The research-teaching nexus in the sciences : scientific research dispositions and teaching practice

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Chapter 6

General conclusions and discussion

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6.1 Introduction

In this chapter, the main findings with regard to the research questions are summarised and general conclusions based on the findings of the studies presented in this thesis are described. Furthermore, the strengths and limitations of this thesis are considered and suggestions for further research into higher education are presented. This chapter concludes with recommendations for three categories of stakeholders in higher education: policy makers, teachers, and students.

6.2 Links between research and teaching

Many issues need to be considered when enhancing links between research and teaching in higher education. These issues can be divided along the organisational levels, ranging from government policy on higher education and institutional policies to curriculum development and implementation by individual teachers (cf. Elsen et al., 2009; Jenkins et al., 2003; Clark, 1997). One of the aims of strengthening the research-teaching nexus is to improve student understanding of science and scientific research (cf. Jenkins et al., 2007; Zubrick et al., 2001). The studies presented in this thesis were focused on the level of teaching and learning; academics' characteristics, such as research dispositions and teaching intentions, were examined. The central aim of the studies presented in Chapters 2 and 3 was to improve understanding of the research dispositions of experts in the field of scientific research. The overarching aim of the studies presented in Chapters 4 and 5 was to identify patterns between science academics' teaching intentions and their actual teaching practice. The teachers' intentions investigated in this thesis were intentions regarding research activities for students in their courses and regarding the stimulation of the development of students' research dispositions. The findings of the studies reported in Chapters 1 and 2 provided a categorisation of aspects of research dispositions; this was used in Chapter 5 to investigate teachers' intentions regarding the development of students' research dispositions. Furthermore, teachers' actual teaching practices were explored by analysing their discourse during course meetings, their methods of instruction, and students' perceptions of the learning environments.

In the research literature about higher education, research dispositions have been identified as relevant elements of the intangible nexus; they have also been recognised as an under-emphasised theme in education and in educational research (cf. McLean & Barker, 2004; Elen & Verburgh, 2008). In the first two

studies, therefore, the nature of scientific research dispositions was considered. The main research aim of the first study, reported in Chapter 2, was to identify aspects of science academics' research dispositions, and to describe the differences and similarities between the individual research dispositions of the participants. An interview study was performed among academics (n=23) from the Faculty of Science of Leiden University. The interviews were analysed, and the *in vivo* responses of the participants about their research dispositions were identified and categorised. Academics with similar research dispositions were clustered using a hierarchical cluster analysis, combined with a principal components analysis, with the objective of finding differences and similarities between participants' research dispositions and their background variables. This study resulted in a classification of aspects of research dispositions and in the identification of similarities and differences between academics. This classification of aspects of research dispositions (for a description see Chapter 2) was later, in the study reported in Chapter 5, used to identify teachers' intentions regarding the stimulation of the development of students' research dispositions.

The research aim of the second study, described in Chapter 3, was to examine potential ways to describe a person's research disposition. In this study, first, the concept of disposition found in the research literature was described to identify principles which may be useful for the development of an empirically based notion of disposition. Second, three instruments to assess a person's research disposition were investigated in a case-study approach (n=3): a semi-structured open-ended interview, a hierarchical ordering task, and a cognitive mapping task.

The third and fourth studies, described in Chapters 4 and 5, respectively, were focused on associations between teachers' intentions and actual teaching practice in research-intensive learning environments. The central research aim of the third study was to identify and describe typical sequences in individual teachers' speech during course meetings, and to draw associations between these typical sequences of speech and teachers' approaches to teaching. University science teachers' (n=12) discourse during course meetings was recorded. An analysis scheme was developed to identify the underlying rationale behind teachers' spoken language. This scheme was based on speech act theory from the field of philosophy of language. The teachers were also asked to complete a questionnaire, in retrospect, on their approaches to teaching. The central aim in the fourth study was to identify associations between teachers' intentions concerning, on the one hand, the emphasis on research in their courses and students' research dispositions, and on the other hand, students' perceptions of

the research intensiveness of university science courses. Pre-course interviews were held with university science teachers (n=11) to gather information about their intentions regarding the implementation of research in their courses and the stimulation of the development of students' research dispositions. The students (n=104) were asked to complete a questionnaire about the research intensiveness of the learning environment (Van der Rijst et al., 2009). Associations between teachers' intentions and students' perceptions of the learning environments were described and related to results from previous research findings.

6.3 Findings with regard to the research questions

6.3.1 Research question 1a

What aspects can be distinguished in the ways science academics conceive of their scientific research dispositions? (Chapter 2)

The result of this study is a classification of aspects of academics' scientific research dispositions. The findings of the analysis of the interview transcripts enabled us to distinguish six qualitatively different aspects of scientific research disposition: inclination (1) to achieve, (2) to be critical, (3) to be innovative, (4) to know, (5) to share knowledge, and (6) to understand. See Section 2.3 for an overview of the aspects of scientific research dispositions.

6.3.2 Research question 1b

What are the differences and similarities between groups of academics with comparable research dispositions? (Chapter 2)

Possible associations between the differences and similarities of academics' research dispositions and their background variables were explored by examining patterns of background variables within clusters of academics with similar research dispositions. The differences and similarities in the sample indicate that academics from more applied and experimental fields of study tend to put more emphasis on the aspects 'to be innovative' and 'to be critical', while academics from fields with a theoretical research orientation tend to focus more on the aspects 'to achieve' and 'to understand'. These observations suggest that disciplinary differences or institutional cultures, or both, have an influence on the scientific research dispositions of academics.

6.3.3 Research question 2

Which instruments or combination of instruments can best be used to investigate a person's research disposition? (Chapter 3)

The exploration of the educational research literature about dispositions described in Chapter 3 shows that the concept of disposition is still in a developmental stage. Three general principles were identified as potentially supportive in clarifying the concept of disposition in educational research. First, dispositions only become apparent under specific circumstances. Second, dispositions always have an explanatory basis, which can be found in intrinsic attributes. Third, dispositions can be investigated empirically. A combination of a hierarchical ordering task and a structured mapping task provided an adequate combination, in the sense that it produced relevant results and was more time-efficient than a semi-structured open-ended interview method. The findings presented in Chapter 3 show, among other things, that a distinction can be made between respondents' implicit conceptions of research dispositions and their explicit research dispositions. A first observation was that the interviews and the hierarchical ordering task showed similar results. The aspects which were most frequently mentioned in the interviews were also the aspects which appeared high in the hierarchical order. This indicates that the interview and the ordering task can be used to discern a similar feature of the concept of disposition. A second observation was that the results from the interview did not match with the results from the structured mapping task. A possible explanation was found in the crucial differences between the instruments. The degree of freedom within these three instruments decreases from the interview, via the ordering task, to the mapping task. The semi-structured open-ended interview and the hierarchical ordering task gave the participants insight into what they presented as their scientific research dispositions. The structured mapping task was explicitly designed in such a way that the academics could not easily recognize patterns in their answers. Therefore, the conclusion was drawn that the results from the structured mapping task indicate the *implicit*, or tacit, scientific research disposition, while the results from the interview and the hierarchical ordering task represent academics' *explicit* ideas about their scientific research disposition.

6.3.4 Research question 3a

What typical sequences can be recognised in individual teachers' speech during course meetings? (Chapter 4)

To answer this research question regarding the characteristic patterns recognisable in teachers' speech acts, teachers were clustered into groups characterised by their speech sequences. Broadly two groups were identified, one using relatively more assertive speech, such as giving information or drawing predictions, and the other using relatively more directive speech acts, such as

giving instructions or posing questions. The assertive-sequence group was subdivided into two groups, one group determined by assertive reflection acts and the other by assertive prediction acts. The directive-sequence group was subdivided into a group of teachers who used questions relatively more frequently and a group who uttered instructions relatively more frequently. The speech act sequences which were typically present during course meetings were identified as potential determinants of the applied repertoire of speech of individual teachers.

6.3.5 Research question 3b

Are teachers' typical speech act sequences associated with their approaches to teaching and the method of instruction used during science courses? (Chapter 4)

The findings from the analysis of teachers' speech acts during university courses illustrate that speech acts in which teachers assertively informed students were most frequently present in teachers' sequences. The conclusion based on this finding was that whatever the method of instruction or whatever the approach, the teacher always informs students, for example, about course content or about assignments. Second, the findings show that during lectures teachers mostly used assertive speech acts, while during laboratory courses teachers relatively more often used directive speech acts. In a lecture-type method of instruction teachers primarily explained course content, while during laboratory courses teachers more often gave students instructions, for example, on how to proceed with the inquiry. This finding relates to the common perceptions of lecture and practicals, and provides us with evidence that the analysis of teachers' speech acts is a valid research method. Finally, the conclusion was drawn that teachers who emphasised conceptual changes of students (conceptual change/student-focused approach) in their approach more often used directive speech acts, such as questions or instructions, while teachers who emphasised knowledge transfer (information transmission/teacher-focused approach) more often used assertive acts. Teachers who put emphasis on conceptual change engaged in dialogue with students more often than did teachers who emphasised information transmission.

6.3.6 Research question 4

What associations can be identified between teachers' intentions and students' perceptions of the research intensiveness of university science courses? (Chapter 5)

The aim of the study presented in Chapter 5 was to identify associations between teachers' intentions with respect to emphasis on research during courses and students' perceptions of the research intensiveness of university science courses.

Generally, the results show that teachers' intentions were moderately congruent with students' perceptions of the research intensiveness of the learning environments. Teachers' intentions related to the tangible elements of research were relatively more often congruent with students' perceptions, while intentions related to intangible elements of research were relatively more often incongruent with students' perceptions. This was explained in two ways. First, intangible elements are more difficult for students to perceive than are tangible elements. Second, intangible elements are more difficult for teachers to emphasise during university courses. It is, therefore, likely that teachers' intentions such as working towards the development of students' research dispositions or the creation of an inquisitive atmosphere are more often incongruent with students' perceptions than are teachers' intentions such as letting students participate in research or using the teachers' own research.

6.4 General conclusions

The general conclusions can be categorised into conclusions about scientific research dispositions, evaluation of research dispositions, teachers' speech acts, and teachers' intentions regarding research in teaching. Although the conclusions in this section are presented as solitary units, they can only be interpreted properly and understood in combination with the information presented in the chapters of this thesis.

6.4.1 Research dispositions of academics

- Six aspects are fundamental to research dispositions of academics in the sciences: inclination (1) to achieve, (2) to be critical, (3) to be innovative, (4) to know, (5) to share knowledge, and (6) to understand (Chapter 2).
- Academics from more applied and experimental fields of study tended to put more emphasis on 'to be innovative' and 'to be critical', whereas academics from fields with a theoretical research orientation tended to focus more on 'to achieve' and 'to understand' (Chapter 2).

6.4.2 Evaluation of research dispositions

- A distinction can be made between academics' explicit conceptions and their tacit conceptions of their research dispositions (Chapter 3).
- Semi-structured open-ended interviews and hierarchical ordering tasks showed explicit conceptions, whereas structured mapping tasks represented the tacit conceptions of academics' research dispositions (Chapter 3).

6.4.3 Teachers' speech acts

- The typical sequences of teachers' speech acts illuminate their speech act repertoires in action (Chapter 4).
- Teachers who emphasised conceptual changes of students more often use directive speech acts, such as questions or instructions, whereas teachers who emphasised knowledge transfer more often use assertive speech acts (Chapter 4).

6.4.4 Teachers' intentions regarding research in teaching

- Teachers' intentions are moderately congruent with students' perceptions of the research intensiveness of the learning environments (Chapter 5).
- Teachers' intentions related to tangible elements of the nexus are relatively more coherent with students' perceptions than are teachers' intentions regarding intangible elements of the nexus (Chapter 5).

6.5 Strengths and limitations of the studies

6.5.1 Strengths

Broader applicability of aspects of research dispositions

The classification of aspects of research dispositions was developed through the analysis of interviews with 23 academics who had a great deal of experience in doing scientific research. Through these interviews with experts on scientific research, a complete picture of aspects of research dispositions emerged. The results of a methodological study of the saturation point in qualitative interview studies show that, in general, after 12 transcripts most of the categories (>90%) are identified in interview transcripts (Guest et al., 2006). We can assume that the classification of aspects developed in the study reported in Chapter 2 is adequate for describing scientific research dispositions. Individuals with less experience in doing research, such as students, can develop their research dispositions, analogous to students developing their skills or knowledge about the process and products of research. It is plausible that individuals who have less experience in doing research have similar aspects, but ambiguously expressed, or underdeveloped. For example, a person who has not yet encountered academic debate through peer-reviewed feedback on manuscripts for scientific journals might be less inclined to consider collegial feedback an essential part of research. This person might express a weak correlation between the inclinations 'to share' information and 'to be critical' when asked to express an opinion. The development of a person's research disposition can be measured in at least three ways, through examining the number of aspects which are explicitly part of the

disposition, the number of relationships between these aspects, and the personal hierarchical order of aspects (cf. Chapter 3). In the studies presented in Chapters 2 and 3, academics showed aspects which were more prominently present and aspects which were peripherally present in their personal research dispositions. The development of students' research dispositions is also a personal matter, in the sense that no single constitution of aspects can be considered to be the ideal disposition for doing scientific research. When examining the development of students' research dispositions, at least three points are necessary to consider: students' 1) awareness of the potential aspects and relations between aspects, 2) awareness of their own research disposition and of those of others, and 3) awareness of individuals' personal choice in developing their own research disposition. The strength of the classification scheme of aspects of research dispositions is that it can be used to identify aspects and create awareness among academics and among less experienced groups of researchers, such as students.

A diverse set of research tools

In the study reported in Chapter 3, an analysis tool from social network theory was used to evaluate academics' research dispositions. In the study presented in Chapter 4, a 'theoretical' framework from the philosophy of language was re-evaluated and re-developed into an empirically useful instrument to assess teachers' classroom discourse. Remodelling theoretical frameworks from other disciplines for empirical use in the field of educational research might improve the applicability and reliability of the results of educational studies. Various authors in the field of teaching and teacher education have revealed the complexity of 'teaching' (cf. Verloop et al., 2001; Shulman, 1986; Borko & Putman, 1996). This complexity can only be properly analysed and understood when the phenomena are investigated from different perspectives and by using various research tools. Researchers who investigate teachers and teaching in higher education should thus have a strong inclination to look over the disciplinary fence, to borrow ideas, models, and research tools from fields close to educational research, such as psychology, sociology, pedagogy, or philosophy, and also from more distant domains, such as mathematics, economy, or linguistics. The studies presented in Chapter 3 and in Chapter 4 show examples of how ideas from other fields can improve the analysis of phenomena in the field of education.

Combination of teachers' conceptions and teaching practice

In early research on teaching, much emphasis was put on teaching effectiveness. Studies were predominantly focused on a description of what teachers did and

what the effect was on the students (Gage, 1963; Rosenshine, 1971; Shulman, 1986). Although this behavioural process-product line of research was recognised as the most vigorous and productive programme of research on teaching at that time, in recent decades studies on teacher cognitions have become a central focus in the field of research on teaching (Floden, 2001). At this moment, the pendulum is swinging back towards more effectiveness studies, as can be seen, for example, in the evidence-based programmes, in which evidence is seen as 'scientifically proven' effectiveness of teaching. In the studies presented in Chapters 4 and 5 elements of teacher cognitions, namely, teachers' orientations (Chapter 4) and teachers' intentions (Chapter 5), were examined in combination with measures of teacher behaviour, namely, teachers' speech acts and students' perceptions of the constructed learning environment. The strength of future research on teaching lies in the design of studies in which teachers' cognitions and teachers' behaviours are investigated in concert. These studies should stand on the shoulders of previous programmes and paradigms, for example, by intelligently using research design and methods from previous studies or through reflection on the current usefulness of the results from previous programmes. For example, in the sixties and seventies studies were designed concerning the topic of teacher classroom talk (Rosenshine & Furst, 1973). At first, the proportion of teacher talk to total classroom speech or the proportion of teacher talk to student talk were determined. Later on, more sophisticated observation schemes were designed in which, e.g., teachers' approval and disapproval were discerned. These studies yielded consistent, low positive correlations with student achievement, which were often not significant (Rosenshine, 1971). In the study reported in Chapter 4, a more refined analysis tool was developed to examine teacher talk, use of which made it possible to discern determinants of teacher talk per method of instruction.

6.5.2 Limitations

Considerations concerning the samples

The participants in the studies presented in this thesis were all affiliated with the Faculty of Science of Leiden University. This means that, strictly speaking, only conclusions can be drawn about academics of the science faculty at Leiden University. The findings presented in Chapter 2 showed that disciplinary and cultural differences can be expected in academics' research dispositions. Although the differences between research universities in the Netherlands are much smaller than are the similarities, differences in the ways academics teach in the various teaching cultures at higher education institutions can be expected.

Therefore, when applying findings from these studies to other research cultures or teaching cultures, one has to pay attention to relevant differences.

Only academics from science domains participated in the studies presented in this thesis. Therefore, the conclusions drawn in this thesis are applicable to academics who teach 'science' courses. In these studies, the sample consisted of academics from different disciplines within the sciences, such as physics, chemistry, biology, and mathematics. Within these disciplines, large differences between participants in approaches to scientific research were present. For example, academics in theoretical physics may have more in common with mathematics than with academics working in experimental physics. Likewise, experimental physicists might be more similar in their research dispositions to experimental chemists. Therefore, disciplinary differences become ambiguous, and the traditional disciplinary boundaries become inadequate demarcation lines, when examining research dispositions (Brew, 2008). Nevertheless, attention should be paid to differences in research and teaching cultures. Conclusions drawn in this thesis can not be transferred directly to other disciplines without further consideration.

All participating academics were selected on a voluntary basis. It can be expected that the participating academics were, more than average, open to reflecting on educational issues, such as pedagogy, the curriculum, and student learning, and they might already have developed more sophisticated ideas about teaching and learning. The findings described in this thesis might be limited by this selection of participants. This needs to be taken into consideration when these conclusions are transferred to situations in which participants are present who have less clear ideas about teaching and learning.

Considerations concerning students' research dispositions

Students' research dispositions were not directly measured in the studies reported in this thesis; the study presented in Chapter 5 was focused on the stimulation of the development of students' research dispositions. Academics' research dispositions and students' research dispositions are not the same, and the aspects of research dispositions found in Chapter 2 cannot be used for both groups without further consideration. A further study should be undertaken, with the aim of verifying the applicability of the aspects to students. In the studies reported in this thesis, academics' research dispositions were considered to be characteristics of experts in the field of scientific research. In their studies, students are working towards achieving more developed research dispositions. The research dispositions of final-year students are more developed than those of

first-year students. A plausible relation between academics' research dispositions and students' research dispositions is that academics have more developed research dispositions than students.

Further research is needed to examine the value of the development of students' research dispositions for student learning. Borda (2007) provided some interesting suggestions for the cultivation and assessment of research dispositions in college science classroom settings, such as open-ended styles of inquiry, raising appropriate research questions, and careful use of language. It might be interesting to examine the influence of such approaches on students' learning and development of research dispositions.

A rationale behind these studies is that the research experiences and research dispositions of academics can support them in teaching students about science and scientific inquiry. For example, an academic who in his/her daily research continuously works on creative, innovative solutions, can stimulate students to work on their creative skills and reflect on the innovative aspects of their research dispositions. Although it is acknowledged in the research literature that professional experience and craft knowledge are important elements of the knowledge base of teaching in higher education (cf. Van Driel, Verloop, Van Werven, & Dekkers, 1997), academics who teach courses in higher education do not always know how to apply their professional experience effectively during teaching. During the pedagogical training of teachers in higher education it might be beneficial to put explicit emphasis on links between professional knowledge and teaching students about science and scientific inquiry. Future research on methods to stimulate the development of students' research dispositions may provide relevant and valuable findings for teaching practice in higher education.

6.6 Suggestions for further research into higher education

6.6.1 Further development of the research instruments

In the studies presented in this thesis, innovative research tools were developed. In the study presented in Chapter 2, a categorisation scheme to examine the aspects of a person's research disposition was developed; in the study reported in Chapter 3, a cognitive mapping task (cf. Bakkenes et al., 2007; Wassink et al., 2003) based on Graph Theory was used; in the study reported in Chapter 4, an analysis tool to examine teachers' classroom talk was constructed; and in the study presented in Chapter 5, a questionnaire to evaluate students' perceptions of the research intensiveness of learning environments was constructed and administered (cf. Van der Rijst et al., 2009). Four suggestions for further research using tools developed and used in this thesis are put forward below.

First, further research is needed to explore the applicability of the categorisation of aspects of research dispositions for groups other than science academics at research universities. Studies using other groups, such as academics in disciplines other than mathematics and the sciences, teachers in vocational higher education institutes, teachers in secondary and primary education, students at universities (research, vocational, or applied universities), pupils in secondary education, and pupils in primary schools, can lead to new conceptual insights.

Second, the techniques from Graph Theory used in Chapter 3 effectively discriminate between characteristics of individual nodes within graphs as well as between structural global properties of academics' cognitive graphs. More research is needed to examine the validity and the reliability of this instrument, to assess dispositions in other contexts, and to identify other fields of educational research in which this technique can be used. Furthermore, the mathematical possibilities of this Graph Theory framework are large, and need further development to uncover their full potential.

Third, use of the speech act analysis tool described in Chapter 4 has shown that it is possible to determine typical sequences in teachers' speech acts. Further research is needed to examine the applicability of this tool to identifying students' speech acts. A possible following step is to design studies on classroom discourse in which the speech acts of both teachers and students are examined with the aim of identifying interaction patterns and relating these patterns to, for example, the interpersonal relationships between students and teacher (Wubbels et al., 1992; Wubbels, Brekelmans, Den Brok, & Van Tartwijk, 2006). Studies in which students' as well as teachers' speech acts are analysed might provide a better understanding of the discourse between student and teacher (cf. Rogers et al., 2005; Saarinen, 2008; Scott & Mortimer, 2006). Further research on speech acts related to student understanding and students' perceptions of the learning environment would be of interest to those aiming to improve teaching practice in higher education; this might be done, for example, by providing teachers with tools to evaluate their actions and become aware of how their speech acts on the students.

Finally, in the study described in Chapter 5, students' perceptions were evaluated in relation to teachers' intentions. It might be interesting in future research to relate teachers' intentions to a combination of students' perceptions and students' expectations. Students' experiences of course meetings depend not only on their perceptions, but also on their expectations (Könings, 2007). Students with low expectations of the forthcoming research activities during a course could

have different perceptions of the research activities than have students with high expectations. A research design in which both perceptions and expectations are evaluated can provide an understanding of the influence of the created learning environment on students' experiences.

6.6.2 Student evaluation of research-intensive learning environments

In Chapter 5, a study is described in which students' perceptions of different kinds of learning environments were investigated. The differences were categorised into three methods of instruction, namely lectures, seminars, and practicals, and into the four modes of the research-teaching nexus proposed by Healey (2005b). The results suggest that there are differences and similarities between these kinds of learning environments in students' perceptions. Future studies in which the student questionnaire on the research intensiveness of learning environments (Van der Rijst et al., 2009) is administered to students following various courses, can provide valuable information about the differences and similarities in students' experiences of these different learning environments. Studies in which the questionnaire is used should be focused not only on large-scale and longitudinal administration, but also on the applicability of the questionnaire to other higher education institutes, such as vocational universities, or universities of applied sciences. The findings from large-scale questionnaire studies will give teachers as well as curriculum developers in higher education information about the potential strengths and weaknesses of the various kinds of learning environments with respect to the purpose of the teaching programme.

6.7 Recommendations for teaching practice in higher education

Possible implications for higher education are discussed in this section. Recommendations are made for various stakeholders in higher education, such as policy makers, educational developers, teacher trainers, teachers, and students.

6.7.1 Educational policy and consultancy

This thesis focuses on teaching and on learning environments. Therefore, recommendations for educational policy makers are presented at the level of curricula and the learning environments. In the research literature on higher education, many suggestions can be found for strengthening the research-teaching nexus at the institutional policy level (cf. Boyer Commission, 1998; 2002; Deem & Lucas, 2007; Durning & Jenkins, 2005; Elsen et al., 2009; Jenkins et al., 2003; Zubrick, et al., 2001; Leisyte et al., in press). More evidence-based literature on higher educational policy can be found in higher education research journals,

such as *Higher Education Policy*, *Higher Education Quarterly*, or *Higher Education Research and Development*.

The findings of the studies presented in this thesis show variation among academics in their scientific research dispositions and in their teaching practice. Awareness of this variety in higher education leads to the idea that each teacher has personal strengths. For example, some teachers are strong in giving lectures, others are better in guiding students through research internships; some academics are strong in the innovative aspects of scientific research, while others excel in the critical aspects. In situations which are not hindered by practical or financial constraints, policy makers might consider assigning teaching staff to activities which are in line with their strengths. Furthermore, to foster their mature epistemological dispositions (Elen et al., 2007) and to develop a sophisticated notion of the nature of science and scientific inquiry (Abd-El-Khalick & Lederman, 2000), students need to come in contact with a variety of research activities as well as with a diversity of research dispositions, modelled by the teachers who teach them. This implies that when policy makers at higher education institutes are aware of the human resources in their teaching staff, they might manage these resources, taking into account possible constraints, in such a way that students get as many learning opportunities as possible and get acquainted with a broad variety of researchers and research practices during their studies. This awareness of the variation among academics might also influence the policy for contracting new faculty, in the sense that it is valuable for an educational organisation to have as much variation in teaching staff as possible.

A well-considered design of the programme and curriculum can be of great help in providing students with learning opportunities regarding research. Throughout the programme learning tracks, or educational trajectories, about research can be designed, in which students gradually develop individual competences in doing research. Well-designed parallel learning tracks, for example, a theoretical track and a practical track, can stimulate students to apply theoretical knowledge in actual research activities (cf. Ruis, 2007; Van der Rijst & Jacobi, 2009). In this thesis, scientific research dispositions are presented as relevant elements for doing research (Chapters 2, 3, and 5). For educational consultants, who advise higher education institutes about curriculum design, the idea of the development of students' research dispositions throughout the programme is of interest. The categorisation of aspects of research dispositions can be of assistance to educational consultants and curriculum developers in considering the design of curricula in higher education.

6.7.2 Teaching practice and teacher training

In this section three recommendations are presented which endorse awareness of and encourage reflection on and monitoring of scientific research dispositions and teaching practice in order to promote further professional development to improve the pedagogical quality of teachers in higher education. In the following sections three examples are described, which follow directly from the findings of the studies presented in this thesis.

First, an understanding of scientific research dispositions can be helpful for university teachers when teaching students about research. Teachers in higher education, who scaffold research activities and supervise students in research activities, need to know a variety of ways to effectively teach students about research. If university science teachers are able to discriminate between the six aspects of research dispositions, it is possible for them to scaffold the development of students' research dispositions during science courses. Encouraging teachers to reflect on implicit aspects of their own and their peers' research practices, such as scientific research dispositions (Chapters 2 and 3), is likely to help them become more receptive to student conceptions and misconceptions about research practice, and support them in guiding students to develop adequate conceptions about scientific research.

Second, the method of speech act analysis presented in Chapter 4 can uncover teachers' speech act repertoires, and can be used in professional development programmes for teachers. Speech act theory provides teachers with a method to reflect on their own speech act repertoires, and with a framework to expand their repertoires. When university teachers and teacher trainers recognise that teachers' speech acts play a relevant role in educational practice in higher education, and that it is possible to expand one's speech act repertoire, teachers might become more inclined to work on the scholarship of teaching and learning, and on their knowledge base of teaching (Verloop et al., 2001).

Third, evaluation of students' perceptions of the constructed learning environments can be an effective tool to stimulate teachers to reflect on their own teaching practices. The questionnaire used in Chapter 5 can be used as an evaluation tool for teachers to become aware of students' perceptions of the constructed learning environment, and specifically of their perceptions of research activities in the courses.

6.7.3 Student learning

Although knowledge about scientific research dispositions has the potential to support student learning about research, academics do not frequently stimulate

students to reflect explicitly on aspects of these dispositions. The categorisation of six aspects of scientific research dispositions presented in Section 2.3 can be helpful when encouraging student learning about research. During their studies, students learn about both implicit and explicit elements of research practice. The aspects of research dispositions can be used by students to reflect on specific implicit elements of research in order to gain a deeper understanding of research practices. For example, through reflection on the research dispositions of others, scientists and peers, students might come to understand the unique feature of research practice that there are different ways to do research.

The findings presented in Chapter 5 also suggest that reflection on scientific research dispositions might be stimulated most through observation of others, such as peers, experts, or the teacher, while doing research activities, and sharing ideas through discussions about research. It might be more difficult for students to reflect on the research process and research disposition when they are actively involved in improving their research skills. It might be more profitable for student learning about the processes of science to stimulate students' reflection on the process afterwards.