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

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Chapter 2

Exploring scientific research disposition from the perspective of academics

2. Exploring scientific research disposition from the perspective of academics[1]

In many science departments at universities, academics are searching for ways to strengthen links between research, teaching and learning. By making intangible elements of research practice, such as scientific research disposition, a more explicit part of the science curriculum these connections could be made stronger. Understanding differences and similarities between academics' scientific research dispositions could help to enhance intangible links between research, teaching and learning. These dispositions are personal mixtures of tendencies to act while performing research. The aim of the present study is to explore scientific research dispositions of academics. A semi-structured open-ended interview was administered to 23 academics from the Faculty of Science of Leiden University. The participants had different backgrounds in terms of discipline, research experience and teaching experience. Six different aspects were identified in a qualitative analysis which reflected the variety of the academics' scientific research dispositions: inclination to (1) achieve, (2) be critical, (3) be innovative, (4) know, (5) share and (6) understand. A hierarchical cluster analysis provided insight into subgroups of participants with similar scientific research dispositions. A principal component analysis of categorical data was performed to explore latent variables underlying these subgroups. Combining results from the hierarchical cluster analysis with the principal component analysis allowed the clusters to be interpreted in terms of similarities between cases within clusters. Implications for teaching and learning at universities are explored.

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2.1 Introduction

A profound understanding of scientific research practice is needed to teach students to undertake scientific research at universities. The call for the enhancement of links between research, teaching and learning at universities has been answered recently in many studies in various countries (cf. USA: Boyer, 1990; Boyer Commission, 1998 and 2002; Australia: Brew, 2006; UK: Barnett, 2005; Griffiths, 2004; Healey, 2005b; Jenkins et al., 1998; Continental Europe: Van der Rijst et al., 2009). These studies present positive views on stimulating student learning by developing pedagogies and instructional approaches aimed at enhancing these links in higher education institutions. Knowledge of scientific research practice can be helpful when looking for ways to strengthen the link between research, teaching and learning in science departments.

Studies into scientific research practice have shown that the idea of a common single scientific method is overly misleading. Scientific inquiry cannot be characterised as a fixed set of steps that all scientists follow (American Association of the Advancement of Science (AAAS), 1993). Many scholars have described the phenomenon of scientific inquiry in ways which deviate from the idea of a single scientific method (cf. Bauer, 1992; Latour, 1987; Latour & Woolgar, 1979; Rowbottom & Aiston, 2006). Generally, these studies were undertaken to provide a better understanding of research practice as can be seen from the actions undertaken by the scientists themselves. It has become apparent that processes of inquiry are highly dependent on the specific context of a particular investigation, on the discipline in which a study is performed, and on personal characteristics of the scientists involved. However, these studies also show that general principles to describe the different processes of scientific inquiry can be distinguished. Latour (1987), for example, described six principles underlying science in action from a sociological perspective. These kinds of principles provide deeper understanding of the variety of processes in scientific research.

2.1.1 Scientific research dispositions in literature

Every scientist has a personal tendency to act in a specific way when undertaking scientific research, for instance, a tendency to innovate, to seek understanding, to share new insights or new ideas. Some scientists might focus strongly on critically observing the outcomes of their experiment. Others, however, might tend more towards developing new innovative ideas. We label these personal combinations of tendencies to act as 'dispositions'. A scientist's research disposition is his or her individual mixture of tendencies to act while performing scientific research. Although scientific research dispositions are individual characteristics, similarities between aspects within dispositions can be expected. Although shared aspects of these dispositions provide understanding of research practice, no systematic investigations into scientists' dispositions in their research practice have been carried out. The aim of the present study is to categorize a variety of aspects within scientists' research dispositions.

In line with psychological literature (Albarracin, Johnson & Zanna, 2005), we refer to the changeable and intentional tendencies to act in practice as the disposition of an individual. We first note that this concept is different from the concept of 'attitude' used in psychological literature, which contemporarily is defined as 'a psychological tendency that is expressed by evaluation a particular entity with some degree of favor or disfavour' (sic.) (Albarracin et al., 2005: p. 4). In science education research literature the concept 'attitude towards science' is used (e.g. Lichtenstein, Owen, Balalock, Liu, Ramirez, Pruski, Marshall, & Toeperwein, 2008; Caleon & Subramaniam, 2008) to express a bi-polar feeling towards science. Furthermore, we note that the concept of 'attitude *towards* something' should be discriminated from the broader intuitive notion of an 'attitude *while performing* something', in the sense that commonly an 'attitude *while performing* something' is considered to be a characteristic way of behaving, while a 'attitude towards something' is a positive or negative feeling towards something. For example an 'attitude towards science' is not the same as a 'scientific attitude', because a student can have very negative feelings towards doing scientific lab-work (attitude as a concept in psychology), while being very critical when performing a lab-work assignment (attitude as a notion daily life). Finally, we note that the concept of 'disposition' is strongly related to Bourdieu's (1977, 1988) use of his notion of 'habitus'.

The concept of 'disposition' has been used in educational research before but not always in a consistent way. Katz and Raths (1985) defined a disposition in teacher education as referring to 'a pattern of acts that were intentional on the part of the teacher in a particular context and at particular times' (p. 303). This definition interprets the concept of disposition in a strongly behavioural sense. However, from philosophical debates about the concept of disposition (as a conditional property of material, like fragility or solubility), it becomes clear that a disposition is not always 'a summary of actions observed'. For example, a glass vase still has the disposition to be fragile, even though I hold it in my hands unbroken. Similarly, an individual who is irascible does not need to be angry constantly. On the other hand, however, a single observed action does not need to be 'caused' by a disposition; it could be just an uncharacteristic event. For example, we cannot infer that a person is characteristically hot-tempered if he leaves the room angry after an unpleasant incident, he might be intrinsically rather mild-natured. Dispositions are, in some significant way, an intrinsic matter. To cut the philosophical debate short for now, we therefore propose, in line with Fara (2005), that an individual is disposed to *M* when *C* if and only if he has an intrinsic property in virtue of which he does *M* when *C* occurs, where *M* is a verb related to psychological disposition (e.g. to get angry, be critical, or be innovative) and *C* is a sentence stating the condition (e.g. people shout at him, he reads a manuscript from a colleague, or is writing a research proposal). That is why in this study we use the term disposition to refer to tendencies to act, rather than to the actual actions observed.

A study by Neumann showed that academics conceive relations between research and teaching in three distinct ways: (1) global connection, (2) tangible connection, and (3) intangible connection (Neumann, 1992). The global connection describes the nexus at departmental level and relates to research activity in the department, which can guide teaching activities in university courses. The tangible and intangible connections describe the relations on an individual level. Neumann defined the intangible connection between research and teaching as being related to students developing approaches and attitudes towards knowledge development and research. While the tangible connection emphasizes the transmission of advanced knowledge and results from recent research, the intangible connection relates to more implicit relations between research, teaching and learning. Scientific research dispositions are mostly related to these intangible connections between research and teaching at universities. However, it is possible to reflect on scientific research dispositions explicitly, by making it part of explicit curriculum messages, rather than giving students only implicit curriculum messages about aspects of scientific research dispositions (Ryder, Leach & Driver, 1999). Underlying aspects of scientific research dispositions can be made explicit by academics during teaching practice, for example, by guiding students with their reflections on the processes of inquiry in specific authentic research situations.

2.1.2 Nature of science and scientific inquiry

Alongside knowledge of concepts, principles and theories, one of the elements of scientific literacy is to understand the processes of scientific inquiry (American Association for the Advancement of Science, 1990; 1993; Laugksch, 2000). The university curriculum should pay attention to these processes of scientific inquiry, when preparing scientifically literate students. Naturally, a scientifically literate student should develop a functional understanding of the nature of science and scientific inquiry (NOS) (Abd-El-Khalick & Lederman, 2000; Abd-El-Khalick, 1998). However, scientific inquiry cannot be described as a fixed set of general rules or steps that scientists follow. Which steps and procedures are followed within a particular scientific inquiry depends greatly on the individual, the context, and the particular investigation (AAAS, 1993, chapter 'The scientific enterprise'). University curricula should, therefore, emphasize both discipline-independent factors and individual-scientist factors which influence the processes of inquiry. Aspects of the NOS are typically described in terms that are independent of discipline, i.e. in terms specific to the domain of science but not specific to a particular discipline within science (Schwartz & Lederman, 2008). Factors specific to the individual scientist, which influence and might explain the processes of inquiry he or she applied, have not been highlighted in literature. This means that individual choices cannot always be understood fully by scrutinizing the scientist's knowledge and beliefs about the NOS. For example, there might be two scientists who have the same knowledge and similar beliefs about the NOS but who approach the same problems quite differently. While both, for example, express similar beliefs about social-cultural influences on the processes of science, one scientist might still choose to scrutinize the problem on his own first, while the other might be more inclined to discuss the problem with colleagues abroad. Knowledge and beliefs about the NOS as well as an individual's scientific research disposition are both elements which can help us to understand the processes of scientific inquiry. Furthermore, Samarapungavan, Westby, & Bodner (2006) showed that 'immersion in authentic research experiences provides students with important opportunities to learn about the processes of scientific inquiry specific to their discipline'. More than that, the level of research expertise is a predictor of the sophistication and consistency of scientists' and students' conceptions about the processes of scientific inquiry. Learning about the characteristics of scientific inquiry, such as the NOS and scientific research dispositions, can therefore best be situated in authentic research practice where students play central participatory roles (Samarapungavan et al., 2006; Schwartz et al., 2004).

In many science courses explicit attention is given to knowledge of the discipline and research skills appropriate to the discipline. However, less attention is given to the dispositions that students need to become proficient researchers. Furthermore, every academic has certain preferred dispositions, like an inclination to be critical, to be curious or to be innovative. Although science staffs at universities have much experience in research as well as in teaching, they rarely explicitly express their inclinations to act. The idea underlying the present study is that university science teaching and student learning of science in research-intensive environments might be positively influenced by giving explicit attention to scientific research dispositions in science curricula. Focusing explicitly on aspects of scientific research dispositions could provide students with a more realistic picture of scientific practice. Understanding differences and similarities between the various tendencies to act during research activities could be helpful when developing pedagogies and approaches to enhance links between research, teaching and learning, for example, by emphasizing what teachers need to focus on when improving students' understanding of scientific research practice. This study aims to provide academics with knowledge about the nature of scientific research practice, which could be valuable when they are trying to enhance student research competence. The implications for teaching practice at universities are anticipated.

2.1.3 Context and research question

The present study was conducted at the science faculty of a research-intensive university in the Netherlands. Academics at this faculty are involved in both research activities, and teaching. Their skills, knowledge and dispositions towards research influence their teaching in one way or another. The aim of present study was first to identify the variety of aspects of scientific research disposition from the perspective of science academics, and secondly, to describe differences and commonalities between their preferred dispositions. The guiding research questions were *what aspects can be distinguished in the ways science academics conceive of their scientific research dispositions* and *what are the differences and similarities between groups of academics with comparable research dispositions*.

2.2 Methods

To identify the qualitative variation in aspects of scientific research disposition, a semi-structured open-ended interview was designed and administered to science academics. Aspects of the academics' scientific research dispositions were categorised qualitatively. Commonalities and differences between participants were identified quantitatively.

2.2.1 Participants

Before selecting participants two issues were considered. Firstly, the sample should cover the variety of research institutes present at the Faculty of Science of Leiden University. Secondly, participants with a large variety of experience in research as well as in teaching should be included in the sample.

Academics at different research institutes of the faculty were asked to participate. During the time in which the interviews were held, a pedagogical training for university science teachers was taking place. All academics, who had subscribed to this training, were asked to participate. Altogether, 41 faculty members were sent an email to ask for their cooperation, of whom 23 (56%) were able to be interviewed during the interview period. The main reasons given for not participating were 'staying abroad' and 'no available time' to be interviewed. Six of the participants (26%) were female. The participants held positions ranging from full professor (6), associate professor (3), assistant professor (9), lecturer (4), and post-doctoral researcher (1). All participants in this study were PhD graduates and were participating, or had participated, in research areas similar to the areas in which they taught their courses. This sample was representative of the population of faculty members of the faculty of science, in the sense that it contained members (a) from all disciplines within the Science Faculty, (b) from all levels of positions, and (c) with a variety of experience in research and teaching. The disciplines of the participants can be grouped into 5 sets; chemistry (30%), astrophysics (22%), mathematics and computational sciences (22%), physics (17%), and biology (9%).

2.2.2 Procedure

Open-ended interview questions were designed to be flexible, offering participants opportunities to raise matters they considered to be important. The interview questions were tested in a pilot study with educational experts in the fields of science teaching and science research. The main aim was to find out whether the interview questions stimulated participants to explain ideas about scientific research dispositions. The wording of the questions was adapted slightly in response to their comments. Participants in the pilot interviews were excluded from the main study.

The semi-structured interview consisted of two parts. In the first part of the interview, general questions were asked about research activities, teaching activities, and background variables. The background variables were gender, position, educational experience, research institute, research orientation and research strategy. The research orientation was defined as pure or applied. When the research was described by the participant as focusing on improving scientific theory or models, the research orientation was labelled as pure, while research described as focusing on improving practice was labelled as applied. This demarcation relates to the categorization of disciplines in higher education from Becher's adaptation (Becher, 1989) of Biglan's categorization (Biglan, 1973).

Becher categorised research disciplines on two dimensions, namely pure-applied and hard-soft. While all natural science disciplines can be categorised as hard disciplines in the Becher categorization, the pure-applied dimension was used in this study to define the academics' research orientation. Furthermore, the background variable 'research strategy' related to the principle strategy academics used in their daily practice. Two strategies were considered, namely theoretical or experimental.

Part two of the interviews included questions about scientific research dispositions of academics and students and their behaviour related to these dispositions. When answering questions about their own scientific research dispositions, participants were encouraged to reflect on their current or previous research activities. Interviews took approximately 70 minutes and transcripts were sent to participants for member checking to establish data credibility (Janesick, 1994). In this study we only report on the four questions about academics' scientific research dispositions that are relevant to the aim in this study. The interviews were held in the first language of the interviewees. The questions and answers were translated from Dutch.

a) *Can you describe which attitudes/dispositions are necessary to do scientific research?*

b) *Picture a 'good scientist'. Explain why, according to you, this scientist is a 'good scientist'?*

c) *Which attitudes/dispositions best fit your description of a good scientific researcher?*

d) *Can you describe which attitudes/dispositions are necessary when conducting research in your field of study?*

Participants responded to these questions differently, for example some responded at length to questions *a* and *b*, while only referring to their earlier answers at questions *c* and *d*. Others were rather brief at question *a* and elaborated their answers at questions *b* and *d*. When selecting interview fragments for the analysis, we left out the fragments where interviewees only referred to their earlier answers on these four questions. This resulted in 72 interview fragments, consisting of question and answer, of approximately 296 words each. These interview fragments were used in the further analysis.

2.2.3 Qualitative analysis of interview data

The aim of the qualitative analysis of the interview data was to capture the variation in aspects of scientific research dispositions conceptualised by academics in science and mathematics. An open coding approach was followed when analyzing the data. 'During open coding the data are broken down into discrete parts, closely examined, compared for similarities and differences, and questions are asked about the phenomena as reflected in the data' (Strauss & Corbin, 1990, p. 62). The analysis of the interview data consisted of five steps, analogous to procedures of the grounded theory approach (Bryant & Charmaz, 2007; Strauss & Corbin, 1990). The first step in the analysis process was to analyze interview transcripts to create a preliminary list of 'in-vivo codes', in which words and phrases used by the participants were applied as code labels (Strauss & Corbin, 1990, p. 69). Secondly, similar in-vivo codes were clustered creating a list of meaningful descriptive categories. Codes which initially seemed to portray a new theme were assigned to new categories. In the open coding process of qualitative analysis the point when no new categories appear, the data saturation point is typically reached after 12 participants (Guest, Bunce, & Johnson, 2006; Straus & Corbin, 1990). Short definitions and demarcation rules for each category were added based on underlying in-vivo codes. Interview fragments, in which participants did not refer to the subject of scientific research disposition or anything related to the subject were labelled as 'no code'. In the third step a research assistant was involved to verify whether the meaningful descriptive categories could be applied by a person not familiar with the data. Half of all interview fragments (n=36) were coded independently by the author and the research assistant using the list of meaningful descriptive categories, definitions and demarcation rules generated in the previous step. Categories, definitions and demarcation rules were refined, based on negotiated consensus between raters, creating the final list of meaningful descriptive categories, definitions and demarcation rules. In the fourth step of the analysis procedure all other interview fragments (n=36) were coded independently by a first and a second rater using the final list. The inter-rater reliability with two raters was 0.77 (Cohen's κ), and 78.4% agreement based on 36 interview fragments and 28 meaningful descriptive categories. The first and second rater reached consensus on all codes during discussion and re-reading of interview fragments. Subsequently, descriptive categories were assigned to all 72 interview transcripts using Atlas-ti, a software program for qualitative analysis (Muhr, 1997). Finally, all descriptive categories were clustered into groups with similar meaning, creating the main aspects of scientific research dispositions.

2.2.4 Quantitative analysis of codes

To study commonalities within the distribution of aspects in interview transcripts, a hierarchical cluster analysis (HCA) and a principal component analysis for categorical data (PRINCALS) were performed on the distribution of the six aspects of all 23 participants in our sample (see Table 2.2 for the percentage distributions of the codes). A hierarchical cluster analysis was carried out to explore whether relatively homogenous subgroups could be identified, based on the distribution of codes in their interviews. Pearson correlations were calculated as a measure of distance, and between-groups linkage was used as a clustering method. This clustering method is based on the average distance between all inter-cluster pairs. Secondly, a PRINCALS was carried out to explore how the subgroups of participants were related. This exploratory technique is related to Principal Component Analysis in that it allows loadings to be calculated for variables on the same dimensions, i.e. latent variables. PRINCALS, as opposed to Principal Component Analysis, can be applied to categorical data (De Heus, Van Leeden, & Gazendam, 1995). Furthermore, PRINCALS allows a plot of an n-dimensional manifold to be generated, in which both cases and variables are represented by 'points' and 'vectors' respectively (Gifi, 1990; Van Driel, Bulte, & Verloop, 2007). In the present study the cases were the distribution of codes in participants' interviews and the vectors were the aspects of scientific research dispositions. The relative distance between points within this manifold represents the relative similarity between cases. Furthermore, the position of the points with respect to a vector indicates the score on that variable represented by that vector. Points on the positive side of a vector score above average on the scale, while points on the negative side score below average.

Combining the clusters from the HCA and the manifold from the PRINCALS analysis allowed an interpretation of the clusters in terms of similarities between cases within clusters. By labelling all cases with cluster numbers from the HCA, cluster areas could be identified within the PRINCALS manifold. A 'cluster area' is the space on the manifold in which all cases from a particular cluster are present, and which could overlap other cluster areas. These areas allowed similarities and differences to be distinguished between clusters from the HCA based on identified dimensions (i.e. latent variables) and vectors (i.e. variables) from PRINCALS. To study cluster areas more deeply, 'cluster-cores' and 'cluster-boundaries' can be recognised. The cluster-core is that part of the cluster area in which only cases from a single cluster are present and which does not overlap with other cluster areas, while the cluster boundary is that part of the cluster area in which cases from other clusters are present or which does overlap with other cluster areas.

Cases within the cluster-cores can be used to give a qualitative description of common characteristics of cases in that particular cluster, while cases within the cluster-boundaries share characteristics of cases from the adjacent cluster.

Because the number of participants in this exploratory study was low, no statistical measures could be used to explore significant correlations between background variables of participants and clusters. To explore possible relations between the background of participants and the identified clusters, all cases are presented with their background variables and their cluster in Table 2.2. Some noteworthy relations between clusters and background variables will be presented at the end of the Results section.

All statistical analyses were performed using SPSS software, version 14.0.1 [note that in this version, PRINCALS is part of the optimal scaling technique 'Categorical Principal Components' (CATPCA); see also Statistical Package for the Social Sciences Incorporated, 1990: chap.8].

2. 3 Results

2.3.1 Six aspects of scientific research dispositions

Six qualitatively different aspects were distinguished from the interview transcripts: (1) inclination to achieve, (2) inclination to be critical, (3) inclination to be innovative, (4) inclination to know, (5) inclination to share, and (6) inclination to understand. Based on the qualitative analysis of the interview data these six aspects were interpreted as the core aspects of a scientific research disposition. These six aspects reflect the qualitative variation in the academics' conceptualization of scientific research disposition within the data. In the following sections the content of each aspect will be described in words. These descriptions are based on the underlying codes, which are presented in the first column of Table 2.1. Table 2.1 also presents two quotes to illustrate each aspect of scientific research disposition. The research institute and all codes assigned to the fragment from which this quote originates are shown in brackets.

Explanation of 'inclination to achieve'

Many of the participants described their scientific practice as 'hard work and very time-consuming'. They described outstanding scientists as having strong elements of discipline, persistence and perseverance. When describing an inclination to achieve as one of the aspects of a scientific research disposition, academics put emphasis on the *ambition* and *drive to completely devote oneself* to the issues under study. Being *passionate* and *persistent* were characteristic features within this aspect. A considerable amount of *personal discipline* was considered necessary: not giving up before you are satisfied and keeping up the effort even when it becomes difficult. *Patience* was considered crucial when conducting scientific research. Those academics, which put emphasis on this aspect, evaluated themselves as *full of initiative* and referred to the importance of bearing in mind the final goal of the project. Often this aspect was related to *passion* and *putting all of your energy into the project*. The inclination to *persist until you are satisfied* was found to be important, but should be balanced by the need to keep in mind the construction of an appropriate end, even when you still know so little about the phenomenon under study.

Table 2.1 Underlying codes with illustrative quotes of the six aspects of scientific research disposition (translated from Dutch by the author; between brackets: research institute and codes assigned to the fragment)

Aspect (with underlying codes)	Example Quote 1	Example Quote 2
To Achieve - ambition - discipline - full of initiative - patience - passionate - persistent	'To concentrate, to focus, that's something central to this profession. It [research] is no hocus-pocus, it isn't very extraordinary. You just need a certain routine and discipline'. (Chem; *discipline*)	'I consider thoroughness important. As I already said, dummies are unacceptable. You can have innovative ideas but you have to put these ideas into practice in a scientifically correct and theoretically sound way, and if your ideas do not seem to work afterwards, you just have to dismantle them'. (Astro; *discipline*)
To be Critical - critical (general) - critical towards others - honesty - observing - self-critical	'Being critical, being independent, and having the ability to present well are the core aspects, I believe, especially being critical'. (Chem; *critical (general), skilled communicator, choosing own path*)	'To be critical is most important. They [students] have to weigh all the information they receive, not only from literature, but also the results from their own experiments. […] many things can be related to that, open attitude, open towards other ideas and towards different results, […] but all is closely related to being critical.' (Phys; *self-critical, critical towards others*)

Table 2.1 (continued)

Aspect (with underlying codes)	Example Quote 1	Example Quote 2
To be Innovative - anticipating - associative - choosing own path - creative - original - unconventional	‘A good study has some innovative element. Many articles are produced which just present small technical steps. Anyone with brains can write these. A good study needs at least one original thought.’ (Math; *original*)	‘The ability to ask exciting new questions and to create new mental images, originality is important. Some people are good researchers, but they follow standard procedures. Others are better, recognizing new areas of research.’ (Bio; *original*)
To Know - curious - excitement	'On the one hand, getting curious, while on the other hand, not getting too excited. So, being enthusiastic on the one hand, and yet keeping disciplined, keeping calm to proceed by conveniently arranged steps'. (Chem; *curiosity and discipline*)	'Curiosity, in particular within science, I suppose, but that might be my limited perception. Curiosity is a major motive, should be the most important motive'. (Astro; *curiosity*)
To Share - explaining - openness towards others - persuasive - skilled communicator - working together	'Presenting, naturally, if it all goes well, is an archetypical form, it includes aspects such as being independent, being critical, showing drive, passion, it includes all these aspects, doesn't it?'(Chem; *skilled communicator, choosing own path, critical (general), passionate*)	‘Nowadays, as a researcher, it won’t do anymore to withdraw yourself to your room, to think it all out on your own. Interaction with other groups can’t be underestimated nowadays, that’s how you will make progress.’ (Chem; *working together*)
To Understand - overview - scrutinizing - solving problems	'The drive to understand a phenomenon, to feel the inner joy when you understand the issues, when you solve a problem, but then again, it isn't just about solving puzzles. It is about the joy of understanding issues in a way nobody else understands them. That is so special, that is what you have to experience'. (Astro; *scrutinizing*)	‘Yes, the desire to understand how something works and to experience the thrill when you understand it, when you solve the issue.’ (Astro; *solving problems*)

Explanation of 'inclination to be critical'

Many participants perceived 'being critical' as the core issue in scientific practice. When describing an inclination to be critical as one of the aspects of a scientific research disposition, academics put emphasis on a *critical attitude towards others*, for example, articles, colleagues, but also *toward the observations from experiments*. A *self-critical attitude*, being critical of one's own ideas and own work, also fits within this aspect. Generally speaking, issues within this aspect all boiled down to sophisticated doubt, which initiates critical questioning of all kinds of issues. Academics who emphasised this aspect often talked about critically observing the experimental setup and data. Continuously *being attentive and open towards strange incidents and observations*, which ask for critical reflection, was essential to most of these academics. Always double checking the set-up and considering issues of accuracy were connected with this aspect. Furthermore, part of this inclination revolved around *critically honest* management and presentation of your data, such as meticulously avoiding plagiarism and twisting data to suit your private opinion.

Explanation of 'inclination to innovate'

Good science was perceived by the participants as an innovative endeavour. Originality and creativity are elements of this. Participants acknowledged that not all scientific projects are highly innovative, but creating innovative ideas and practices was perceived as an aspect of scientific research practice. When describing an inclination to innovate as one of the aspects of a scientific research disposition, academics put emphasis on *originality*, *creativity* and *choosing their own line of research*. Many academics referred to the benefit of *'unconventional behaviour*', which was explained as behaviour that contradicted, for example, the conventions within the research group, or within the field of research as a whole. To do this, a certain amount of courageousness or naivety is necessary. Some paid tribute to the naivety of, for example, new scientists, who can be innovative because they are not yet inhibited by various conventions in the field. Developing new instruments and explaining innovative ideas was reported as a major drive. A degree of creativity and following your intuition was felt to be necessary. *Associative thinking* and combining various issues, for example from diverse fields of research, was considered very beneficial. Academics who put a strong emphasis on this aspect might be perceived as ahead of times, or having an outlook that anticipates future studies.

Explanation of 'inclination to know'

When describing an inclination to know as one of the aspects of a scientific research disposition, academics put emphasis on *curiosity* and being knowledge-thirsty. Scientists exhibiting this inclination were highly motivated to read about new issues and listen to new ideas. Their attention was drawn towards phenomena and perspectives, which were novel to them. They were motivated to gain knowledge of more facts about new issues. Their broad interest made them curious about various topics. These topics were not only related to their own field of study, but could also be related to other fields. This inclination was strongly associated with a basic interest in and curiosity about the unknown. Issues such as *motivation* with an intrinsic orientation and *excitement* when the curiosity was fed, were often reported.

Explanation of 'inclination to share'

Research results are disseminated among others within the scientific community on a regular basis. Some participants highlighted sharing results as an element of a scientific research disposition. When describing an inclination to share as one of the aspects of a scientific research disposition, academics put emphasis on *explaining*, *convincing others* and *openness towards other ideas* and conclusions. These other ideas and conclusions may come from immediate colleagues and students, from international contacts, from conferences, or from journals. Academics emphasizing this aspect often reported that *interdisciplinary exchange of knowledge*, methods and ideas is rather important. Academics acknowledged benefiting from an *open-mind towards others*. This aspect was said to often co-occur with becoming a *skilled communicator*, being good at creating social contacts, not only in *working together with colleagues*, but also being good at assembling people around your ideas and generating funding for further research. Certain intrinsic characteristics, such as optimism, empathy, and strategic sensitivity, were considered to be very helpful.

Explanation of 'inclination to understand'

When describing an inclination to understand as one of the aspects of a scientific research disposition, academics put emphasis on the inclination to *scrutinize underlying causes* and meaning of phenomena and facts around us. These academics put emphasis on a search for *deep understanding*, to get to the bottom of the issue. They were not satisfied with only knowing the facts, but wanted to understand how the facts are connected to each other. They often stressed the inclination to seek the *broad view* and to *relate facts to the bigger picture*. An inclination to develop a *broad-minded view of their subject area* and to unite the various findings and results from individual studies was often reported by academics, which emphasised this aspect.

One might tend to read the aspects 'inclination to know' and 'inclination to understand' as being similar. However, the differences between these two aspects can be explained in terms of the underlying codes, which are presented in the first column of Table 2.1. The demarcation criteria were deduced from the underlying codes. Underlying codes of 'to know' were assigned to fragments in which participants talk about their initial curiosity about a subject, the curiosity which focuses the motivation to learn more about a topic, which excites you as a scientist. The underlying codes of 'to understand' were assigned to interview fragments in which participants talk about scrutinizing phenomena, the drive to understand the issue in depth, to create an overview of the facts and the relations between facts related to a specific topic. Some participants related this aspect to a kind of internal frustration, whereas the aspect 'to know' did not generally involve any frustration.

2.3.2 Percentage distribution of codes among participants

Table 2.2 presents the percentage distribution of the main aspects of scientific research disposition. The distribution of codes is presented as a percentage of occurrences of codes within the interview per participant. Background variables (educational experience, gender, position in department, and affiliation with educational institution) are also presented in Table 2.2. The distribution percentages were used as indicators of the ‘amount of attention or the degree to which an attitude or belief permeates a population’ (Krippendorf, 1982, p. 109). These distributions indicate the 'amount of attention' given to that particular aspect in the interview.

2.3.3 Hierarchical cluster analysis and principal component analysis

To study commonalities within the distribution of aspects in the interview transcripts, a hierarchical cluster analysis (HCA) and a principal component analysis for categorical data (PRINCALS) were performed on the percentage distribution of the six aspects of participants. Five clusters were defined from the hierarchical cluster analysis. The number of clusters was estimated by the demand that every case was included in a cluster and there was a reasonable increase in the clustering criterion (Everitt, Landau & Leese, 2001).

The five clusters identified by the HCA can be interpreted through a PRINCALS analysis. Combining the results from the hierarchical cluster analysis and the PRINCALS analysis allowed the clusters to be interpreted in terms of similarities between cases within clusters. Figure 2.1 shows all cases on a two-dimensional manifold calculated by PRINCALS.

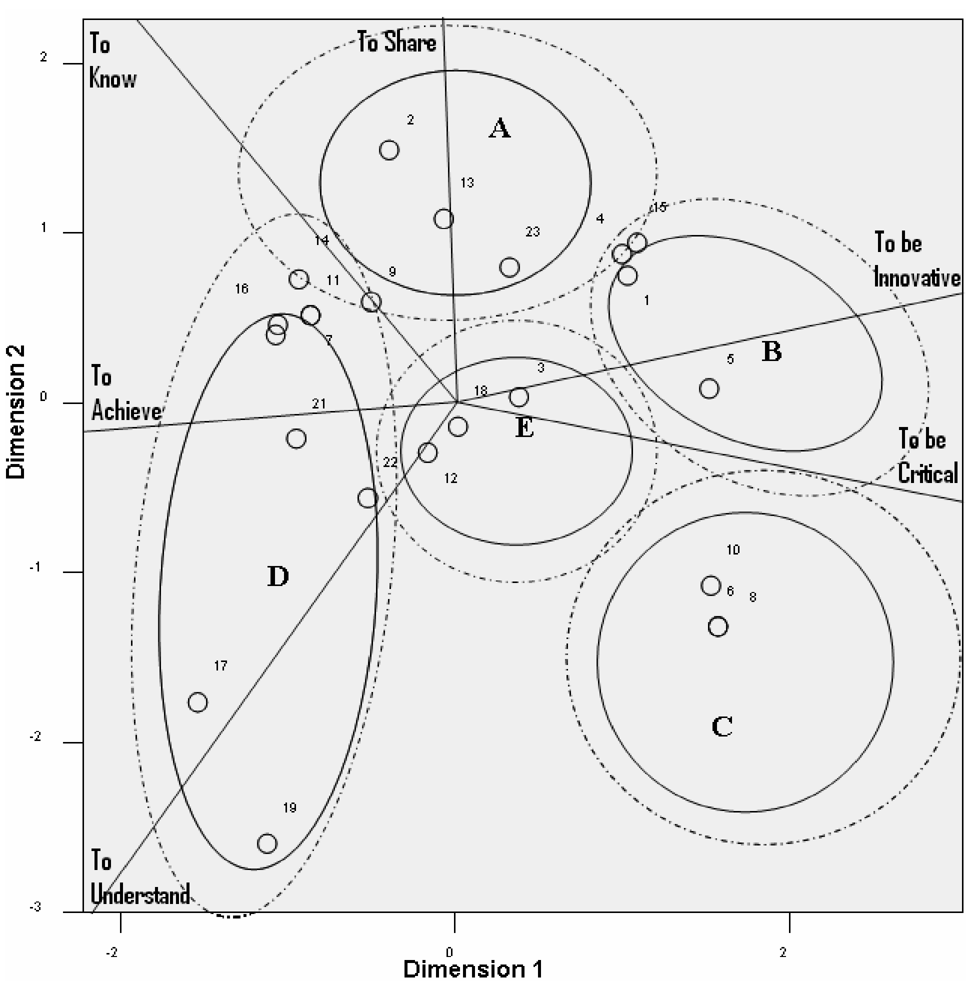

Figure 2.1 Cases plotted on a two dimensional manifold and labelled with case numbers from the cluster analysis (vectors of the six aspects of scientific research dispositions are plotted on the manifold)

Table 2.2 Percentage distribution of the aspects of scientific research disposition

Cluster (from HCA)	Case number	Educational experience (years)	Gender	Position	Institute	Orientation	strategy	To Achieve	To be Critical	To be Innovative	To Know	To Share	To Understand	No Code	Total number of codes
A	2	15	male	Full	Chem	applied	Exp	25	0	13	50	13	0	0	8
	7	40	female	Lectu	Biol	applied	Exp	20	0	0	40	20	20	0	5
	11	2	male	Assist	Phys	pure	Exp	20	0	0	40	20	20	0	5
	13	6	male	Assist	Astro	pure	Exp	20	0	20	40	20	0	0	5
	15	20	male	Assist	Math	applied	Theo	0	18	18	36	18	0	9	11
	23	10	male	Assist	Chem	pure	Theo	0	0	14	29	29	14	14	7
Mean values cluster A								14.2	3.0	10.8	39.2	20.0	9.0	3.8	6.8
B	1	1	male	Assist	Phys	applied	Exp	9	36	9	18	27	18	0	11
	4	30	male	Assoc	Chem	applied	Exp	0	25	13	25	38	25	0	8
	5	15	female	Assoc	Chem	applied	Exp	0	20	20	0	60	0	0	5
Mean values cluster B								3.0	27.0	14.0	14.3	41.7	14.3	0.0	8.0
C	6	20	male	Full	Biol	applied	Exp	0	30	40	10	0	10	10	10
	8	30	female	Lectu	Chem	applied	Exp	0	40	0	0	20	20	20	5
	10	8	male	Assist	Phys	pure	Exp	10	70	10	10	0	0	0	10
Mean values cluster C								3.3	46.7	16.7	6.7	6.7	10.0	10.0	8.3

Table 2.2 (continued)

Cluster (from HCA)	Case number	Educational experience (years)	Gender	Position	Institute	Orientation	strategy	To Achieve	To be Critical	To be Innovative	To Know	To Share	To Understand	No Code	Total number of codes
	9	5	male	Full	Phys	pure	Exp	33	0	11	22	11	22	0	9
	14	10	male	Assist	Astro	pure	Exp	43	0	0	14	43	0	0	7
	16	21	female	Full	Chem	applied	Theo	33	0	0	22	33	11	0	9
	17	20	male	Lectu	Math	pure	Theo	33	0	0	33	0	33	0	3
D	19	22	male	Lectu	Math	pure	Theo	33	0	0	0	0	33	33	3
	20	10	male	Post-D	Math	pure	Theo	43	0	0	14	29	14	0	7
	21	20	male	Full	Astro	pure	Theo	60	0	0	40	0	0	0	5
	22	2	male	Assist	Astro	pure	Theo	36	14	7	29	0	14	0	14
Mean values cluster D								39.3	1.8	2.3	21.8	14.5	15.9	4.1	7.1
	3	25	male	Full	Chem	applied	Exp	41	12	29	12	6	0	0	17
E	12	8	male	Assoc	Astro	pure	Exp	22	0	33	33	0	11	0	9
	18	10	female	Assist	Math	pure	Theo	50	17	17	17	0	0	0	6
Mean values cluster E								37.7	9.7	26.3	20.7	2.0	3.7	0.0	10.7
Total mean values								19.5	17.6	14.0	20.5	17.0	10.6	3.6	8.2

The two dimensions are the latent variables identified by PRINCALS, which together account for 73.1 % of the variation in the data. The five 'cluster areas', from the clusters identified in the HCA, are plotted on the manifold to provide an indication of how the clusters are related. The 'cluster-cores', represented by dotted lines, and 'cluster-boundaries', represented by closed lines, are presented in Figure 2.1. Cases 4 and 15 are positioned within cluster-boundaries of cluster A and B, and so can be documented as mixed cases, having characteristics of cluster A and characteristics of cluster B. Cases 7, 9, 11, and 14 are positioned in the boundaries of cluster A and D. The directions of the vectors on the two-dimensional manifold were calculated, and are presented in Figure 2.1. These vectors represent the arrangement of the six aspects of scientific research dispositions (variables) towards the two identified dimensions (latent variables).

The vectors of the six aspects of scientific research dispositions presented in Figure 2.1 provide an interpretation of the two dimensions of the manifold. Dimension 1 runs from 'to achieve' on one side to 'to be innovative' and 'to be critical' on the other side. Dimension 2 divides cases between scoring high on 'to understand' and scoring high on 'to share' and 'to know'.

Cases, which score low on 'to achieve' and high on 'to be critical' and 'to be innovative', are positioned on the right hand side of Figure 2.1 (high on dimension 1), while cases, scoring low on 'to understand' and high on 'to share' and 'to know', are positioned on the top halve of Figure 2.1 (high on dimension 2). We can now interpret the clusters based on the dimensions defined by the vectors of the six aspects of scientific research dispositions. For example, cases in cluster D all score relatively high on 'to achieve', while cases in cluster C score relatively high on 'to be critical'. By combining the results from HCA and PRINCALS, we identified five clusters of participants, which have more or less similar scientific research dispositions. Table 2.3 presents short descriptions of each cluster, based on similarities and differences between cases in cluster-cores using the distribution of codes from Table 2.2. These cluster descriptions are based on the cases in the cluster-cores, because these cases best represent the characteristics of each cluster. We refer to distribution frequencies greater than or equal to 27% as 'high' scores and distribution frequencies less than or equal to 18% as 'low' scores.

2.3.4 Relationship between clusters and background variables

Possible relations between the clusters and the background variables of the participants were explored by examining patterns of background variables within the clusters. The idea behind this step was that differences of culture between disciplines within an institute could have an important influence on participants' personal research dispositions. Table 2.2 presents the background variables of all cases within each cluster. Interestingly, cases in clusters B and C generally had an applied research orientation and an experimental research strategy, while cases in clusters D and E had a pure research orientation. Table 2.2 and 2.3 indicate, based on visually examining of the results, that academics from more applied and experimental fields of study (Cluster B and C) tend to put more emphasis on the aspects 'to be innovative' and 'to be critical', while academics from fields with a theoretical research orientation (Cluster D) tend to focus more on the aspects 'to achieve' and 'to understand'. Furthermore, all participants from the mathematics institute are in clusters D and E, while no participants from astrophysics are in clusters B and C. Visually, no patterns between cluster and gender, position or educational experience were recognised in the data.

Table 2.3 Descriptions of clusters based on cases in cluster-cores and the vectors of the aspects of scientific research dispositions

Cluster	Cases in 'cluster-core'	Description *The scientific research dispositions of persons who are positioned in the core of this cluster typically consist of...*
Cluster A	2, 13, 23	... high scores on 'to know' and low scores on 'to understand' and 'to be critical'.
Cluster B	1, 5	... high scores on 'to share' and low scores on 'to achieve' and 'to understand'.
Cluster C	6, 8, 10	... high scores on 'to be critical' and low scores on 'to achieve' and 'to know'.
Cluster D	17, 19, 21	... high scores on to achieve and low scores on 'to be critical' and 'to be innovative'.
Cluster E	3, 12, 18	... both similar scores on 'to achieve' and 'to be innovative' and/or similar scores on 'to understand' and 'to share'.

2.4 Conclusions and discussion

2.4.1 Scientific research dispositions

The results of this study present a diverse picture of how science academics conceptualize their scientific research disposition. The analysis of the interview transcripts distinguished 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. Three of these aspects, *inclination ‘to know', 'to be critical', and 'to share'*, resemble aspects in literature on research dispositions and scientific attitudes (De Vos & Gensenberger, 2000), but they have never been verified in an empirical study of the research practice of academics. Three aspects, *inclination 'to achieve'*, *'to understand'*, and *'to be innovative'*, were new to our understanding of scientific research dispositions and provided new insights into scientific practice.

The six aspects found in this study can also be compared to the classes described by Thagard (2005). Thagard discussed a broad range of factors for scientific success, based on a short survey and written advice to young scientists from three Nobel Prize laureates in the field of biology. 'Six classes of successful habits' emerged from this discussion; (1) make new connections, (2) expect the unexpected, (3) be persistent, (4) get excited, (5) be sociable, and (6) use the world. Although Thagard uses the term 'habit', he does not make a distinction between incidental actions and habitual actions of an individual. A 'disposition', as defined earlier in this manuscript, is not characterised by 'accidental' behaviour, but is characterised by an intentional behavioural pattern. The 'actions' of successful scientists, described by Thagard can therefore be considered to be 'dispositions', if an individual intentionally follows a pattern of actions in similar situations. Habits classified by Thagard within the class 'making new connections' can be interpreted as analogous to elements in our main category 'to be innovative'. Similarly, elements in our category 'to achieve' resemble habits classified as 'be persistent'. However, a clear difference in interpretation is apparent when we look at the aspects 'to know' and 'to understand'. Thagard does not make any distinction between habits related to 'knowing' and habits related to 'understanding'. Elements from the class 'get excited', like 'never do anything that bores you' and 'have devotion for truth', are similar to elements of our aspect 'to know', like 'excitement' and 'curiosity'. Other elements from this class, like 'have a strong desire to comprehend' incline more towards 'to understand'. Likewise, actions in the class 'be sociable' can be mapped onto the inclination 'to share', and actions in the class 'expect the unexpected' can be interpreted as part of an inclination 'to be critical', in the sense that scientists who tend to critically scrutinize observational data are receptive to unexpected trends in the data. We can conclude from this that although not much has been written in research literature about the research disposition of academics, some similar aspects do emerge in different studies.

Before discussing the statistical procedures, identifying clusters and relating these clusters to background variables of academics, we will first discuss the assumptions underlying the present study. Firstly, the analyses are based on the percentage distribution of the six aspects in interviews with academics. The relationship between the distribution of aspects and the actual research disposition of academics was not always very straightforward. To put it another way, we did not necessarily expect to find a one-to-one correlation between what academics say in an interview and their actual dispositions. To overcome this difficulty, multiple opportunities were presented to the participants during the interviews to say whatever they perceived to be related to the topic under debate. Secondly, we had to be careful to define the aspect with the highest percentage distribution as being the most central or most important aspect within a participant's research disposition. This assumption behind the analysis used in this study might limit the conclusions. However, the interview consisted of multiple questions and responses, and during the qualitative analysis of the fragments each code could only be assigned once to each interview fragment. This means that an aspect with a high percentage distribution must be interpreted as an aspect that was mentioned by the participant in different interview fragments, and therefore in response to different interview questions. Finally, in any interview procedure it is difficult to determine the extent to which the responses to interview questions are being influenced by perceived social desirability. However, all participants were informed about the complete confidentiality of the interview, and no possible reasons for socially desirable responses could be identified in the interview scheme. Nevertheless, we have to be careful when drawing general conclusions from this data alone. Further research on academics' scientific research dispositions should be done to verify the results in other contexts.

Furthermore, some differences and similarities in the background variables of the participants were observed between the identified clusters. From the differences and similarities in this sample we were able to draw the conclusions that 1) academics from more applied and experimental fields of study tended to put more emphasis on 'to be innovative' and 'to be critical', while academics from fields with a pure research orientation tended to focus more on 'to achieve' and 'to understand'; and 2) academics in mathematical sciences tended to focus more on aspects 'to achieve' and 'to understand', while astrophysicists often put less stress on aspects 'to be innovative' and 'to be critical', relative to other groups of academics. These final observations indicate that disciplinary differences and/or institutional cultures might have had an influence on the scientific research dispositions of these academics. However, these observations should not be overstated, as they do not show unambiguous relationships between investigative disciplines and research dispositions. Studies presenting possible relationships between the investigative context and academics' views on the nature of science and scientific inquiry (Schwartz & Lederman, 2008) also did not show unequivocal results.

2.4.2 Implications for research and teaching

We anticipate three implications for university science education: helping university science teachers with scaffolding and supervising research-intensive education, improving student learning about research practice, and supporting the professional development of university teachers.

Firstly, university science teachers scaffolding research activities and supervising students participating in research activities need to understand the diversity in research approaches. As scientific research dispositions are essential for understanding the underlying mechanisms of scientific practice, university teachers should at least be aware that differences in research dispositions do exist. If university science teachers are able to discriminate between the six aspects, it should become possible for them to scaffold the development of students' research dispositions on science courses. Furthermore, by explaining scientific research dispositions, university science teachers should be able to encourage students to consider aspects of research dispositions and offer students opportunities to develop a realistic understanding of scientific research practice. Finally, to provide university teachers with tools to identify scientific research dispositions in educational settings, the aspects of research dispositions should be 'translated' into observable behavioural patterns which can be observed in student activities. This means that for each aspect a description should be generated of the related behavioural pattern. Such a description can then be used in educational settings to identify the research disposition, for example, of students undergoing research activities in their curriculum. Further studies are needed to identify which observable behavioural patterns are related to each of the six aspects of scientific research dispositions.

Secondly, science students learn about research practice both implicitly and explicitly. Academics giving an explicit account of their research practice experiences as part of their university teaching can be of great value to student learning in research-intensive environments (Seymour et al., 2004). A unique feature of research practice is that there are different approaches to research and that all scientists will choose their approach based on their dispositions. Although, dispositions towards scientific research are acquired by students during their university study, there are relatively few moments during university courses when students explicitly reflect on the nature of knowledge development. As with their learning about the nature of science (Abd-El-Khalick et al., 1998), students do not learn about scientific research dispositions implicitly by doing science. Students could use the framework of six aspects of a research disposition presented here to understand implicit aspects of research practices more deeply. Furthermore, science students should be acquainted with the diversity of processes of inquiry to develop a realistic picture of research practice. A possible approach to accomplishing this is to arrange multiple ways to come into contact with different research groups within the science curriculum.

Thirdly, an understanding of scientific research disposition can be helpful for the professional development of university science teachers. Encouraging teachers to reflect on implicit aspects of their own and their peers' research practice, such as scientific research dispositions, is likely to help them become more receptive to student conceptions and misconceptions about research practice. Although these student conceptions about research could be informative when designing and teaching university science courses, especially at research-intensive universities, academics rarely explicitly use knowledge about students' conceptions. Aspects of scientific research dispositions, such as those defined in this study, could help university science teachers to understand students' conceptions and misconceptions about scientific practice, for example by identifying missing aspects of scientific research disposition within students' conceptions about research.

Although knowledge about scientific research dispositions can support both university science teaching and student learning, academics rarely reflect explicitly on preferred aspects of scientific research dispositions in their discipline (cf. Neumann, 1992). Results from this study provide us with new perspectives on academics' practice. The framework of six aspects of scientific research dispositions presented in this study could be helpful in university science teaching, learning, and professional development of academics.