form of language is too complex for their students, and so they tend to ‘over-adapt’ their language to the verbal abilities of their students. Secondly, teachers are often unaware of the importance of academic language in the development of scientific reasoning, and academic language is therefore not used as a factor within science education.
A first step towards implementing a successful intervention is to perform the intervention on highly motivated participants (Ryan & Decy, 2000). It is very likely that if an intervention does not work with moderately motivated participants, it will certainly not work with unmotivated or reluctant participants. Motivation is particularly important in the context of early science education because of the negative feelings and feelings of incapability towards (teaching) science. Our results indicated that ‘doing science’ – independent of the learning gains resulting from these science activities (both control and intervention condition) – affects the enjoyment and the anxiety of teachers in a positive way. In this dissertation, the teachers’ motivation was addressed by strongly focusing on the personal learning goals as input for the coaching sessions. For future implementation, insight into teachers’ attitudes can be helpful to make the intervention more adaptive to the need of individual teachers (Lumpe, Hany, & Czerniak, 2000; Van Aalderen-Smeets et al., 2012).

- Can the LaT intervention be implemented during the final internships of teacher education?

With regard to educating our future teachers, one of the goals of this dissertation was to assess whether the LaT intervention could be successfully implemented in classrooms of novice teachers. In Chapters 4 and 5 the effectiveness of the intervention was evaluated in terms of behavior (Chapter 4) and attitude (Chapter 5), and the possible differences between experienced teachers and novice teachers were thereby addressed. There were clear indications for differences in initial attitudes towards teaching science between those groups. These differences concerned that experienced teachers perceived teaching science as more relevant and more difficult to teach than the novice teachers. The experienced teachers also reported that they enjoyed teaching science more and that they felt more capable of teaching science. However, they felt more dependent on contextual factors than the novice teachers. This is what is also basically found in the literature (e.g. Lumpe et al., 2000). The finding that there were almost no indications for differences between those two types of teachers in terms of global behavioral measures motivated us to perform an in-depth analysis of the quality of teacher-student interaction, and changes in the patterns of interaction, in those two groups (Chapter 6). Aside from the small sample size, the results of this dynamic analysis suggested that the changes in the quality and structure of interaction during the intervention in both groups seemed quite similar and independent of teaching experience. The effectiveness of the LaT intervention in novices’ teaching practices was demonstrated in this dissertation and therefore the intervention can be successfully implemented during the final internships of teacher education. The adaptive nature of the intervention – in terms of the use of video feedback coaching based on personal learning goals in teachers’ own teaching situations – may be of particular value when implementing the LaT at teacher education.
8.4 Surplus value of dynamic systems approach to study effectiveness of interventions

As outlined in the Introduction, both the design of the LaT intervention and the analyses (and codings on which analyses were based) were taken from a complex dynamic systems approach. The surplus value of taking the dynamic, bidirectional aspects of interaction into account when designing the intervention is that teachers and researchers gain insights into the mutual influences of teachers and students during the interactions. The fact that the intervention took place in their actual teaching practice and during multiple sessions provided teachers with multiple practice experiences that form the basis to continue practicing these skills in their teaching routines. The surplus value of taking multiple perspectives to study the effectiveness of the LaT intervention is that it provided rich information on the teaching-learning processes as they occur in real-time. Moreover, using this approach enabled us to explore and detect the patterns and changes in these processes within sessions (short-term or real-time) and over multiple sessions (longer-term). The combination of global and dynamic measures allowed us to conclude that the intervention yielded positive results. These results addressed teachers’ and students’ behavior in isolation (See Chapter 2 and 4) as well as the teacher-student interaction as a whole (see Chapter 3, 6, and 7). These points are of course not the exclusive property of a complex dynamic systems approach. However, the advantage of using a complex dynamic systems approach is that it provides a consistent and general theoretical framework from which a wide variety of such perspectives and theoretical and methodological approaches result.

The complex dynamic systems approach is the underlying basis of the analyses throughout this dissertation. However, some of the findings discussed in this dissertation (Chapters 2, 4, and in part 5) do not explicitly relate to dynamic properties of the process of co-constructing science discourse (such as increases in teachers’ questioning skills or students’ reasoning in isolation). However, the findings emerged from the dynamic properties that are part of the complex and intertwined teaching-learning processes as observed – and coded as such – during the science activities. Although, these dynamic properties (i.e. interacting time scales, self-organization, variability) are not explicitly used for the analyses in the empirical chapters, the microgenetic coding that formed the basis for these chapters is, in fact, dynamic. For instance, the global measures of the teacher or the students are a reflection of the interactions and teaching-learning processes. This means that the aggregated measures of the microgenetic coding are the result of the multiple mutually influencing interactions between teacher and students. As an illustration, the aggregated number of open-ended questions is determined by the total interaction, that is to say opportunities to ask open-ended questions, responses of students to open-ended questions, adapting questions to abilities of students, getting no answers of students which does not lead to more open-ended questions but rather closed-ended to scaffold the students etc.
8.5 Future research

The focus of this dissertation was on the verbal behavior of students during science activities. Although there is no doubt about the importance of language skills in the development of students’ reasoning, a large part of the communication during science activities considers non-verbal behavior. Previous studies on early elementary students performing science tasks revealed that, in terms of reasoning, the non-verbal skills were ahead of the verbal skills (Guevara-Guerrero, 2015; De Jonge-Hoekstra, Van der Steen, Van Geert, & Cox, 2016). The verbal expressions of students during real-time science activities may partly consist of non-verbal expressions (Pine, Lufkin, Kirk, & Messer, 2007). This non-verbal behavior, for instance in the form of manually exploring and manipulating materials, is considered an important aspect of the development of reasoning skills (De Jonge-Hoekstra et al., 2016). In the context of learning, the so-called ‘mismatch’ between non-verbal and verbal behavior may be an indication of (developmental) difficulties. The moments of non-verbal behavior being ahead of verbal behavior are particularly likely to occur when students are on the threshold of learning a new task or skill (Golden-Meadow, 2009). This suggests that students are able to express this (new) knowledge in gestures but that they are not yet capable of verbalizing this knowledge. Continuation of research on science and language learning in early elementary education should therefore include studies that combine verbal and non-verbal abilities of students. This seems the perfect condition to explore the dynamics of verbal and non-verbal behavior since the science activities offer a challenging environment in which new knowledge is acquired and students often seem to struggle with finding the right words for what they do and think. Insights into this interplay of verbal and non-verbal behavior may, in the end, provide tools for teachers to help students ‘translate’ their actions into words.

The current dissertation explicitly focused on the process of co-constructing science discourse, independent of the content of those resulting moments of co-construction. The combination of a process study focusing on the co-construction process on the one hand with more specific analyses of the actual contents on the other hand would of course add interesting new information. This combination is an interesting topic for future research, especially since it might inform the work on (improvement of) teachers’ pedagogical content knowledge or the expressed pedagogical content knowledge (see Geveke, 2017).

8.6 Limitations

In addition to the limitations discussed in each empirical chapter, there were some limitations that concern this dissertation as a whole. The focus of this dissertation was to explore the characteristics of interactions in early elementary classrooms – which were kindergarten and first grade of elementary school – as this period represents a critical transitional phase from preschool to elementary school. This period is characterized by rapid cognitive and linguistic development as well as growth in, for instance, social skills. As was discussed in the individual chapters, the small number of participants was – notwithstanding the value of the in-depth
analyses that were performed in this dissertation – a limitation. This dissertation is an example of the ever-inevitable trade-off between a small number of participants needed for in-depth analyses and larger numbers of participants to generalize to the population. It is suggested to make a combination of first, examining the effectiveness of an intervention on a small number of motivated participants (Ryan & Decy, 2000) to gain insights into the processes of change on multiple timescale (i.e. within sessions and over sessions), and secondly – after adjusting the intervention based on the insights from the in-depth studies – perform the intervention on larger groups of participants and in order to draw conclusions about whether the intervention generally works in ‘the population’ by means of global effectiveness measures. The latter type of evaluation does not say anything about the working of the intervention in a specific teacher’s situation, but global effectiveness studies – today – cannot be avoided. Boelhouwer (2013) suggested a framework for intervention effectiveness studies. She argued that effectiveness is too often limited to very broad and essentially static measures, e.g. based on tests or questionnaires. Effectiveness should also be studied in the form of analyses of the actual authentic processes that the intervention aims to change. Such analyses are always much more labor-intensive than the analyses based on indirect, more or less static measures. This implies that every attempt to study the effectiveness in a sample that is representative of the total population will always have to cope with the labor-intensive nature of such studies. There is no way in which the broad, quick indirect measurements can actually replace the in-depth process studies. Both forms of study will have to be done as part of any intervention effectiveness study that aims to generalize to the population level.

In the design of the LaT intervention, the setting of small teaching groups was the best choice, both in terms of educational relevance and practical feasibility. A drawback of observing small group interactions is that it obscures the analysis of the input of individual students to the interaction. As it is evident from the studies conducted, our primary interest was to enter the actual teaching practice, because this provides a window to detect opportunities for the improvement of the educational practice, also after the intervention. However, a further detailed analysis of the input of individual students would better inform us about the effectiveness of the teacher’s role and the possible influences of fellow students in the course of the interaction. The dynamic, bidirectional properties of interaction imply that constant adaptations are expected depending on the contribution (input) of the other speaking partner. An individualized type of analysis would allow us to gain insights into the fine-tuning mechanisms of teacher and fellow students. This type of analysis would probably result in a complex interaction network. Recent insights from the area of scaffolding may be helpful (Van der Pol, 2010; 2011). Van der Pol argues that video observations are required to analyze scaffolding interactions because the appearance of scaffolding depends heavily on the context. Scaffolding entails interaction and therefore both teacher and student behavior and their discourse contributions should be included. This way, the means of scaffolding employed by the teacher and the responses of students determine whether an interaction can be pointed out as ‘successful’ scaffolding or not.
The key characteristics of contingency, fading, and transfer of responsibility should be included to determine the effectiveness of scaffolding in future research.

A downside of stimulating teachers’ self-efficacy by letting them choose their own lesson topic is that there was large variation in the topics that were used within an individual as well as between individuals. Some topics elicit a wider variety of different and complex words, whereas others in some way impose restrictions on the vocabulary choice. The materials at hand then constrain the topic of conversation to a certain extent. For instance, a floating and sinking task often resulted in many complex words because of the object naming, and more hands-on activities such as a marble track were associated with more pointing and use of deictic terms. Hands-on activities like the marble track might make it possible distinguish adults who do seize these tasks as an opportunity to engage in rich discourse from adults who do not use rich language during such tasks (Henrichs, 2010). These examples, again, underline the importance of the teachers’ role in providing interesting content but particularly in using that content to stimulate their students’ language skills. The decision to let teachers choose their own topic was motivated by the content-related goals of the LaT intervention (agency), but in terms of research purposes this was a limitation because of a lack of standardization. This is again a typical trade-off situation, similar to the trade-off between the size of the sample and the depth of the analysis. In this case there is a trade-off between standardization on the one hand and authenticity or individual motivation on the other hand. In both cases, it is important to find the best possible balance, but this balance depends very much on the nature of the question asked.

8.7 Implications for practice

The studies in the current dissertation aimed to guarantee ecological and external validity by addressing actual teaching practices in the context of a video feedback intervention that focused on real-time student-teacher interactions. The studies’ ecological validity allows us to infer various implications for both policymakers as well as educational practice.

8.7.1 Implications for policymakers

Maybe one of the most important messages for policy makers arising from this dissertation is that science and language learning can be successfully integrated in early elementary classrooms. The relevance, the usefulness, and the effects of combining science and language learning have been demonstrated. Science therefore does not necessarily need to be an isolated subject, rather the time in the curriculum reserved for language teaching can be spent on science activities and so improve, expand, and deepen the linguistic skills of students. This is very important since teachers often complain that they need to do so many things in addition to what they already have to do. For instance, teachers have to teach language, and in addition to that they have to teach science. This dissertation showed that teaching language and
teaching science are things that can and certainly must go together. This insight might help to solve this typical investment dilemma of teachers.

8.7.2 Implications for educational practice

The findings reported in this dissertation are promising for educational practice in several areas. The first thing to point out is that science and language learning can be successfully integrated in early elementary school. This way, science is not necessarily an additional subject to teach in the standard curriculum, but it can be used to create opportunities for language learning. Secondly, the LaT intervention can be applied to both experienced and novice teachers. This means that the intervention – or the underlying principles of the intervention – can be interwoven in the educational curriculum in teacher education. Thirdly, one of the main strengths of this intervention is the use of video feedback coaching, based on real-time interactions in the actual teaching practices. Teachers learn to observe, recognize, and reflect upon their own behavior as well as on student behavior and on the deeply intertwined nature of their own behavior and that of their students. This methodology is particularly important for establishing behavioral change as opposed to many interventions focusing only on knowledge about important teaching strategies, for instance in the form of an educational meeting. This knowledge is essential in a teacher intervention, but the combination of an educational meeting followed by video feedback coaching is a firm basis to take the first steps towards implementing science education and integrating science and language learning.

For teachers, the results have shown that they have an important role in developing students’ verbal abilities in the context of science activities. The development of language and reasoning skills does not happen in the head of the students, but rather emerges in a dynamic, bi-directional interaction with the context (e.g. the teacher, the materials, the other students, etc.). Teachers can structure the interaction by providing interesting materials, opportunities for language learning, open-ended questions, sophisticated language input, all using scaffolding to adapt these strategies to the abilities and (potential) needs of the students. This way, teachers create a supportive environment, in which sensitivity to the students’ abilities and (potential) needs is essential. One important notion in this context concerns optimal scaffolding. This means, in particular, the use of optimal distances between, on the one hand, the student’s actual language use in actual cognitive understanding – as practiced without help of the teacher – and, on the other hand, the more advanced levels of academic language in reasoning skills that the teacher introduces into the interaction with this student. As said, teachers often have the tendency to over-adapt to the level of their students. Optimal scaffolding means that teachers should try to find the right distance between their own academic language use and the habitual language use of their students. The right distance is the distance that provokes maximal durable learning (Van Geert & Steenbeek, 2005). This right distance is something that has to be monitored – and in a sense negotiated – almost continuously during the educational process. With regard to the use of academic language, an optimal scaffolding distance is not too close to the verbal abilities of the students (which teachers very often do) but it should also
be not too far away from the verbal abilities of the students, because if the latter is the case, students will not be able to assimilate the teacher’s help and information.

Small group activities, which were the focus of the current study, are increasingly becoming part of the everyday educational practice because they allow for more intensive interaction. Teachers indicated that the introduction to teaching science in small teaching groups allowed for more intensive interaction. This also gave teachers opportunities to focus more or better on the individual needs of their students. In whole classroom settings, there are fewer opportunities for deepening understanding and asking follow-up questions, let alone taking into account the abilities of each individual student. In traditional teaching settings in early elementary classrooms, teachers – even experienced ones – are to a large extent concerned with classroom management and giving instructions (Wolff et al., 2015). For the implementation of educational interventions, such as the LaT, it is recommended to start off with small teaching groups. This allows teachers to explore, practice, and improve their teaching skills in a small setting. However, in order to ensure that teachers can apply the learned principles into their daily teaching routines, it is essential to help teachers transfer these skills to whole classroom settings. This can be realized by doing one or two follow-up sessions to help teachers find ways to use the acquired strategies in the whole classroom setting. The advantage of the individual video feedback coaching is that the teachers have learned to observe and reflect upon their own behavior in actual teaching settings, which may help them to apply the learned strategies to the whole classroom setting. Studying the interactional dynamics in whole classroom settings versus small teaching groups is an interesting area for future studies. Co-constructing deep understanding may be harder in the whole group setting but introducing the concept of science activities is definitely possible. A recent evaluation showed that in the upper grades of elementary school a comparable teacher intervention yielded positive results in a whole classroom setting (Van Vondel, 2016). These science lessons often take the form of multiple small groups of students working on experiments while the teacher visits every group now and then to interact with the students. The latter is essential to evoke students’ reasoning and language skills: guidance of a teacher tailored to the (potential) abilities of students. An interesting avenue for future research is to explore whether and how to assist teachers in applying these principles to a whole-classroom setting in early elementary science education.

8.7.3 Suggestions regarding adjustments in the LaT intervention
In addition to the intervention's promising results, there are some suggestions to point out for future implementations. One suggestion is to use the LaT intervention as an advanced professionalization program – for instance, as a follow-up program on the CMC of Wetzels (2015) – for teachers who want to integrate language learning into their science lessons. This arises from the observation that many teachers – as participation in this intervention was their first introduction to teaching science – first wanted to focus on implementing the empirical cycle and open-ended questioning strategies, and in later stages they formulated learning goals explicitly focusing on language learning opportunities for students. A second suggestion is to
expand the number of coaching sessions. Outside the context of performing the intervention for research purposes (effectiveness studies), it is not necessary to spend the first two and last two sessions on performance measurement. These sessions can be replaced by actual coaching sessions, which thus expands the number of coaching sessions without demanding more time investment form the teachers. In this case, it would still be suggested to include one pre-intervention measure for teachers without any science-teaching experience. This way, teachers can briefly experience and explore their own teaching style with regard to science. As regards the information that is provided during the educational meeting, the recommendation is to include a pre-measure so that teachers can relate the theoretical concepts and teaching strategies to their own teaching practice. The video clips of the teachers’ own pre-intervention measures were of great value in this study in that these were used to illustrate the theory during the educational meeting. In fact, this was their first introduction to the method of video feedback coaching. Regardless of the positive impact of the current design of the LaT, a suggestion for future implementations is to expand the LaT intervention. The LaT may include one (videotaped) pre-intervention measure, the educational meeting (including theory and tools to stimulate science and language learning) followed by formulating learning goals regarding questioning strategies and using the empirical cycle, and three coaching sessions focusing on these specific goals. Subsequently, there can be a short educational meeting to refresh the language learning strategies followed by formulating goals regarding language learning, followed by three more coaching sessions with a specific focus on language use, and maybe also a session in which the skills that have been learned in the smaller groups are tested on the level of the whole class.

8.7.4 Using the dynamic analyses for increasing insight in teachers’ own teaching practices

An interesting avenue for future studies is to explore whether the dynamic analyses that formed the basis of this dissertation can be used to provide teachers with insight – on top of the video-based coaching which in itself is a good way of self-reflection – into their teaching practices. To illustrate this suggestion, an example will be given. As Van Aalderen-Smeets and Walma Van der Molen (2013) indicate, to make teachers (more) aware of their own attitudes, individual profile plots based on the DAS instrument can be created to demonstrate the current attitude of individual teachers, and the changes in attitude over time. The same applies to the dynamical analyses that were performed in the current dissertation. During the video-based coaching sessions, teacher and coach discuss and reflect upon several moments of interaction that occurred throughout a lesson. The strength of this coaching method – which in our opinion needs to stay this way – is that the discussions take place immediately after the lesson. In addition, coach and researcher can create, for instance, State Space Grids of the lessons to show teachers what the interaction in their teaching practice looks like. An illustration of using dynamic analysis to improve teaching practices is provided in the handbook of Veenker, Steenbeek, Van Dijk, and Van Geert (2017), in which such techniques are made available for
teachers and teacher education. This book also provides a good and accessible introduction for teachers and future teachers in complex dynamic systems thinking and in understanding the dynamics of teaching-learning processes. Based on, for instance, State Space Grids, teacher and coach can discuss more and less optimal states of interaction in terms of educational relevance. This way, the coaching and the research can be even more adapted to the specific context in which the intervention is implemented. It may allow teachers to gain more insight into their own teaching skills, the corresponding student reactions and – maybe most important – the dynamics of the interaction. Evaluation studies, for instance in the form of multiple in-depth cases, should reveal whether this way of intervening is suitable for teachers and whether the results – in terms of behavioral change – are more beneficial or optimal compared to the current LaT intervention.

8.8 Final remarks

Some final remarks regarding the contribution of the studies presented in this particular dissertation to the larger Curious Minds program are in place. The aims of this research program were to explore what talents young children have and to examine how adults (i.e. parents, teachers) can optimally enhance these talents. Based on insights from previous Curious Minds research regarding the first three questions, this dissertation is the first to provide more understanding of language learning in the context of developing science talents. One of the unique contributions of this dissertation is that fundamental insights and practical research were integrated in the design of the intervention and in the evaluation of the effectiveness. Language use during science activities has a bidirectional character and the use of an open teaching style evokes complex and dense language from students. Several studies in this dissertation have demonstrated that explicitly paying attention to language during science activities – in terms of modeling and open-ended questioning strategies – contribute to better language development and reasoning skills of students. Another important remark is that we should be aware of the fact that many of the choices made by policymakers and by practicing teachers have to reckon with trade-off relations between various concerns. One, for instance, is the trade-off between adaptation to the individual or to small groups on the one hand and addressing the classroom as a whole on the other hand. Another is related to the number of coaching sessions that is needed to establish behavioral change but at the same time fits within the teachers’ or schools’ time (and money) investment. In sum, this dissertation points towards the opportunities for teachers to integrate students’ learning of scientific thinking and using scientific language, which encourages both the development of teachers’ own talents as well as their students’ talents.