Relationships between students' interest in science, views of science and science teaching in upper primary and lower secondary education

Relationships between students' interest in science, views of science and science teaching in upper primary and lower secondary education

Ralf van Griethuijsen

The studies in this dissertation were funded by the seventh framework program of the European Union. The research was carried out at the Eindhoven School of Education in the context of the Dutch Interuniversity Center for Educational Research (ICO).

A catalogue record is available from the Eindhoven University of Technology Library

ISBN: 978-90-386-3799-0

NUR: 841

Printed by: Dereumaux

Cover: Paul Verspaget Grafische Vormgeving-Communicatie

Relationships between students' interest in science, views of science and science teaching in upper primary and lower secondary education

PROEFSCHRIFT

ter verkrijging van de graad van doctor aan de Technische Universiteit Eindhoven, op gezag van de rector magnificus prof.dr.ir. C.J. van Duijn, voor een commissie aangewezen door het College voor Promoties, in het openbaar te verdedigen op woensdag 11 maart 2015 om 16:00 uur

door

Ralf Ard Lars Friso van Griethuijsen

geboren te Leende

Dit proefschrift is goedgekeurd door de promotoren en de samenstelling van de promotiecommissie is als volgt:

voorzitter:	prof.dr. D. Beijaard
1e promotor:	prof.dr. P.J. den Brok
copromotor:	dr. M.W. van Eijck †
leden:	prof.dr. J.H. van Driel (Universiteit Leiden)
	prof.dr. M.J. Goedhart (Rijksuniversiteit Groningen)
	prof.dr. A.M.C. Lemmens
	prof.dr. K.A.H. van Leeuwen
	prof.dr. J. Walma van der Molen (Universiteit Twente)

Contents

CHAPTER 1

General Introduction

1.1 | Introduction

The research in this dissertation focusses on interest in science among students, how interest in science correlates with having particular views of science and the role teachers have in shaping such interest and views. In this dissertation, four studies are presented which were all part of a large international research project named *Science Education for Diversity (SED)*. The SED project was set up to investigate whether and why students held a particular interest in science and how they thought of science, how teachers in different countries taught their classes and how they presented science to their students. One of the ideas behind the SED project was that in the near future European countries will face a shortage of STEM (science, technology, engineering and mathematics) graduates and that new graduates in STEM could be attracted from those groups of students that are currently underrepresented in science studies: girls and students from ethnic minorities (Gago et al., 2004). The four studies together aim to answer the question how, internationally and in the Netherlands, students' interest in science is related to their views of science and what role teachers play in shaping interest in science and views of science among their students. This introductory chapter gives an overview of the research that has been done on student interest in science during the last years. It further looks into how interest in science differs between genders and nationalities and the rationale behind the studies in the following chapters. Also, more information on the SED project itself and its setup will be provided.

1.2 | Interest in science among students

Interest is considered to be a specific and distinguished relationship between a person and an object, which can either be a concrete thing, a topic or a subject matter, that lasts for a shorter or longer period of time (Krapp & Prenzel, 2011). Much has been written about interest in science of young people in the last 40 years, a period in which low interest in science among young people was first seen as problematic (Ramsden, 1998). In most studies and reports published in this period, it was concluded that too few students were interested in science and that as a whole, the student population was less interested in science than it was a few years earlier (Krapp & Prenzel, 2011; Osborne, Simon & Collins, 2003).

Studies on the interest in science have employed different ways of measuring interest in science. The number or percentage of students choosing to take a particular science course or enter a science education is often regarded as a popular approximation of interest in science. The Netherlands keeps track of precisely how many secondary school students take science courses and how many students have entered science studies in tertiary education (Ministry of Education and sciences, 2014). These data show that there is a large gender gap in uptake in science although this gap seems to be diminishing in the last couple of years. The Dutch national data are very complete as they include all students in the country. However, by taking the uptake of science courses as an approximation of interest in science, these studies may not include some students who hold an interest in science but do not choose to take up science courses for some reason (for instance because they dislike how science is being taught in school). Furthermore, these statistics show the choices made by students at certain pivotal moments in their school careers but tell us little or nothing about the development of interest in the periods before and between these moments.

Questionnaire studies and interview studies with small groups of students have revealed the existence of a crucial period in the development of interest in science right before the moment when students have to make a decision whether they take up science or not. The period between the ages 10 and 14 has been identified as the period in which children either develop an interest in science that will stay with them for the rest of their lives or lose interest in science (Krapp & Prenzel, 2011). Before this age, all students seem to display a great interest in science, but it appears that this interest starts to deteriorate during the final years of primary education and the first few years of secondary education (Andre, Whigham, Hendricksen & Chambers, 1999; Murphy & Beggs, 2003). One could argue that it is natural for students to lose their interest in school subject upon entering puberty but it has been shown that students lose interest in science to a greater extent than their interest in other courses (Osborne et al., 2003).

Interest in science should not be looked at as a single construct. There is a difference between on the one hand science as it is given in school courses (school science) and science as it is experienced outside school. There is also a difference between *enjoying* science courses in school and actually *wanting to have a job* related to science. Finally, being interested in one field of science does not necessarily mean that one is interested in other scientific disciplines as well. Jenkins and Nelson (2005) found in their study that there was little interest in school science among secondary school students in the United Kingdom, and even less interest in having a science job in the future, despite the widespread acknowledgement of the importance of science in society. The decrease in interest of students seems to occur primarily in the hard sciences such as physics and chemistry, and much less in biology (Osborne et al., 2003). Other studies have made it clear that there is a difference between being interested in science as it is taught in class and as it is experienced outside school and that participation in extracurricular science activities can increase interest in school science (Jayaratne, Thomas, Trautmann, 2003; Markowitz, 2004). The present study will add to this line of research by focusing on both interest in school science as well as science outside school and it will focus particularly on the period between 10 and 14 years of age.

1.3 | Explanations for interest in science

The decrease in interest of students in science over the last few decades has been well documented. Recently the decreasing interest in science in the Netherlands and other Western European countries seems to have plateaued and there are sign that interest in science is slowly increasing (more about this in one of the following paragraphs). Nonetheless, most academic research so far has focused on the reasons why with each passing generation, students tended to be less interested in science. A myriad of explanations have been given for this decrease. These explanations include, among others, outdated curricula, a lack of role models in science, stereotypical ideas about science and scientists and the perception that science is difficult and demanding (Krapp & Prenzel, 2011; Osborne et al., 2003; Sjøberg, 2003).

Science curricula often discuss developments in science that have occurred over a century ago. This is especially true for science books in chemistry and physics and to a lesser extent biology. This means that many science courses do not discuss the more recent scientific findings in which students tend to be more interested (Sjøberg, 2003), such as global warming, but that do discuss the atomic model and Newtonian physics. Discussing more recent scientific findings in the classroom does have its challenges as more recent developments in science often require 'older' more basic scientific knowledge to understand. Science curricula have also been criticized by students for repetitiveness (Osborne & Collins, 2001).

Several studies have found that students hold stereotypical views of scientists. A well-known experiment is the 'draw a scientist' exercise in which students are asked to draw a picture of a scientist. The exercise has been done over 50 years and it has consistently been found that students draw a picture of a middle aged white man in a white lab coat with disheveled hair working with test tubes (Finson, 2002). Scientists are often portrayed very stereotypically in cartoons and popular films, often as the crazy scientist (Sjøberg, 2003).

Other reasons why students become disinterested in science are related to the way in which science is taught as a school subject. Barmby, Kind and Jones (2008) found that students aged 11 to 14 did not perceive their science lessons as practical or relevant and they said that their science teachers did not explain the content of their science lessons well. Furthermore, science is often considered by students to be a very difficult and demanding subject (Lyons, 2006; Osborne et al., 2003). This appears to be especially true for courses in chemistry and physics and many students question whether they are intellectually able to continue with these courses in upcoming years (Aschbacher, Li & Roth, 2010; Lyons, 2006). Osborne and Collins (2001) also found that students considered the science they currently had difficult but were especially afraid of an increase in difficulty that would occur in their later school careers. These explanations were used as input for the design of several studies in this dissertation, especially in the interviews with students.

1.4 | Interest in science and diversity

Interest in science differs greatly between the genders and between students of different nationalities. Below, the literature on how gender and nationality play a role in interest in science is briefly discussed.

1.4.1 Interest in science and gender

Differences in interest in science between boys and girls have been extensively studied in many countries. Research into interest in science and gender started in the 1970s when low participation of girls in science courses was first seen as a problem. There does not appear to be one single answer to the question why girls become disinterested in science or why girls do not choose to take up science courses, rather a combination of interrelated factors appear to play a role (Blickenstaff, 2005; Eccles, 1994). A multitude of explanations have been given for why fewer girls than boys display an interest in science (Jones, Howe & Rua, 2000; Murphy & Whitelegg, 2006). These explanations partly overlap with the explanations given on why students in general would turn away from science. There are a lack of female science role models in the media and in science textbooks and science textbooks tend to use more examples that appeal to boys (engines, cars, explosions) rather than to girls (Brotman & Moore, 2008). There are persistent gender stereotypes about women being less competent in science than men (Nosek et al., 2009). Girls tend to have less confidence in their own abilities in science even if these are comparable to those of boys (Debacker & Nelson, 2000). Teachers often pay more attention to boys than girls in their science classes, something which many teachers are unaware of themselves but which is nonetheless noticed by the girls in their classes (Guzzetti, 1996).

It seems unlikely that a gender gap in math ability is the cause for the difference in attendance of science courses. In many countries such a gap is actually non-existent or very small (Marks, 2008) and cannot account for the more dramatic gender gap in the take up of science courses.

The gender gap is largest in the physical and mathematical sciences, such as physics, technology, computer science, chemistry, and mathematics. There appears to be no gender gap for biology (Miller, Slawinksi Blessing & Schwartz, 2006). Several studies have found that, in general, even at a young age, girls have a preference for biological topics and boys for technological topics (Jones et al., 2000). Sadler, Sonnert, Hazari and Tai (2012) found that in secondary school around 40% of the boys were interested in a career in STEM as compared to 15% of the girls and while this percentage kept up for the boys it dropped by 3% for the girls during their school career.

The Netherlands, like many other Western European countries has a gender gap in many areas of science and technology. This is reflected among others, in the percentage of boys and girls attending the different educational tracks in the final years of the HAVO (higher general secondary education) and VWO level (pre-university education). In the final years of secondary education, all students have to choose for one of four tracks: science and technology (natuur en techniek), science and health (natuur en gezondheid), economics and society (economie en maatschappij) and culture and society (cultuur en maatschappij). According to the statistics of the Dutch ministry of education, culture and science, about 10% percent of all girls as compared to over 30% of all boys are in the science and technology track at the VWO level (Ministry of education and sciences, 2014). The gender gap is even more dramatic at the HAVO level, where less than 5% of the girls are in the technology track as compared to almost 20% of the boys. The opposite is true for the science and health track, in which girls outnumber boys both at the VWO level (34% versus 22%) and the HAVO level (21% versus 18%). The percentage of students and the percentage of girls taking up one of the two science tracks has gone up in the last few years, at least since 2006 (Ministry of education and sciences, 2009; Ministry of education and sciences, 2014). This is in contrast with the period immediately after the introduction of the four different tracks in 1998 in which the percentage of HAVO and VWO girls taking physics, mathematics and chemistry decreased (van Langen, Rekers-Mombarg & Dekkers, 2008). At the VMBO level (prevocational secondary education), which has the most secondary school students in the Netherlands, female students are underrepresented as compared to boys in the technology and agriculture tracks (Ministry of education and sciences, 2006).

Not only do Dutch students seem to be less interested in science and technology than their counterparts in other countries in the world (OECD, 2012), the gender gap in the Netherlands seems to be even larger than in many other countries in Europe (Bosch, 2002; van Langen & Dekkers, 2005). The same reasons for low take up of science courses that apply in other countries, play their role in the Dutch situation. Several reasons have been postulated on why the gender gap is even greater in the Netherlands than in other countries. The Dutch education system forces students to make a choice at a young age whether they want to be in a science stream or not and once the choice has been made not to continue with science it is difficult to re-enter science education (van Langen & Dekkers, 2005). There may also be cultural reasons why few women participate in science such as a Protestant focus on motherhood and restrictive hiring practices of universities and other institutions (Bosch, 2002). The present study will try to provide more insight into the described situation in the Netherlands and will check if the trend still holds up, by comparing interest in science and views on science between several countries, both within and outside Europe.

1.4.2 Interest in science and nationality

Interest in science of students in primary and secondary education differs strongly per country. Several large scale international studies have compared student interest in science in different countries in the world. The Programme for International Student Assessment (PISA) included an attitude questionnaire in the 2006 version of their test (Organisation for Economic Co-operation and Development [OECD], 2007). Around the same time, the Relevance of Science Education (ROSE) study investigated interest in science education (Sjøberg & Schreiner, 2005a). Both studies found that students in Western Europe and the United States were among the least interested in science. Students in South America, Asia and Africa scored far higher in terms of interest in science. Even within Western Europe, there appeared to be differences between countries. The PISA study found that students from countries in southern Europe displayed a greater interest in science than those in Northern Europe and that the Netherlands was among the countries where interest in science was lowest (OECD, 2007). The findings of the ROSE study revealed a similar pattern, although the Netherlands was not included in this study (Sjøberg & Schreiner, 2005a).

It is unclear why in certain parts of the world students tend to be more interested in science. The ROSE study linked interest in science to the state of development of a country as measured by the human development index of the United Nations with higher levels of development correlating with lower interest (Sjøberg & Schreiner, 2005b). On the basis of the results of the 2006 PISA test, Bybee and McCrae (2011) argue that there is, on an international level, an inverse relationship between the results of the PISA interest in science scores of a country and the national results of the test for knowledge of science. In other words, in the countries where science education performs worst, the students tend to be the most interested in science. The relationship does not hold up within a country where the best performing students tend to be the most interested.

This dissertation includes research conducted in several different countries, both inside and outside Europe and will give a more in-depth look into these international differences in interest in science and the possible reasons behind them.

1.5 | Increase in interest in science and technology among students

In the last 10 years, there are hopeful signs in the Netherlands that interest in science and technology education is increasing, signaling a possible trend break. The percentage of students choosing science tracks in on the upswing and several universities, such as Eindhoven University of Technology, have seen record numbers of new science and technology students. It is not yet clear why science and technology has increased in popularity. The increasing number of students taking science classes and courses is relatively recent and there has no scientific literature has yet been published on the reasons why more students have taken an interest in science.

One of the possible explanations is that education has changed and now better suits the interests of the students. Studies on why students lose their interest in science have been carried out since the 1970s and many of the recommendations on how to increase interest in science have found their way into policy. In 2006, technology became an obligatory subject in Dutch primary education. This increased the time spent on science and technology education for young students which had been criticized for being very limited. Secondary education in the Netherlands has seen several curricular changes. Chemistry, physics and biology are now taught according to the principles of concept-context education in which concepts are discussed in their real world context. This approach has been adapted in order to make it clearer for the student what the applications of these scientific disciplines are. The last 10 years also saw the proliferation of the technasium which offered the course 'design and research' (ontwerpen en onderzoeken), a project-based course in which students work on assignments provided by companies and other agencies. Another interdisciplinary science course called Nature, Life and Technology (Natuur, Leven en Techniek) has also been introduced in secondary education. The curricula of many university studies have been changed to appeal more to students. As an example, Eindhoven University of Technology gives more design based courses. There has been a proliferation of new scientific domains, many of which combine different scientific disciplines, thereby creating more studies that appeal to a larger crowd of possible students. For instance, biomedical engineering combines the disciplines of engineering and biomedical sciences and, 'technology and psychology' combines the disciplines of technology and psychology. Several agencies, such as techniekpromotie[1], have been promoting science and technology in the last ten years and their success may have influenced students to take up science studies. Companies, universities and other educational institutes have also increased their outreach efforts to popularize science.

There may be some more mundane reasons why the number of science and technology students has increased. A few years after the introduction of the four tracks in secondary education in the Netherlands, secondary education got revised again and many of the courses that were split into two were merged again. The science and technology (natuur en techniek) track that was previously considered to be a very difficult and demanding track saw an increase in students. The economic crisis that broke out in 2008 may also have had an impact on the academic choices that students make. Since 2008, there have been many reports in the media about the difficulties graduates encounter in finding employment and that the large demand for science and technology graduates. Science and technology studies may be seen as offering greater employment opportunities than studies in the social sciences or arts. It may be necessary to wait a few years

[1] www.techniekpromotie.nl

after the end of the current financial crisis before it can be ascertained whether there really is a permanent increase in interest in science among Dutch students. In this dissertation, students were interviewed about their opinions on science and the interviews included questions on their science classes and how they perceived a science-related job.

1.6 | Views on science and teaching practice

The studies discussed in this dissertation link interest in science of primary and secondary students with views these students have of science and scientist, and with views their teachers have and with how these teachers represent science in their classes.

An important term that appears in in studies investigating views of science is Nature of Science (NOS). This term refers to knowledge about what science is and how it functions within society (McComas, Clough, Almazroa, 2002). Nature of Science can be seen as the most important aspects of the history and philosophy of science for an audience of primary and secondary school students. Researchers on NOS have made lists of tenets that every student should know, such as the tentative and durable nature of scientific theories, the way science depends on empirical evidence and the existence of social, cultural and historical influences on the practice and direction of science (McComas, 2008). Research has found that many students, and even many grown-ups including teachers, have a very limited understanding of the nature of science (Lederman, 1992). A large proportion of students do not understand well what a scientific theory is. Many students see scientific explanations as fixed and certain rather than changing over time. The work of a scientist is seen as solitary rather than collaborative and creative (Lederman, 1992).

Most studies on the Nature of Science are concerned with the above mentioned misunderstandings and what teachers can do in order to get their students to a better understanding. The studies in this dissertation take a different approach, by using views on science as an *explanatory* factor to explain *why* some student are interested in science and others are not. To investigate how or whether students got their ideas about science from their *teachers* or not, it was also investigated what teachers views on science were and how they presented science to their students in their classes. Not only questions about the inclusion of NOS goals were included in the research but also about teaching the history of science, ethics related to science, environmental topics and teaching style.

1.7 | The SED project

The Science Education for Diversity (SED) project was set up to investigate science teaching in six different countries around the world: the United Kingdom, the Netherlands, Turkey, Lebanon, India and Malaysia. The SED project was funded through the seventh framework programme of the European Union. The project was initiated out of a concern for the low engagement with science by primary and secondary school students in European countries, that has been found in several large scale studies. This is a concern not only because general knowledge of science and scientific ways of thinking are essential for democratic decision-making when scientific issues are at stake, but also because science and technology play a very important role in the European economy and because the European Union needs a large workforce of graduates with degrees in science and technology. The idea behind the SED project was that countries in which students displayed little interest in science and technology would learn from countries in which many students are interested in science. Considering the large differences between girls and boys and between students of different ethnicities in countries such as the Netherlands and the United Kingdom, it was also thought that these countries could learn from the practices of countries where gender and ethnicity were not such important factors in the take up of science courses among students.

It is rather unique that the European Union funded a research project in which many countries not being members of the European Union participated. The reason behind the inclusion of these countries was that the project was set up to investigate science education in countries both within Western Europe and in other parts of the world. The six countries differ greatly in the degree in which their students are interested in science and all have a diverse population of students. This would enable the researchers to find out what was happening in those countries and what European countries could learn from them to improve their science education in order to appeal to more students. The selection of countries participating in the project included two countries from North Western Europe (the United Kingdom and the Netherlands), one country that is part of both Europe and Asia (Turkey), one country in the Middle East (Lebanon) and two countries in Asia (India and Malaysia). Furthermore, since the research was concerned with diversity, the inclusion of Turkey and India in the project enabled comparisons between Turkish immigrants in the Netherlands and Turks in Turkey and between Indian immigrants in the United Kingdom and Indians in India. The countries which participated also differed greatly from each other in terms of economic development and the religions adhered by its populations.

The SED project is thus unique in its scope and the number of countries involved in the project. There have been several large scale international surveys which have investigated interest in science such as PISA, TIMMS and ROSE. All three of these studies included dozens of countries and tens of thousands of students. The scope of the SED project is slightly smaller including six countries and over 9,000 surveyed students. What sets the SED project apart from other studies is that it has the ability to research interest in science in greater depth than other surveys which were limited in the number of attitudinal questions. The SED project included not only a questionnaire for students but also one for teachers as well as in-depth interviews with both students and teachers within each country, focus group interviews with students and classroom observations.

The SED project was split up into 6 different work packages and each of the six partner countries took the lead in one of those work packages. The

Netherlands took the lead in the third work package which consisted of the large-scale questionnaire, and small-scale interview and observation studies.[2] This dissertation is limited to this work package of the project. In this work package, questionnaires and interview as well as observation protocols were developed. Researchers in each country contacted schools for participation in the research project and all students in the appropriate classes and their teachers who gave science classes completed the questionnaires. Each country collected over 1000 student questionnaires and a large number of teacher questionnaires. A subset of the schools that were included in the questionnaire studies also participated in the interview studies and the observation studies.

Working within an international research project had several consequences for the research reported in this dissertation. Whereas the Netherlands had the lead in the work package in which the students and teachers were researched with questionnaires and interviews, all countries were involved in the creation of the research instruments. The questionnaire and interview protocols thus included several questions which were more relevant in other countries than the Netherlands. In order to not create research instruments that were too elaborate to employ in research in schools were time is often limited, not every possible question which could have yielded interesting results was included. In the analysis of research in which data of multiple countries was included, researchers from those countries were consulted in the analysis and were given the opportunity to contribute to the research paper that was being written. Given translation and cultural

[2] The first work package was concerned with the overall management of the project. The second work package consisted of an analysis of all national educational documents concerning diversity and science education and an analysis of science curricula and state-of-the-art studies concerning science education and diversity. In the fourth work package, the information gathered in the second and third work packages were used to create a theoretical framework that can be used to design education programs that are more responsive to the interests and needs of a diverse group of students. Such education is made and tested in a school setting in the fifth work package. The sixth and last work package consists of the dissemination and valorisation of the research project.

interpretation issues, this dissertation will only concentrate on the Dutch data when dealing with interview data.

1.8 | Outline of the dissertation

This dissertation contains four empirical studies that all derived their data from the SED project. The studies presented in this dissertation are concerned with the central research question: *what is the relationship between students' views of science and their interest in science, both in the Netherlands as well as internationally, and which role do teachers play in shaping interest in science as well as views of science?* Answering this question will contribute to the literature on interest in science in several important ways. First of all, so far no cross-national studies have been conducted which have linked interest in science of students to the views students have of science. Furthermore, in most international studies, interest in science is treated as a single construct and therefore little is known about international differences in interest in science when it comes to, for instance, extracurricular activities. There is neither much knowledge on an international scale about how the views of science a teacher holds are reflected in classroom practice. Even in studies that have investigated the relationship between views on NOS and teaching practice in a single country, the results are contradictory (LaPlante, 1997; Mellado, 1998; Tsai, 2002; Water-Adams, 2006). That is, some studies have found a straightforward relationshop between these elements, whereas others have not. Finally, there is a need to zoom in on the Dutch situation because many cross-national surveys have found that there is very little interest in science among Dutch students. However, none of these surveys have looked in more detail at the Dutch situation in terms of what exactly Dutch students think of science. There is neither much evidence on whether it is possible to divide the Dutch student population into different groups of students with different interests in science as is done in, for instance, in the popular BètaMentality model (Platform Bèta Techniek, 2010) and on whether Dutch teachers take such different groups with different interests into account when teaching. The central research question is first answered within the international context of the SED project in chapters two and three and subsequently for the Dutch context in chapters four and five. Chapter two looks into the *student* part of the main research question, how the students of different countries view science and whether they hold an interest in science. Chapter three looks into which views *teachers* have of science and how they teach science in their classes. Chapter four focusses on what *Dutch students* think of science and how they appreciate science. The fifth chapter focusses on how *Dutch teachers* present science in their classrooms and how they take groups of students with different interests in science into account.

The study in chapter two was set up to find out whether there are international differences in interest in science among 10 to 14 year old students and whether these differences correlated with the views student have of science. In this study, the student questionnaire interview data of all six participating countries was used. Several different constructs relating to interest in science and technology, such as interest in school science and interest in science as an extracurricular activity, were constructed on the basis of the answers given in the questionnaire. The six participating countries were compared with each other on these constructs as well as on the answers given to questions about views on science. With multilevel analysis, the correlation between views on science and interest in science was investigated.

The study in chapter three aimed to find out what kind of views the teachers that taught the students of the previous study had about science and how they presented science to the students in their classes. The teacher questionnaire data of all six participating countries was used in this study. The answers to several items were used to create higher order constructs on views of science and teaching of science. Subsequently the teachers of the six countries that participated in the study were compared with each other on these constructs. In a multilevel analysis, the correlation between views of science and the practice of science teaching was investigated in greater detail.

In chapter four, the Dutch students were investigated into greater detail with an analysis of the Dutch student interview data. This study was set up to investigate whether there really is as little interest among Dutch student as has been found in other studies and to find out whether it is possible to identify different groups of students with different interests in science and different views about science. The answers to various questions about whether students were interested in science and how they viewed science were coded and entered into a matrix in order to identify groups of students.

The fourth study, presented in chapter five, makes use of the Dutch teacher interview data. The aim of this study was to find out how teachers in the Netherlands think of diversity, either along lines of gender and ethnicity or groups of students with specific interests, and how they represent science in their classes and what strategies they employ to make their science classes attractive for a diverse group of students. The answers that were given in the interviews were coded in order to find out what teachers believed were best ways of teaching science in their classes.

Chapter six consists of the general conclusions and discussion for all of the preceding chapters. In this chapter, the implications of the study will be discussed as well as the limitations of the study and suggestions for further research.

The chapters of this dissertation were originally written as research papers and have been submitted to several academic journals. As a consequence, there is some overlap between the chapters in the background sections and the description of the research methodology.

CHAPTER 2

Global patterns in students' views of science and interest in science[1]

ABSTRACT

International studies have shown that interest in science and technology among primary and secondary school students in Western European countries is low and seems to be decreasing. In many countries outside Europe, and especially in developing countries, interest in science and technology remains strong. As part of the large scale European Union funded 'Science Education for Diversity' project a questionnaire probing potential reasons for this difference was completed by students in the United Kingdom, the Netherlands, Turkey, Lebanon, India and Malaysia. This questionnaire sought information about favorite courses, extracurricular activities and views on the nature of science. Over 9,000 students aged mainly between 10 and 14 completed the questionnaire. Results revealed that students in countries outside Western Europe showed a greater interest in school science, careers related to science and in extracurricular activities related to science than Western European students. Non-European students were also more likely to hold an empiricist view of the nature of science and to believe that science can solve many problems faced by the world. Multilevel analysis revealed a strong correlation between interest in science and having such a view of the Nature of Science.

---

[1] This chapter has been accepted for publication as:
van Griethuijsen, R. A. L. F., van Eijck, M. W., Haste, H., den Brok, P. J., Skinner, N.C., Mansour, N., Gencer, A.S. & BouJaoude S. (in press) Global Patterns in Students' Views of Science and Interest in Science. To appear in *Research in Science Education*.

2.1 | Introduction

Recent international studies have shown low interest in science and technology among secondary school students in many Western European countries (Organisation for Economic Co-operation and Development [OECD], 2007; Sjøberg & Schreiner, 2005a). This has led to concern among policy makers about their nation's economy, in which science and technology play an important role, as well as the scientific literacy of their populations (Gago et al., 2004). To make matters worse, student interest in science has gradually eroded over the last twenty to thirty years (Osborne et al., 2003). In contrast, in countries outside Western Europe, such as India, students are generally much more interested in science. In 2006, the Programme for International Student Assessment (PISA) effectiveness study measured both science knowledge and interest in science and included OECD countries (European countries, the United States, Canada, Australia, Japan and South Korea) along with countries outside the OECD. Non-OECD countries scored higher than OECD countries on, among other things, general interest in science topics, enjoyment of science learning and motivation to continue studying science (OECD, 2007). In an analysis of the 2006 PISA data, Bybee and McCrae (2011) found that low national average scores on scientific knowledge corresponded with high national average scores for interest in science and vice versa. In other words, in the non-OECD countries, where science education performs the worst, interest in science is the greatest. However, within countries, the better performing students were most interested in science.

Another large international study, the Relevance of Science Education (ROSE) survey, found a similar pattern, with students from industrialized countries, such as Denmark and Norway, scoring lower on interest in science education than students from non-industrialized countries, such as Ghana and Uganda (Sjøberg & Schreiner, 2005b). In an analysis of the ROSE data, Sjøberg and Schreiner (2005b) found a strong correlation (-.85) between an aggregate score for interest in science and the state of development of the country as measured by the United Nations Development Index.

Whereas level of development and average scores on the PISA test are both strongly correlated with disinterest in science among young students, they do not explain the mechanisms that drive students away from science. Researchers have posed various potential reasons for this apparent lack of interest in science in Western European countries. Schreiner and Sjøberg (2010) argue that outdated curricula, a shortage of qualified teachers, stereotypically negative images of scientists, lack of role models in science, alternative religious explanations for scientific phenomena, postmodern attacks on science, and a distrust of modern, ambitious, large-scale scientific research are responsible. However, these suggestions do not explain the difference in levels of science interest in developed countries as compared with less developed countries. Curricula in Asia and Africa are often comparable to those in Western Europe, as they are guided and influenced by initiatives and movements in science education that originated in Western Europe and North America. These curricula are likely to be as outdated, as their counterparts in Western Europe, although they may not be perceived that way by students. In a similar vein, alternative religious explanations for scientific phenomena are likely to be more prominent in religious societies in Asia and Africa than in secularized Western Europe.

Research has found that the most crucial period in which children make up their opinions about science occurs between the ages of 10 and 14 (Bennett & Hogarth, 2009; Osborne et al., 2003; Speering & Rennie, 1996). Students under the age of 10 are generally interested in science, but their interest either remains high or declines as they age. By the age of 14, students have mostly made up their minds about science, and their opinions remain relatively stable for the rest of their lives. Many of the explanations proposed by Schreiner and Sjøberg (2010) for a lack of interest in science are actually reasons why societies in general turn away from science or why older students may choose not to continue their education in science and not why young students become disinterested in science. We believe these suggestions are unlikely to explain why 14-year-old students have lost interest in science. Students of this age are unlikely to be aware of postmodernist attacks on science or to have developed sophisticated views on how science works or how modern science differs from the science they study at school.

The findings reported in this paper come from a questionnaire study that was part of a large research project named 'Science Education for Diversity' (Science Education for Diversity, 2013), which was funded by the seventh framework programme of the European Union and involved research in the United Kingdom, the Netherlands, Turkey, Lebanon, India and Malaysia. We chose this diverse selection of countries because relatively few studies outside North America, Australasia and Europe have investigated the way in which students conceptualize the nature of science and whether this is linked to their interest in science. The studies that do exist have been carried out in countries with relatively high levels of economic development, e.g., Japan (Kawasaki, 1996), South Korea (Kang, Scharmann, & Noh, 2005) and Taiwan (Liu & Lederman, 2002), and did not include less developed countries for which the PISA and ROSE studies revealed high levels of interest in science.

The aim of our research is to find out the effects that particular views of science, gender and age have on different forms of student interest in science. Many studies investigating interest in science have focused solely on science as it is taught in school and often used a single indicator for interest in science. We believe the use of multiple indicators is more appropriate (Kind, Jones, & Barmby, 2007). Students have very different experiences outside school as compared to inside the classroom (Akkerman & van Eijck, 2013). Some students may have positive science experiences outside school (e.g., in science museums), even while indicating disinterest in their school science classes or vice versa. We therefore decided not only to measure interest in science as presented in a school environment, but also to measure science as an extracurricular activity and as a future field of employment in order to broaden the analysis. As shown by Hagay et al. (2013), country of

residence, age and gender also shape student interest in science, and therefore, these two factors are taken into account in our study.
We begin with a brief review of the literature concerning students' views about the nature of science and the approaches researchers have used to reveal these views. These approaches informed the way in which we carried out our study. In this study, we are mostly interested in how students view science as opposed to whether these views are in line with a contemporary understanding of NOS. International differences in interest in science and cross-country comparisons are difficult to investigate and open to many interpretations. Nevertheless, we believe that such research is still valuable in interpreting international differences in science education.

In the background section, we present an overview nature of science (NOS) in the literature on science education and how views on the NOS have been measured in prior research. We discuss studies that have found differences in views on NOS among people of different nationalities, ages and levels of interest in science. These studies provided examples to guide the way our study was carried out, as discussed in the method section. The results section presents findings concerning interest in science and views about science and then presents the connection between the two. This paper ends with a discussion of the findings and their possible implications for science education.

2.2 | Background

2.2.1 Nature of science

Nature of Science (NOS) refers to how science works, its relationship with society and how scientists collect, interpret and use data in scientific research. The meaning of the term NOS has changed considerably over time and has been interpreted differently by different researchers (Abd-El-Khalick & Lederman, 2000). There is, however, a consensus among science education researchers regarding its most important tenets. McComas, Clough and Almazroa (2002) made a list of 14 tenets they argued should be part of science education in primary and secondary education. These include, among others, the tentative nature of scientific theories, the way science uses empirical evidence and logic, the absence of a single scientific method by which all scientific research is done, the relationship between laws and theories, the relationship science has with society and the use of creativity and collaboration in science.

Research into NOS started in the 1970s and 1980s, and studies from that era, as well as more recent studies, have repeatedly found that many students hold ideas about science that are incompatible with contemporary ideas about NOS (Abd-El-Khalick & Lederman, 2000; Deng, Chen, Tsai, & Chai, 2011). These ideas include, among others, misunderstanding the relationship between scientific laws and theories, thinking of scientific theories as unchangeable and 'true' and not realizing that culture and politics can influence science and the direction of scientific research. Prior studies have found that students do not come to a contemporary understanding of how science works on their own and that NOS needs to be explicitly treated in class for students to do so. To address these shortcomings, teaching a modern interpretation of 'how science works' has become part of science curricula in many countries (McComas & Olson, 2002). In contrast, the National Research Council in the United States recently decided to *not* include an explicit teaching of NOS in their framework for K-12 science education (National Research Council [NRC], 2012), and this may eventually impact science education in different countries around the world.

2.2.2 Measurement of NOS viewpoints

Several instruments have been developed to investigate students' views about NOS. NOS research has not only been used to find out whether students have a contemporary view of NOS, it has also investigated how students deal with scientific arguments and has been used to place students on a continuum between constructivist and empiricist[2] views of science (Deng et al., 2011). In broad terms, according to a *constructivist* perspective on the nature of science, scientific knowledge is constructed by humans and tentative. Consequently, expectations, current beliefs and theories shape the way scientists think of science and how they explain their results. According to an *empiricist* or *positivist* perspective, scientific knowledge is taken as solely the result of observation, experimentation or application of a universal scientific method. Hence, from an empiricist perspective, scientific knowledge is usually taken as an unchangeable, absolute truth that results from more or less "neutral" discoveries. In discussing NOS, most researchers view constructivism as a more contemporary approach.

Deng et al. (2011) identified unidimensional and multidimensional frameworks used by researchers to categorize students' views of NOS. Both frameworks measure students' standpoints on a continuum ranging from empiricist to constructivist perspectives. In the multidimensional framework, students can be categorized as both empiricist and constructivist at the same time. For example, a constructivist viewpoint can be seen, for instance when the student agrees with the tentative nature of scientific explanations, yet he or she can be categorized as empiricist for a different tenet, such as the collaborative nature of scientific research (Liu & Tsai, 2008). Students also can have different NOS views regarding different domains of science (Schommer-Aikins, Duell, & Barker, 2003).

2.2.3 NOS, Interest in school science and nationality

There are indications in the literature that support the hypothesis that interest in science is related to having a particular view on the NOS and to

---

[2] The term *empiricist* used here is almost interchangeable with the terms *positivist* and *logicopositivist*. Positivism and logicopositivism denote a more extreme position on the continuum and therefore have a negative connotation. Therefore, the more neutral term *empiricist* is used here. Empiricism does not only refer to the use of empiric evidence in science. In a similar way, the term *relativism* can be considered as a more extreme version of constructivism, which therefore also has a more negative connotation.

nationality (Jehng, Johnson, & Anderson, 1993; Liu & Tsai, 2008). However, the picture emerging is far from clear. The majority of research on NOS has focused on mistakes students make in their interpretation of science and how science education should correct these views (Lederman, 1992). More recently, research has investigated ways in which NOS views vary among different groups of students and professionals and the way in which these views shape their interest in science. This research so far has been limited to college students and other adults and has not investigated students in primary and secondary education.

Several studies have compared the views of students who hold an interest in science and those who do not. In these studies, taking science courses was viewed as a proxy for being interested in science. Liu and Tsai (2008) conducted research with 220 college students, half of them science majors and the other half not, and found that science majors did not have more sophisticated views about science than non-science majors. In fact, science majors had more naive views on the theory-laden and cultural aspects of science than their peers. The authors postulated that science students could have adopted their empiricist views of science in class, as secondary science courses generally present science as objective and universal. Another possibility is that students with strong personal epistemological opinions about certainty and objectivity are more likely to choose science as their field of study. A similar study done by Jehng, Johnson and Anderson (1993) found that students who major in social sciences, arts and humanities are more likely to believe that knowledge is uncertain than, for example, students in the natural sciences, engineering and business.

Similar patterns have been found for professionals who work in the science domains, such as science teachers. Initially, as reviewed by Abd-El-Khalick and Lederman (2000), teachers' conceptions of NOS were thought to be independent of their educational background in the sciences. Dogan and Abd-El-Khalick (2008), however, found that teachers with postgraduate degrees in science had more empiricist views of NOS than teachers with less formal backgrounds in science. A similar observation was made by Aikenhead (1997), who found that teachers held far more empiricist views of science than their students, and wondered whether this was a result of their science education or whether strongly empiricist students chose to study science. The causal relationship in this matter is still not well understood.

As with interest in science, the relationship between epistemological views of science and culture is one that needs to be further fleshed out. It was initially found that misunderstandings of NOS were universal and no difference was found between different ethnicities or backgrounds (Lederman, 1992). More recently, some incidental studies have shown that concepts of NOS differ in different areas of the world. Kang et al. (2005) found that Korean students tended to have an instrumentalist view in which science is seen as an instrument to progress and development. A similar observation has been made in Japan (Kawasaki, 1996). In a study of over 2000 students from 21 different cities in Turkey, Dogan and Abd-El-Khalick (2008) found that students from low SES (social economic status) regions, which were more rural and less Western, had more naive and empiricist ideas of NOS than more Western, urban and high SES students.

2.2.4 Research questions

Our study tried to answer three major research questions. The first research question was: *are there differences in interest in science among the students in the six countries that are involved in the study, the United Kingdom, the Netherlands, Turkey, Lebanon, India and Malaysia?* We not only wanted to measure interest in science as it is taught in school , but also in science as an occupation and as an extracurricular activity. Based on the studies reviewed in the background section, we hypothesized that students from countries outside Western Europe will hold a greater interest in the various forms of science than Dutch and British students. The second research question was: *do the students from the investigated countries differ in their views of science, in their ideas of what science is, what science can do and how scientists work?* We hypothesized on the basis of the reviewed studies that students from countries outside Western Europe will have more empiricist views than students from Western Europe. The third research question was: *is there across countries, a relationship between interest in science in its various forms and views on science?* If the previous two hypotheses were found to be true, our hypothesis was that such a relationship indeed exists and that stronger empiricist views correlate with higher interest in science.

2.3 | Methods

2.3.1 Sample

Data were collected from students aged mainly 10 to 14 years, with the selection of students within a country being made by local researchers within the larger project. Attention was paid to school location (rural, urban or suburban) and composition of the school population (religion, ethnicity, socio-economic status) in an attempt to ensure the samples were reasonably representative of the diversity of students found in the population of the countries. Because entire school classes completed the questionnaire, a small number of students were slightly older or younger than the intended sampling age group of 10 to 14. A total of 9171 students in the age range 8 to 16 completed the questionnaire, with 93% of them in the target age group. Each country had roughly equal numbers of boys and girls, but the percentage of primary and secondary school students varied between countries, as shown in Table 2.1. In some countries, it was difficult to obtain a diverse sample. The Malaysian sample consisted of school classes from both the peninsula and Borneo. Malaysian society has three major ethnic groups: Malay, Tamil and Chinese. Our sample has a slight overrepresentation of Chinese students versus Malay and Tamil students, as compared to the national census. The Indian sample came from English-language schools in the Mumbai region because it was impractical to sample all over India and translate the questionnaire into each of the many languages used in India.

The Indian sample did, however, include students from a variety of socio-economic backgrounds.

Table 2.1
Sample properties

	Total number of students	Girls	Boys	Primary school students	Secondary school students
United Kingdom	1618 (17.6%)	774 (47,9%)	843 (52,1%)	282 (17,4%)	1336 (82,6%)
The Netherlands	1239 (13,5%)	633 (51,1%)	605 (48,9%)	137 (11,1%)	1102 (88,9%)
Lebanon	1260 (13,7%)	615 (48,9%)	643 (51,1%)	666 (52,9%)	594 (47,1%)
Turkey	1198 (13,1%)	609 (50,8%)	589 (49,2%)	878 (73,3%)	320 (26,7%)
Malaysia	2334 (25,4%)	1294 (55,5%)	1036 (44,5%)	704 (30,2%)	1628 (69,8%)
India	1522 (16,6%)	672 (44,2%)	850 (55,8%)	883 (58,0%)	639 (42,0%)
Total	9171 (100,0%)	4595 (50,1%)	4566 (49,8%)	3550 (38,7%)	5619 (61,3%)

2.3.2 Instrument

The questionnaire was designed to measure students' level of interest in science and their views regarding the nature of science. It included, among others, items relating to science as it was taught in school, about potential careers in science and extracurricular activities. The number of items for each of the topics included in the questionnaire are summarized in Table 2.2. Not all of the items included in the questionnaire are used in the analysis discussed in this chapter. Below, the questions concerning interest and views on the Nature of Science are discussed.

Table 2.2
Composition of the questionnaire

Topic	Number of items
Personal attributes	17
Favorite course	7
Least favorite course	7
Interest in extracurricular activities	15
Interest in science courses	8
Opinion on students who like science	9
Ethics	5
Nature of science	16
Opinions on the future	7
Future job	8
Personal use of technology	7
Total	106

A large number of items were included about interest in school science and in other school courses. Students were asked to provide the name of their favorite course, answer questions about their interest in science courses and their interest in having a job related to science later in life. Because we were interested in how students perceived science outside school, a list of extracurricular activities was included for which students could indicate whether they enjoyed doing these activities or not (see Table 2.4).

Designing questions concerning the nature of science that could be understood by 10-year-old students posed several challenges. Existing questionnaires, such as the 'Views on the Nature of Science' questionnaire (Lederman et al., 2002) and the 'Views of Science-Technology-Society' questionnaire (Aikenhead & Ryan, 1992), were designed for older students and were not appropriate for our sample. We included four items about the nature of science. These covered the utility of science, the tentative nature of scientific explanations, the creative nature of science and the collaborative nature of scientific research (the statements and their answers can be found in Figure 2.4). Because the term 'science' has different connotations in different languages, we also included a question in which students were asked to indicate which of 12 different activities they believed could be thought of as 'science' (see Table 2.5).

The questionnaire was short enough to be completed by students in 30 minutes and most questions used a three- or four-point Likert scale to obtain responses. Some open-ended questions were included, most of which could be answered with a one-word answer (e.g., the name of a course). In the Netherlands, Turkey and Malaysia, the questionnaire was translated into the appropriate language by local researchers, and then translated back to English by their colleagues to check for possible translation errors. The United Kingdom, India and Lebanon used an English questionnaire because the language of science instruction is English in these countries. The questionnaire was trialed with a small group of students in each country and adjustments were made to improve the comprehensibility of several items. For instance, instructions were added on how to answer Likert-type scale questions, because it turned out that several students had problems understanding these questions. The questionnaire was completed individually by students during science classes in the presence of a researcher who was able to offer clarification if needed.

2.3.3 Analysis

Descriptive analysis, factor analysis and multilevel analysis were used to investigate students' levels of interest in science and their different views of science.

2.3.4 Factor analysis

Exploratory factor analysis was used to reduce the large numbers of items to a smaller set of factors to make international comparison more straightforward. Factor analysis was carried out using the entire sample. The factors that appeared were checked for stability in single countries by running the factor analysis again with national samples. The same factors appeared for the national samples.

The factor analysis was performed on questions about interest in extracurricular activities, interest in school science, the meaning of the word science and the nature of science. Factor analysis was carried out with the computer program SPSS. Principal Component Analysis was used with varimax rotation with Kaiser normalization. Only those factors with an eigenvalue over 1 were extracted.

Factor scores for interest in school science and interest in a science-related career were created using the items listed in Table 2.3. These were all Likert scale items, apart from two questions asking students to indicate favorite and least favorite courses. Because different science courses were offered by schools in each of the countries, answers to this question were coded as either belonging or not belonging to the realm of science and mathematics. The outcomes of this analysis in Table 2.3 show how much each item contributes to the factors. Completely overlapping with a factor would result in a score of 1 or -1, whereas those items that have nothing in common with the factor have a score of 0. Only factor scores over 0.4 or under -0.4 are displayed in Table 2.3. The factor analysis created two different factors, one relating to *interest in school science* and the other to *interest in science jobs*. For each factor, Cronbach's alpha was calculated based on the items that contributed over 0.4 to the factors. Several of the values calculated for Cronbach's alpha are below the acceptable values of 0.7 or 0.6. This is mainly due to the small number of items that contributed to the factors. The Spearman Brown prediction formula shows that for these factors, slightly increasing the number of items would lead to acceptable values for Cronbach's alpha. Both the factors for interest in school science and interest in science jobs had normal distributions with skewness values of -0,257 and 0,081 respectively.

Table 2.3

Factors for interest in school science and science jobs (rotated factor loadings)

	Factor	
	1 Interest in School Science	2 Interest in Science Jobs
I like all science lessons in school	.728	
I like some science lessons but not all of them	-.595	
I don't like any science lessons	-.552	
I would like a job where I can discover and invent new things		.872
I would like a job related to science and technology		.829
Favorite course	.446	
Least favorite course	-.515	
Cronbach's alpha	.502	.673
Spearman Brown Lengthening needed to reach 0.7	2.31	1.13

Notes. Factor analysis was performed on several items related to interest in school science. Two factors were identified that explained 47.4% of all variance. For the first three items, students could indicate whether they found the statements to be very true, a bit true or not true. For the fourth and fifth statements, students could indicate whether they would like something very much, a little or not. The final two items were coded as either a STEM course or not.

To construct factors indicating the extent to which students were interested in various extracurricular activities, we analyzed the 15 activities listed in Table 2.4. For each of these activities, a student could indicate whether they enjoyed or did not enjoy them. As shown in Table 2.4, three underlying factors were revealed: *interest in science-related activities*, *interest in technology-related activities* and *interest in domestic activities*. Many of the science-related activities concern learning about science, whereas technology activities are generally more hands on. The factors for technology activities and domestic activities were normally distributed (the values for skewness were -,188 and -,107 respectively). The distribution for the science activities was slightly negatively skewed with a value of -,404. This is still within acceptable boundaries for a normal distribution. There were no outlying factor scores.

The factor analysis of the items concerned with whether different activities were part of the realm of science revealed three underlying factors: *natural science*, *social science* and *applied science*, as detailed in Table 2.5. The distribution of the applied science factor was normal (skewness of - ,027), whereas the social science factor was skewed slightly positively (skewness value of ,230), and the natural science factor was skewed slightly negatively (skewness value of -,772). Values for skewness were within acceptable boundaries for a normal distribution. There were no outlying factor scores.

Table 2.4

Factors for interest in extracurricular activities (rotated factor loadings)

	Factor 1 Interest in Science Activities	2 Interest in Technology Activities	3 Interest in Domestic Activities
Going to science museums	.646		
Watching TV about animals & nature	.640		
Finding out how our bodies work	.623		
Watching TV about space & planets	.662		
Finding out about new inventions and discoveries	.544	.423	
Helping to look after people when they are sick	.521		.419
Using new machines and technology		.679	
Fixing things when they break		.721	
Thinking about ways I & my family can help the environment	.640		
Cooking and preparing food			.747
Making things out of wood or metal		.756	
Making or altering clothes			.778
Talking to my parents about science	.739		
Watching TV about natural events e.g. volcanoes	.668		
Talking to my friends about science	.720		
Cronbach's alpha	.852	.641	.446
Spearman Brown Lengthening needed to reach 0.7		1.31	2.90

Notes. Factor analysis on 15 items about doing a particular activity. Students could indicate they liked activities very much, a bit or not at all. Three factors were identified that explained 56.5% of all variance.

Table 2.5

Factors for Nature of Science (rotated factor loadings)

Rotated Component Matrix			
	Factor		
	1 Natural Science	2 Social Science	3 Applied Science
Making music			.496
Looking at fossils and dinosaurs	.629		
Finding out how to cure diseases	.588		.469
Exploring space	.730		
Finding out about climate change	.611		
Digging up old cities and temples		.563	
Healing people who are sick			.711
Farming			.694
Building a bridge		.454	.529
Finding out why some countries are poor and some rich		.770	
Finding out why some people learn things more easily than others		.631	
Reading about people in the past who discovered or invented things		.544	
Cronbach's alpha	.604	.671	.622
Spearman Brown Lengthening needed to reach 0.7	1.53	1.14	1.41

Notes. Factor analysis on 12 items for which students indicated whether each belonged to the realm of science or not. Students could indicate whether they believed something was always, sometimes or never part of science. Three factors were identified that explained 47.5% of all variance

2.3.5 Multilevel analysis

Multilevel modelling using the software package MLwiN Version 2.02 (Rasbash, Charlton, Browne, Healy, & Cameron, 2005) was done to investigate the relationship between the different factors. In this study, the factors and variables for having a particular view of science (natural, social and applied science, and the four NOS tenets) were used to explain variance in the various forms of interest (interest in school science, in science jobs and in science, technology and domestic activities). Age and gender are known to be related to interest in science and the national samples differed in the number of boys vs. girls and primary vs. secondary school students. Therefore, gender and school type (primary and secondary education, which correspond to younger and older age groups) were included in the multilevel analysis to correct for these influences.

Multilevel analysis makes use of statistical hierarchical linear regression models with different levels and provides a measure of the percentage of variance explained at each level. The models in this study use three different levels: student, school and country. Each student is situated in a school within a particular country. School and country levels have an impact on an individual student's level of interest in science because students in the same school or country will experience similar cultural and educational experiences. For instance, all students from one particular school where teachers succeed in making their science lessons interesting will score higher on average than students from a school in which science is taught in an uninspiring way.

Two models were used in this analysis: an 'empty model', in which no explanatory factors were used, and a 'significant model', which included those factors that made a significant contribution to the explanatory power of the model. The empty model assumes that interest is similar for all students, a prediction that is at odds with the real score and therefore there is much unexplained variance. The significant model, which predicts different scores for each student based on their statistically significant characteristics, gives a better description of reality. A reduction in unexplained variance shows the improvement of the predictive power of the model.

Effect sizes were calculated in order to make the found coefficients of factors, four Likert-type scales and dichotomous values, comparative. Effect sizes were calculated by multiplying the coefficients by the standard deviation of the corresponding factor, scale or value divided by the standard deviation of the corresponding interest factor, as described by Snijders & Bosker (1999).

2.4 | Results

2.4.1 Interest in science

Student responses to questions asking them to list their favorite and least favorite school subject are summarized in Table 2.6. Students from India were the most likely to have written down the name of a science or mathematics course as a favorite class, Dutch and English students were the least likely to do so. Nearly half of the English students and only a quarter of the Indian students indicated that a science subject or mathematics was their least favorite subject. The factor related to interest in school science that emerged from the factor analysis provides further evidence for a division between the two Western European countries and the other four countries. Figure 2.1 shows how the mean country scores on the 'interest in school science' factor deviate from the international mean, which is set at 0. The factor related to interest in a science career shows even larger differences between the countries.

Table 2.6

Favorite and least favorite courses

	The Netherlands	United Kingdom	Lebanon	Turkey	Malaysia	India
Science or mathematics as a favorite course	22.5%	29.6%	56.0%	52.8%	48.3%	60.5%
Science or mathematics as a least favorite course	39.0%	48.8%	37.8%	41.5%	44.7%	27.0%

Notes. Mathematics, Chemistry, Physics, Biology, Technology, Computer Science and Geography were counted as science or mathematics courses.

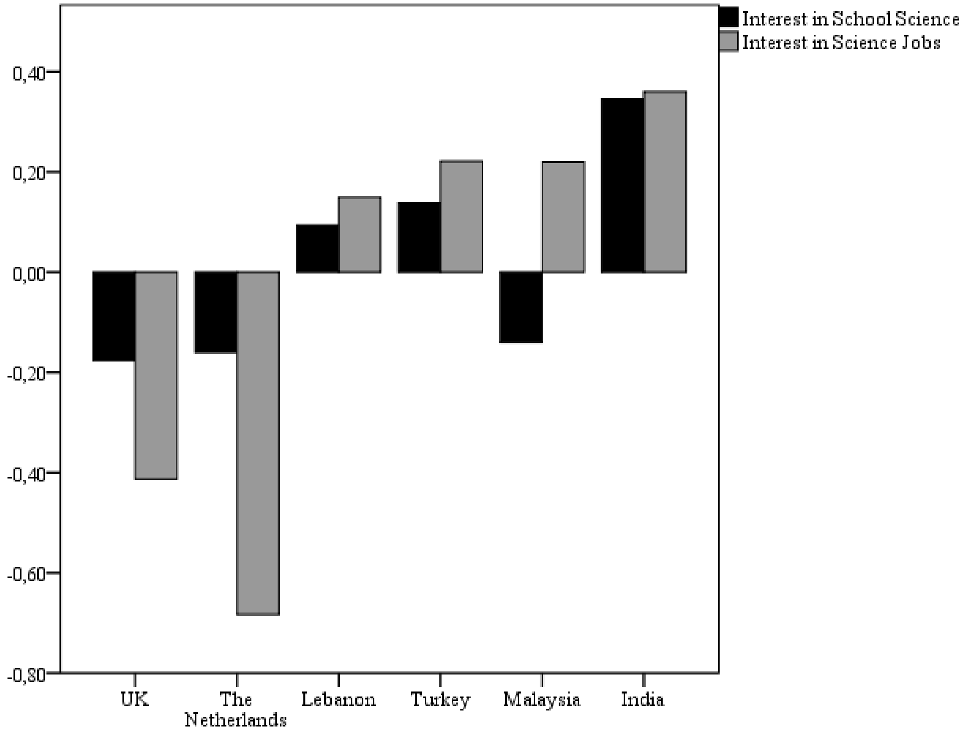

Figure 2.1. Interest in school science and a career in science
Mean country scores for interest in school science and interest in a career in science. The mean for the entire sample of students is set at 0 and national variations around the international mean are shown. A higher score indicates a greater interest.

The next question to answer was whether, next to this greater interest in science in school, there was also a greater interest in science outside of school in countries outside Western Europe. Factor analysis also showed that students from Lebanon, Turkey, Malaysia and India displayed a greater interest in extracurricular activities related to science than Dutch and English students (Figure 2.1), with students from India again giving the most positive answers. Interest in more practical activities related to technology and in domestic activities, such as preparing food, showed similar levels in all countries.

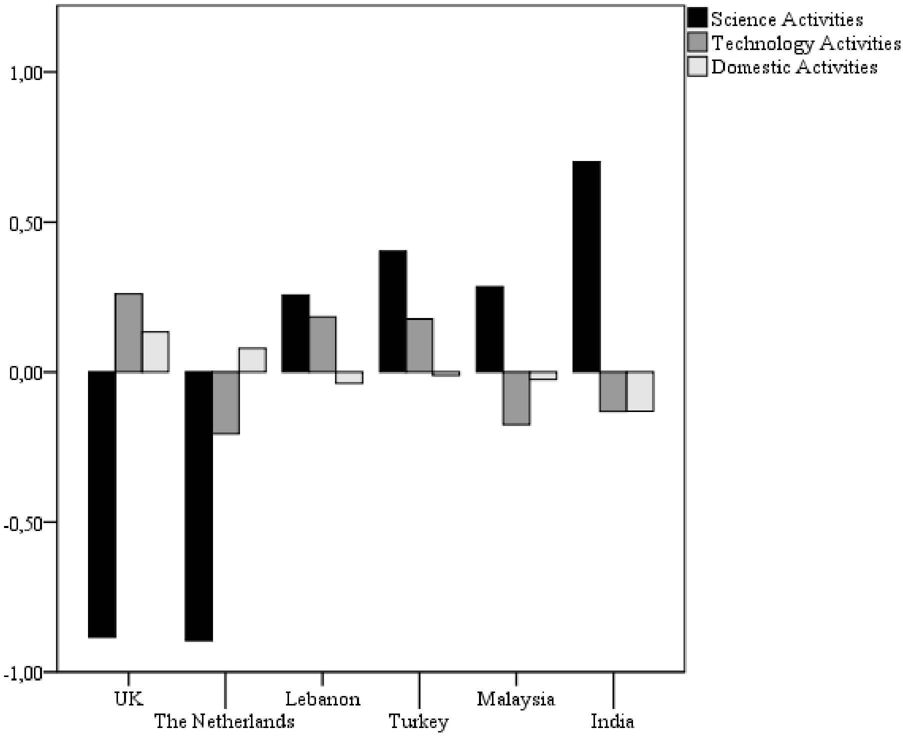

Figure 2.2. Interest in extracurricular activities
Mean country scores for the factors science, technology and domestic activities. The mean for the entire sample of students is set at 0 and national variations of the international mean are shown. A higher score indicates a greater interest.

2.4.2 Students' views on science

Mean country scores on the three factors related to views on science show how students in different countries differ from each other in their views of what does and does not belong to the realm of science. Figure 2.3 shows whether, on average, students from the six countries are more (higher score) or less likely (lower score) to believe that natural science, social science and applied science are part of science as a whole. Dutch and Turkish students generally have a broader interpretation of the word 'science' than students in the United Kingdom and Lebanon. The scores for applied science do not adhere to the general pattern formed by the natural and social science scores.

Dutch students do not consider applied science to be part of science but generally have a broad view of science that includes many of the natural and social science items. The opposite is true for India. Here again, a division can be made between Western Europe and the other countries.

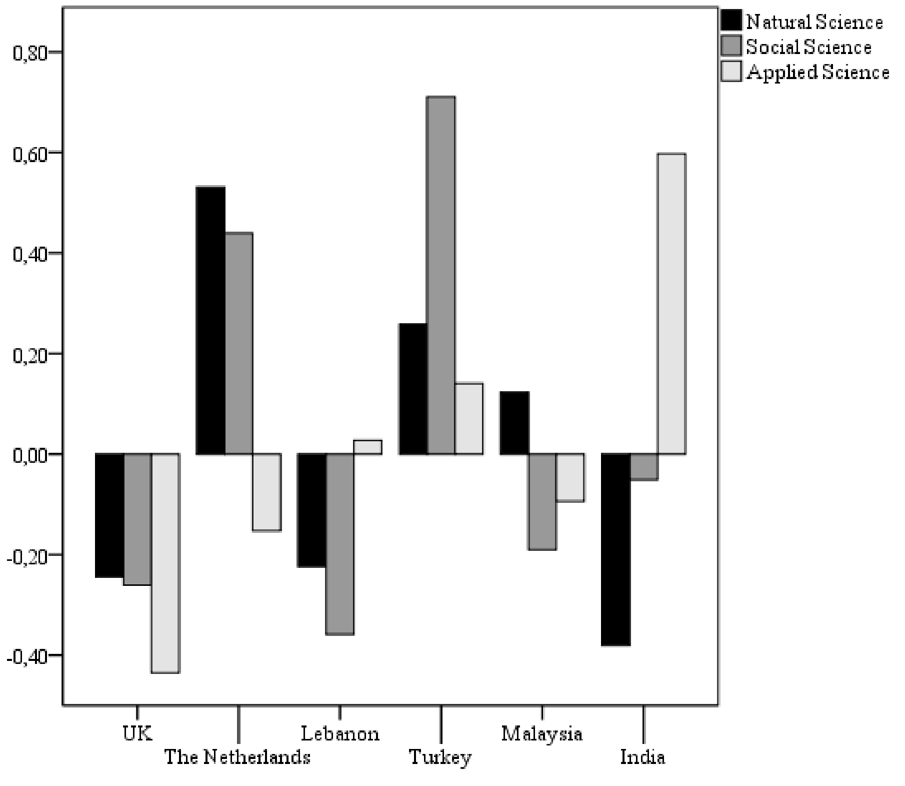

Figure 2.3. Interpretation of the word science
Mean factor scores per country for the factors natural science, social science and applied science. The mean for the entire sample is set at 0 and the national variations on this mean are shown. A positive score indicates a greater likeliness that something is considered to be science.

Students were asked four questions concerning the tenets of nature of science: two questions about how science works and two about the work of a scientist. Figure 2.4 shows the percentage of students who chose a particular answer on a 4-point Likert scale. Large differences could be observed between the countries. The questions about science itself showed that more students from the four countries outside Western Europe held empiricist views about NOS. In India, 60% of all students answered that science can solve most problems people face in their life and 43.1% of all students believed that science tells us what is completely true. Only a small percentage of Dutch and British students gave these answers. There were small differences in the answers to the item relating to whether scientists work in groups or alone. Turkish, Malaysian and Indian students viewed science as a more creative and less 'fact-based' activity than Dutch, British and Lebanese students.

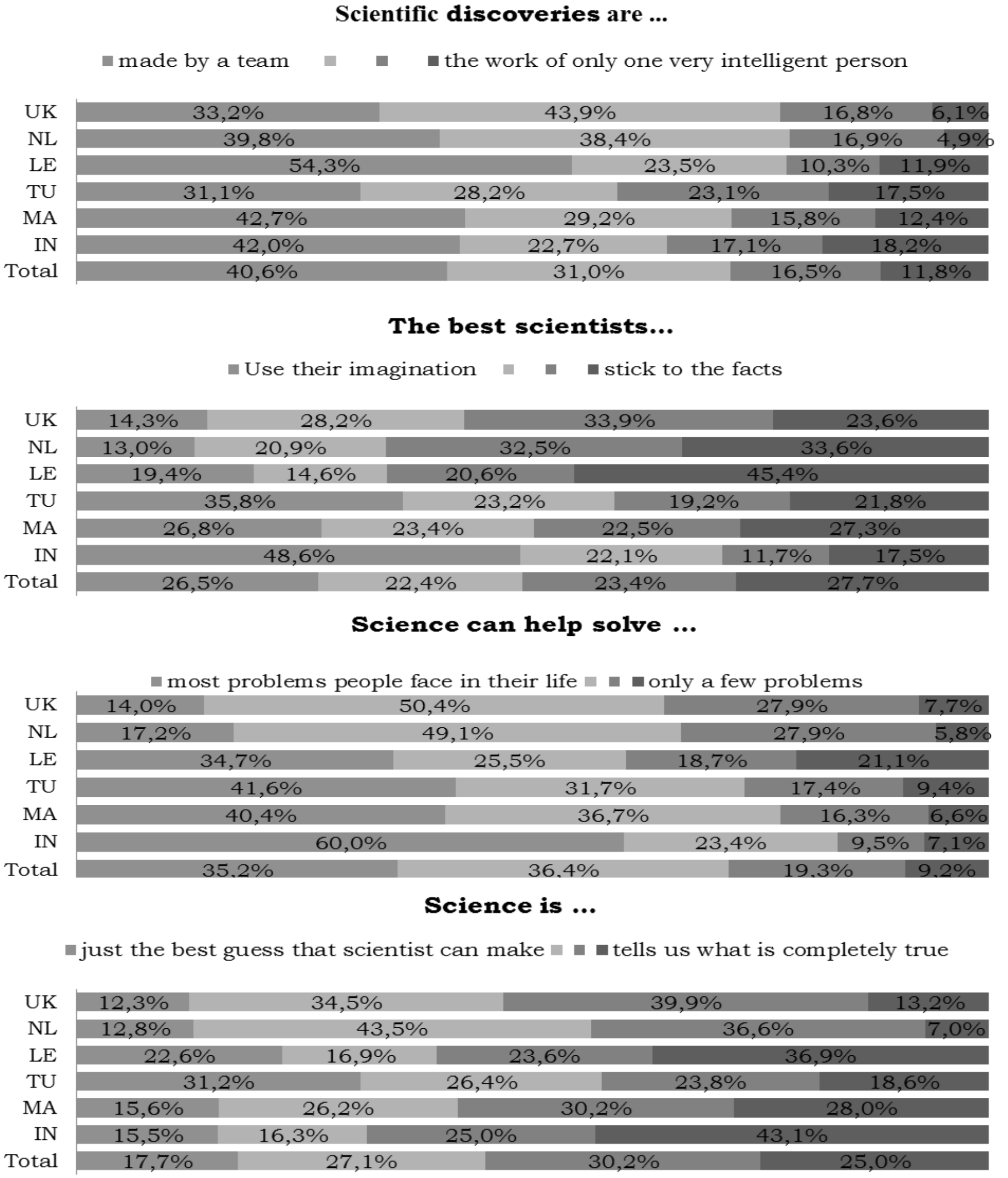

Figure 2.4. NOS views of students

Percentages for each of the answers to four point Likert scale questions on the nature of science for the six countries. UK=United Kingdom, NL=Netherlands, LE=Lebanon, TU=Turkey, MA=Malaysia, IN=India.

2.4.3 The relationship between students' views of science and their interest in science

Multilevel analysis was used to investigate the relationship between students' interest in science and their views on NOS. Tables 2.7 and 2.8 show both the empty and the significant model and the reduction in variance between those two models. Reduction in variance is shown at the three different levels and in total, as denoted by the number for 2 log likelihood.

Despite the large country differences found in our previous analyses (Figures 2.2, 2.3 and 2.4), multilevel analysis showed that most variation for the different forms of interest (58.6% to 94.0%) could be identified at the student level (Tables 2.7 and 2.8). Interest in school science appears determined for a greater part at the school level than interest in extracurricular activities or interest in jobs in science.

The coefficients of the explanatory factors in the significant model show how much higher or lower mean interest scores are for students with particular factor scores or scores on one of the Likert scales. Table 2.7 shows, for instance, that for each point students score themselves higher on the 4-type Likert scale for science offering solutions to life (Figure 2.4), interest in school science would decrease by -0.116. The corresponding effect size of -0.110 shows that the effect of this scale is about twice that of gender (0.049) and about half that of school level (-0.201).

Across countries, boys appeared more interested in school science, science jobs and activities related to science and technology, and girls showed a higher interest in domestic activities. Primary school students had a higher interest in all activities and in school science, but not in science careers, for which primary and secondary school students had similar scores. For example, the effect sizes in Table 2.7 show that boys scored higher than girls on interest in school science (0.049) and secondary school students scored lower than primary school students (-0.201). The gender difference was relatively small for interest in school science and interest in science activities, but larger for interest in technology activities and careers related to science and technology.

Holding a broader view of science, which includes more aspects of natural, social and applied science, correlated with higher levels of all constructs of interest in science across all countries. Three of the four questionnaire items concerned with the tenets of NOS had an impact on the interest variables. Believing that science is creative, involves teams of researchers and offers solutions to many problems in life correlated with higher levels of interest for all factors except domestic activities.

Table 2.7

Multilevel analysis for interest in school science and science jobs

		Interest in School Science		Interest in Science Jobs	
		Coefficient	Percentage	Coefficient	Percentage
Empty model	Country	0.018 (0.015)	1.8%	0.140 (0.082)	13.9%
	School	0.110 (0.018)	10.7%	0.025 (0.006)	2.5%
	Student	0.896 (0.014)	87.5%	0.842 (0.013)	83.6%
	2 log likelihood	25337.175		24598.006	
		Coefficient	Effect Size	Coefficient	Effect Size
Significant model	Boy	0.097 (0.021)	0.049	0.271 (0.019)	0.136
	Secondary	-0.412 (0.046)	-0.201		
	Nat. Science	0.061 (0.011)	0.061	0.090 (0.010)	0.090
	Soc. Science			0.075 (0.010)	0.075
	App. Science			0.116 (0.010)	0.116
	Solutions	-0.116 (0.011)	-0.110	-0.106 (0.010)	-0.100
	Teamwork			-0.032 (0.009)	-0.032
	Creativity			-0.051 (0.009)	-0.058
		Coefficient	Percentage	Coefficient	Percentage
	Country	0.010 (0.009)	1.0%	0.113 (0.067)	11.2%
	School	0.082 (0.015)	8.0%	0.029 (0.007)	2.5%
	Student	0.876 (0.013)	85.5%	0.776 (0.012)	77.0%
	Percentage explained		5.5%		9.3%
	2 log likelihood	25083.121		23878.925	
	Reduction	254.054		719.081	

Notes. Coefficients for Natural, Social and Applied science, which range from -3 to 3, and for the four NOS tenets, which ranged from 1 to 4, were not standardized

Table 2.8

Multilevel Analysis for interest in extracurricular activities

		Interest in Science Activities		Interest in Technology Activities	
		Coefficient	Percentage	Coefficient	Percentage
Empty model	Country	0.323(0.190)	34.0%	0.033(0.021)	3.3%
	School	0.077(0.012)	8.1%	0.027(0.007)	2.7%
	Student	0.549(0.008)	57.9%	0.935(0.014)	94.0%
	2 log likelihood	20891.061		25551.516	
		Coefficient	Effect Size	Coefficient	Effect Size
Significant model	Boy	0.048 (0.016)	0.024	0.564 (0.020)	0.282
	Secondary	-0.315 (0.036)	-0.153	-0.100 (0.035)	-0.049
	Nat. Science	0.092 (0.008)	0.092	0.096 (0.010)	0.096
	Soc. Science	0.107 (0.008)	0.107	0.091 (0.011)	0.091
	App. Science	0.080 (0.008)	0.080	0.091 (0.010)	0.091
	Solutions	-0.119 (0.008)	-0.113	-0.026 (0.011)	-0.027
	Teamwork	-0.035 (0.008)	-0.035	-0.030 (0.010)	-0.030
	Creativity	-0.016 (0.007)	-0.018	-0.024 (0.009)	-0.027
		Coefficient	Percentage	Coefficient	Percentage
	Country	0.268 (0.157)	28.2%	0.048 (0.029)	3.3%
	School	0.051 (0.009)	5.3%	0.021 (0.005)	2.1%
	Student	0.508 (0.008)	53.5%	0.831 (0.012)	83.5%
	Percentage explained		13.0%		11.1%
	2 log likelihood	20117.533		24463.805	
	Reduction	773.528		1087.711	

Notes. Coefficients for Natural, Social and Applied science, which range from -3 to 3, and for the four NOS tenets, which ranged from 1 to 4, were not standardized.

Table 2.8 (continued)

Multilevel Analysis for interest in extracurricular activities

		Interest in Domestic Activities	
		Coefficient	Percentage
Empty model	Country	0.010(0.008)	1.0%
	School	0.052(0.011)	5.1%
	Student	0.950(0.014)	93.9%
	2 log likelihood	25756.727	
		Coefficient	Effect Size
Significant model	Boy	-0.837 (0.019)	-0.419
	Secondary	-0.356 (0.039)	-0.173
	Soc. Science	0.083 (0.010)	0.083
	App. Science	0.091 (0.010)	0.091
		Coefficient	Percentage
	Country	0.030 (0.019)	1.0%
	School	0.042 (0.009)	4.2%
	Student	0.777 (0.012)	76.8%
	Percentage explained		18.0%
	2 log likelihood	23917.563	
	Reduction	1839.164	

2.5 | Conclusions and discussion

The statistics we report showed that students from countries outside Western Europe had greater interest in school science than students within Western Europe. This parallels findings reported in other international studies in which interest in school science was investigated (such as PISA and ROSE). Students outside Western Europe also had a greater interest in careers in science and in extracurricular activities related to science. The greater interest in science courses was not simply caused by an overall greater interest in school courses. Students in Turkey, Lebanon, India and Malaysia preferred science courses over other school courses (Table 2.6). Similarly, greater interest in extracurricular activities related to science was not caused by an overall greater interest in extracurricular activities. Students from all six participating countries had a comparable interest in activities related to technology, whereas Dutch and British students had slightly more interest in domestic activities.

There were also differences in the ways in which students in different countries perceived science. Large differences were found in the interpretation of what belongs to the realm of science and what does not. Turkish and Dutch students generally had a broader interpretation of the term 'science'. Part of the pattern seen in Figure 2.3 may be attributed to the connotations that translated terms for science have in different languages. The Turkish and Dutch words for science appeared to have broader meanings than the English word. However, applied science did not follow the pattern of natural and social science and was more often considered to be part of the science realm by students in Turkey, Lebanon, India and Malaysia than in the Netherlands and the United Kingdom. This cannot be attributed to language differences, as the United Kingdom, Lebanon and India all used questionnaires in the English language and each scored very differently on applied science.

Students outside Western Europe were also more likely to hold empiricist views on several tenets relating to the nature of science. For instance, they had greater confidence in what science can achieve through believing that science can solve most problems in life and that science is completely true. A similar relationship between empiricism and the level of development was reported by Dogan and Abd-El-Khalick (2008) in their study of the views of science held by students living in rural and urban areas of Turkey.

How should the observation that empiricism and nationality seem to be related be interpreted? In our view, there are two possible explanations. The first is that in developing countries, science teachers pay less attention to NOS in their lessons than their Western counterparts and that therefore their students tend to know less about NOS. Since the 1980s, science curricula in European countries, such as the UK (e.g., Solomon, 1991) and the Netherlands (Eijkelhof & Kortland, 1988), have increasingly stressed NOS and the relation between science, technology and society, probably to a greater extent than outside Europe. Students may have changed their views of science according to what they have read in their textbooks and from what they have heard from their teachers.

The second explanation is that the country differences found in this study are cultural. This means the prevalence of a particular view of science is a feature of a country that could be related to the state of development of the country or, from a historical perspective, a relatively recent encounter with Western science. The existence of such culturally determined viewpoints is very well possible. It has been argued that the promotion of science as a way of increasing the development of a country led to the instrumentalist view of science that is prevalent among many Asian societies (Kang et al., 2005; Kawasaki, 1996). Our finding that the applied aspects of science tend to be far more often considered part of science in non-Western nations, especially in India, confirms this. If instrumentalism is part of a national conceptual idea of science, then the same could be the case for empiricism.

It should be mentioned that we merely measured the positions students took on several key tenets of NOS. We were not explicitly interested in whether or not these students had correct epistemological understandings, something which the questionnaire used in this study could not measure.

Generally, science educators consider the constructivist viewpoint as more contemporary and correct than the empiricist viewpoint. Strict empiricist viewpoints, such as believing in science as an absolute truth, are often seen as a 'wrong' interpretation of NOS. This, however, does not imply that the opposite viewpoint, believing that science is 'just the best guess scientist can make', should be interpreted as an informed NOS view. Interviews or additional questionnaire items would be required in order to find out whether or not students had informed beliefs, which would have made the questionnaire longer and more complicated for young students. Nonetheless, some highly empiricist views present among many students stand in contrast with the desired views of NOS that are advocated by science educators and are written down in many policy documents (American Association for the Advancement of Science [AAAS], 1990; AAAS, 2009; National Science Teacher Association [NSTA], 2000).

It is difficult to pinpoint what aspects within a country are causes for different views of science. Is it the educational system present in the country, the state of development, other underlying cultural values or a combination of these three? In the case of Japan, interest in science is as low as in North European countries with a comparable level of development (Sjøberg & Schreiner, 2005a), yet an instrumentalist view of science persists (Kawasaki, 1996).

Multilevel modelling showed that a model that took account of gender, age and perspectives on science provided a better fit for the findings than an 'empty' model that did not include these factors. However, the various different factors for interest in science have very different associations with background characteristics in the multilevel analysis and show that greater interest in school science does not necessarily equate with wanting a career in science or liking activities that are related to science. The model also shows that when students move from primary to secondary school, their interest in school science and in extracurricular activities drops (Tables 2.7 and 2.8). However, interest in a science career is not affected by the transition from primary to secondary education. Boys show a greater preference than girls for a career in science and also have a clear preference for hands-on practical activities related to technology. In contrast, gender effects were relatively small for interest in school science and for extracurricular science activities, which are more oriented towards learning than the hands-on technology activities. Domestic activities, which include gendered activities such as cooking and making clothes, were liked better by girls.

Multilevel analysis also revealed a relationship between student views concerning the nature of science and their interest in science. The statement that science can solve all problems people face in their life had the largest effect in the multilevel models, showing that students who had such a view of science were much more interested in science. Students who believed that scientists had a creative job were also more interested in a career in science than those who believed scientists only dealt with 'facts'. Believing that scientists work in groups or alone had a similarly small effect in the multilevel model. However, not all tenets of NOS correlated with interest in science. Believing in science as an absolute truth did not correlate in any way with students' interest in science. None of NOS tenets were in any way correlated with interest in domestic activities. Students who were interested in science tended to have a slightly broader interpretation of the term 'science' than those not interested in science. This broader concept of science is, however, not limited to a single aspect of science but encompasses natural, applied and social science.

In addition, multilevel analysis showed that, despite large international differences, most variance existed at the individual student level. Interest in school science is also determined to a greater extent by variables at school level than either activities related to science or interest in science jobs. This is understandable because individual teachers have a direct impact on whether students like or dislike courses and have far less influence on individual preferences for extracurricular activities or jobs. The addition of explanatory factors to the models decreased unexplained variance at all three levels, including the country level. Views on the nature of science can thus be considered as an important explanatory factor for international differences in interest in science.

There are some limitations to our study. In some cases, the sampled population was not representative of the diversity of students that can be found in one country. One has to take into account that the data from the urbanized Mumbai region might not be generalizable for other regions of India. The Malaysian data has a slight oversampling of Chinese students, who tend to be slightly less interested in science courses than Malay or Tamil students. Furthermore, this study focused on students in the age group of 10 to 14, and the majority of students in the sample were part of that age group. The results of this study cannot be generalized to younger and older age groups. Finally, only quantitative methods were used in this study as we intended to sample a large group of students. More qualitative measures will enable us to learn in more detail why students like or dislike particular aspects of science and how culture affects these views. A more elaborate study involving qualitative research methods could also find out whether there is a relationship between having a contemporary understanding of the nature of science and interest in science.

What are the practical implications of these results for science education? In the multilevel analysis, we found that interest in science jobs and in activities related to science and technology was higher when students believed that scientists are creative people who work in teams and when students believed that applied science was part of science (Tables 2.7 and 2.8). Teaching that science is a creative and collaborative endeavor and teaching applied aspects of science have long been goals of science education, and this study reaffirms that this may have a positive impact on various forms of interest in science. Believing that science can offer solutions to all problems in life is strongly correlated with greater interest in science. Application of this finding in the practice of science education is problematic because presenting science as offering solutions in life is at odds with the way science works in reality.

The findings that views on science impact students' interest in science and that these views differ raises further questions for research. The exact nature of the relationship between interest in science and views of science needs to be investigated in greater detail. Furthermore, can different views on science be identified that positively or negatively impact the various forms of student interest in science? When students change their views on science because they receive new information, either in their classes or outside school, does this automatically imply that their interest in science will increase or decrease? It also needs to be established why international differences in NOS views exist. Do students form their ideas about science in their science classes and are these ideas shaped by what their teachers believe or how they present science in their classes? Or are there underlying cultural values at play that shape students' views of science? The further elucidation of the dynamic between nationality, views on science and interest in science would be valuable for science education in countries both inside and outside Western Europe. For countries where science generally is not among the most chosen courses in secondary and tertiary education, knowledge about such a dynamic could be used to improve science education and make it more appealing to students. The results from this study suggest the answer to the problem of decreasing interest in Western Europe would be to develop teaching materials that present scientific research as collaborative, creative and as beneficial for society, rather than simply copying teaching practices from countries where students tend to be more interested in science. Countries outside Western Europe may not face a decreasing interest in science at this moment, but they may in their future. Knowledge of this dynamic can and should be used to make changes in curriculums to make science education more appealing for a new generation of students.

CHAPTER 3

Teachers' views on nature of science, teaching goals and practice of teaching the nature of science around the world[1]

ABSTRACT

In order to find out how views on the Nature of Science (NOS) correlated with teaching goals and teaching practice in an international context, a questionnaire study was conducted in which 331 primary and secondary school teachers from the United Kingdom, the Netherlands, Turkey, Lebanon, Malaysia and India participated. It was found that teachers from the United Kingdom and the Netherlands held more constructivist and less empiricist views on the Nature of Science than teachers from the other four countries. This was however not reflected in their teaching practice, as Dutch and British teachers said to pay less attention to the constructivist Nature of Science in their classes than Indian and Turkish teachers. Results from multilevel analyses confirmed that there was a correlation between having an empiricist view of science and teaching NOS goals that are essentially constructivist in their nature. A similar correlation was found between having an empiricist view and teaching in a constructivist way according to the scales of the constructivist learning environment survey (CLES). These results point towards underlying cultural values that shape personal views on the NOS and call into question the relationship between personal views of teachers and their teaching.

---

[1] This chapter has been submitted for publication as:
van Griethuijsen, R. A. L. F., van Eijck, M. W., den Brok, P.J., Haste, H., Hetherington, L., Gencer, A.S., Khisfe, R. (submitted). Teachers' views on nature of science, teaching goals and practice of teaching the nature of science around the world.

3.1 | Introduction

The research aim of this study is to explore what perceptions teachers have of the Nature of Science (NOS) and the extent to which these perceptions impacted their reported approaches to teaching science. Findings reported elsewhere (see chapter two) showed that among students in countries outside Western Europe, a view on the Nature of Science is prevalent which is empiricist as compared to a more constructivist view held by students in Western European countries. The empiricist view of science correlated strongly with having a greater interest in science (see chapter two). It is, however, not clear how students have come to these views, whether these views were explicitly taught in the classes these students attended or whether students adopted these views because they were pervasive in the culture they grew up in. To find this out, it is necessary to know what the teachers that teach these students believe and whether they report to teach according to their own views in their classes.

Our research aim is scientifically relevant since a controversy exists in the scientific literature on the relationship between teacher's views of the Nature of Science and their impact on their teaching. Research into views on the Nature of Science routinely finds that many teachers have a limited understanding of what science is and how it works (Akerson, Abd-El-Khalick & Lederman, 2000; Irez, 2006). Given that teachers cannot teach what they do not know or understand well themselves, Nature of Science has increasingly become a component of teacher education programs (Abd-El-Khalick & Lederman, 2000). However, it is not yet clear whether teachers would actually teach their students their own views. Several studies suggest that teachers do indeed teach what they personally believe (LaPlante, 1997; Tsai, 2002) but a similar number of studies fail to find any correlation between views and practice (Mellado, 1998; Water-Adams, 2006). This study uses a larger number of respondents than previous small-scale studies on the relationship between beliefs and the practice of teaching NOS and includes respondents from several countries in the world where this relationship has not been investigated before.

Using questionnaire data from over 300 primary and secondary school teachers from the United Kingdom, the Netherlands, Turkey, Lebanon, Malaysia and India, we explore the relationship between teachers' views on NOS and their practice and how this relationship plays out in these six countries. This data comes from the international 'Science Education for Diversity' project, which was set up to study differences in science education around the world and which enables us to draw more far reaching conclusions than previous studies which relied on smaller numbers of respondents in only one or two countries. The following background section describes in more detail what has been found in previous studies about teachers' views on the Nature of Science, international differences in views on the Nature of Science and their relation with teaching practices of both primary and secondary teachers.

3.2 | Background

In order to investigate our research aim, it is first necessary to discuss the meaning of the term Nature of Science and what previous studies have found out about school teachers and their views on the Nature of Science. We will further review studies in which the relationship between views on NOS and teaching style was investigated and studies in which international differences in views on NOS were found.

3.2.1 Nature of science

Nature of Science (NOS) refers to the philosophical, historical and societal aspects of science. The term describes what science is, how science is done and what role science plays in a society. The term NOS is mostly used when discussing primary or secondary education where no separate courses in science history or science philosophy are offered. NOS must be incorporated into regular science classes to teach students the most important tenets of the history and philosophy of science. As there is no single philosophical standpoint on science or a single narrative of the history of science or the societal impact of science, there is neither a single interpretation of Nature of Science as a construct. Nonetheless, a consensus has risen among science education researchers on the most common tenets of NOS that should be part of primary and secondary science education (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002; McComas et al., 2002). These include the tentative nature of scientific theories, the way science uses empirical evidence and logic, the lack of a single scientific method, the use of creativity in scientific discovery and the relationship between laws and theories.

Initial research from the 1970s and 80s showed that many students had uninformed or incomplete views on the Nature of Science (Lederman, 1992). Since then, teaching NOS in science classes has increasingly become a part of science curricula standards over the world. Unfortunately, not all teaching methods include sufficient information on NOS and research still finds that many teachers focus solely on scientific concepts and formulas and do not treat any philosophical or historical aspects of science in their classes (Abd-El-Khalick, 2005). It has been argued that NOS needs to be explicitly taught in class for students to develop an understanding of NOS. Without an explicit discussion of NOS tenets in class, students will not develop such an understanding on their own (Lederman, 1992).

Teaching NOS is often further complicated by teachers who themselves have NOS views that are not in line with contemporary beliefs about how science functions and who may, implicitly or explicitly, teach their students these views (Abd-El-Khalick & Lederman, 2000). Common misunderstandings which have been found in several countries around the world include thinking of scientific theories as solid and unchangeable and not considering that culture and politics can have an impact on research (Akerson et al., 2000; Iqbal, Azam & Rana, 2009; Irez, 2006).

In this publication, we follow the example of Deng, Chen, Tsai & Chai (2011) in using the terms empiricism and constructivism for the two most commonly held beliefs on NOS. Empiricism is a view of science as solid, certain and unchangeable, independent from the society in which it is practiced or in which it originated and primarily originating from empirical experiments. Constructivism, on the other hand, sees scientific theories as tentative and constructed by human beings which are embedded in a society (Deng et al., 2011). These two views are the two most discussed views that teachers have in the literature on NOS. Still, both the terms empiricism and constructivism can lead to some confusion. In philosophy, empiricism refers to a theory of knowledge, which states that knowledge comes from sensory perception, or in the case of science from the results of experiments which can be observed by scientists. The term empiricism in the discussions of NOS is broader as it also views science as unchangeable and separated from society. Nor does the term imply that those who adhere to the constructivist view on science believe that doing experiments is not an important part of science. Constructivism as a view on the Nature of Science can be confused with constructivism as a learning theory (the difference is discussed below). There are many terms almost used interchangeably for empiricism and constructivism. Empiricism has also been named as positivism, logical positivism or logical empiricism. Positivism, however, denotes a more extreme position which states that sensory perception is the only source of knowledge, and therefore has a more negative connotation than empiricism. Logical positivism and logical empiricism both combine positivism with rationalism, stating that both logic and sensory perception are needed for the practice of science[2]. Constructivism can also be referred to as antipositivism, stressing its opposition to positivism, or more negatively as relativism. To avoid using judgmental terms, we neither use the terms naïve and informed or traditional and contemporary views.

3.2.2 Views on NOS and teaching practice

This study is concerned with the relationship between the views a science teacher has and what happens in the classroom. This question not only

[2] http://plato.stanford.edu/entries/logical-empiricism/

entails whether teachers would teach their personal views of the Nature of Science in class but also whether their teaching practice changes in terms of making science personally relevant for students, doing experiments or sharing control over learning goals with the students. In this study, we want to find out whether a teacher teaches in a constructivist way or not. The term constructivism is not only used to describe a particular view of the Nature of Science but also a particular learning theory that stresses that the learner should construct knowledge with the help of pre-existing knowledge. This leads to a pedagogy that stresses the use of pre-existing knowledge, conceptual learning and doing experiments as an alternative to authority based teaching that often is the norm in science classrooms (Phillips, 2005).

A readily-made assumption is that teachers would teach their students the ideas about science they hold themselves. It would also be logical to assume that teachers who have a constructivist view of the Nature of Science would teach in a constructivist way and that empiricist teachers would teach in a more traditional teacher-centered way where practical work, if used, is conducted to demonstrate and consolidate understanding of the material presented. However, there is a controversy in the literature whether this is really the case. A number of studies did indeed find such a correlation (Laplante, 1997; Tsai, 2002; Tsai, 2007), but several other studies often found that ideas about science and about teaching science were incongruent with what happened in the classroom (Tobin & McRobbie, 1997; Water-Adams, 2006). Studies that found such a correlation, as well as those that did not are discussed below along with the possible reasons for the presence or absence of such a correlation.

Several studies offer clues as to why some teachers teach in accordance with their own beliefs and others do not. Tsai (2002) interviewed 37 Taiwanese science teachers and categorized their beliefs about teaching, learning and the Nature of Science as either 'traditional', 'process' or 'constructivist'. About half the teachers had traditional views in all three areas, meaning that they believed that teaching is best done by transferring knowledge directly from teacher to student, that learning science consists of acquiring knowledge and that science provides correct answers. Constructivist views and views in which the processes of science were central for teaching, learning and the Nature of Science were central, were far less common. A total of 57% of all teachers had 'nested' beliefs, meaning that their beliefs of teaching, learning and the Nature of Science were congruent with each other. Teachers with few years of experience were less likely to have nested beliefs than more experienced teachers, perhaps because they were less likely to take traditional approaches, thus reducing their chances of congruency. More experienced teachers were also more likely to be able to juggle with the demands of the curriculum, potentially leading to a more congruent presentation of the relationship between their beliefs about teaching, learning and science.

Similar results have been found in smaller qualitative studies. In a follow up study, Tsai (2007) selected 4 from his initial 37 science teachers and found that their educational background was an important factor that determined for a part whether they taught in a constructivist manner or not. A highly empiricist teacher, a highly constructivist teacher and two teachers which fell in-between these two extreme teachers on the empiricist to constructivist dimension were specifically selected for this study. The constructivist teacher had far more background in science education than the empiricist teacher. The most constructivist teacher spent by far the most of his time (52%) on interactive discussion and on small group inquiry activities, while the most empiricist teacher spent only 2% of his teaching time on these activities. The empiricist teacher spent far more time on one way lectures and problem practice. Along these lines, Laplante (1997) studied two Canadian teachers who did not succeed in teaching in a constructivist way and concluded that "teachers cannot be expected to model and teach how to be a knower in science any differently from how they themselves know in science" (p. 290).

In a questionnaire study on 35 Palestinian science teachers, (Hashweh, 1996) found considerable differences between constructivist teachers and empiricist teachers and the ways they dealt with the alternative conceptions students had. It was found that teachers with constructivist views were more likely to detect alternative conceptions among students and in turn were more able to teach for conceptual change. They spent more time refuting the alternative conceptions students had and restructuring the reasoning of the students. These teachers thereby used a larger repertoire of teaching strategies than the empiricist teachers who restricted themselves to explaining and convincing their students of the correct theories.

While the above studies all found a correspondence between classroom practice and views on the Nature of Science, many other studies failed to find such a correspondence (Mellado, 1998; Saad & BouJaoude, 2012; Tobin & McRobbie, 1997; Water-Adams, 2006). Mellado (1998) analyzed the views on NOS of four preservice teachers and compared those with observations of science classes and found no correspondence between the two. An in-depth qualitative study by Tobin and McRobbie (1997) on a single teacher drew the same conclusion, but also found that the views on NOS of the students did not concur with the enacted curriculum of the teacher. In a larger scale study of 34 Lebanese science teachers, it was found that most teachers had restricted views of NOS and unfavorable views on science enquiry and that there was no consistent relationship between views of Nature of Science and classroom practice (Saad & BouJaoude, 2012). After not finding a link between views and practice of four primary school teachers in the UK, Water-Adams (2006) concluded that this relationship cannot be understood without considering wider beliefs about teaching, learning and the curriculum. Along with Water-Adams, there are others who believe there are mediating factors that complicate the relationship between views and practice. Often, there are barriers restricting teachers from teaching according to their personal vision of education, the most important barrier being the demand to cover a curriculum in which NOS is not stressed. Apart from curriculum demands, some other determining factors have been found. Lederman (1999) studied five teachers who had the freedom to emphasize parts of the curriculum that they chose to. Still, the extent to which teachers discussed the Nature of Science in class was mediated by several factors, such as experience and perceptions by students. Not only experience seemed to be a determining factor but also the school level the teacher taught in. Pomeroy (1993) did a study on the views on Nature of Science and included scientists and both primary and secondary school teachers. The primary school teachers had more constructivist views on the Nature of Science than the secondary school teachers. No other study has yet repeated these findings. Studies on views on nature science and teaching practice have not yet reached a consensus, thus still necessitating further research on this relationship.

3.2.3 International differences in views on NOS and teaching practice

As reviewed by Alexander (2001), there is a long tradition in international comparative studies on education dating back to at least 1817. These studies range from the large scale international surveys into student knowledge to small scale studies on school practice and policy. For the present study, we restricted ourselves to reviewing only those international studies that investigated either the teaching practices of science teachers specifically or their views of the Nature of Science. This is still a small area of research and the studies we found took place in other countries than the countries involved in our research.

While the majority of studies found differences between nations in practices or teacher views on the subject, science education turns out to be remarkably similar in some respects, such as curricula (Cobern, 1996). Innovations in science education often originate in Western Europe or the United States and from there spread to other parts of the world (Tobin, 2011). Therefore, schoolbooks and study methods in non-Western countries are often adaptations of European or American books.

Greater country differences have been found with respect to how teachers adapt these curricula in their own classes and regarding what they find important in their teaching. For instance, Gao & Watkins (2002) conducted research on physics teachers in China and compared those to findings on American teachers. Chinese teachers considered performance on standardized tests as the most important indicator of good teaching and were more concerned with the development of good learning attitudes while American teachers focused more on creating interest in science among their students and on facilitating learning of science. In a similar vein, Aldridge, Fraser, Taylor and Chen (2000) conducted research on the teaching practice of teachers in Australia and Taiwan with the Constructivist Learning Environment Survey (CLES). The CLES is an instrument which measures what science teachers do in their classrooms and to what degree the actions of those teachers are in line with constructivist views on learning. In their study, students judged the learning environment provided by their teachers. There were significant differences between Australia and Taiwan for the various scales that were measured by the CLES. Most notably, Taiwanese teachers paid more attention to the uncertain, tentative nature of scientific theories and Australian teachers allowed their students more opportunities to voice critique.

Several more studies have been conducted on international differences in views of the Nature of Science. For instance, Park and Lee (2009) conducted research on the views on Nature of Science of preservice teachers in the United States and Korea and made comparisons of the views along various dimensions. In several respects, the teachers in both countries were similar to each other. In both countries, teachers were on the whole more relativistic than positivist and thought of science as a process of scientific discovery rather than in terms of content. The American teachers, however, believed to a greater extent that scientific discovery was an inductive process, while Korean teachers had a more deductive view of science. Aikenhead and Otsuji (2000) compared Canadian teachers who taught aboriginal students to Japanese teachers who taught Japanese students. In many ways, the two groups of teachers had comparable ideas about science, for instance, both groups saw science as an activity. However, the Canadian teachers were more reductionist and the Japanese teachers had a more holistic view of science, not seeing a separation between humans and nature.

Taken together, the studies that are discussed above lead to the conclusion that whereas there are many international comparative studies on education, few of these studies address views on NOS of science of teachers in relation to their teaching practice. This relationship has so far been investigated in several countries, mostly countries from North America, Europe and East Asia, but much less in the rest of the world. Despite the evidence for the existence of international differences in practice and views, the studies have not yet reached a consensus on the relationships in practices and views on NOS. Furthermore, the studies often relied on small numbers of respondents. The present study aims to contribute to this line of research by addressing the mentioned limitations.

3.2.4 Research questions

When reviewing the previous studies and the various gaps in the literature, we came to the three following research questions for the present study. The first question is: *how do the teachers in the six countries that took part in the study differ in their views about the Nature of Science?* Based on the literature reviewed in the background section and the results of a previous study on views of NOS of students (chapter two), we expect substantial differences in views between the countries. We expect that teachers from countries outside Western Europe tend to have more empiricist views on the nature of science than teachers from the UK and the Netherlands. The second question is: *how do the teachers from these six countries differ in their perception of their own teaching practice?* Considering the different cultures of these countries and the corresponding differences in education systems, we do expect substantial differences in perception of practice. Previous studies have found cases in which teaching practice was congruent with the personal views of the teacher as well as cases in which this relation was incongruent; therefore we cannot hypothesize the exact nature of these differences. Considering the international differences we expect to find for the first two research questions, the third question is: *is there a relationship between having a particular view on the Nature of Science and teaching practice?*

3.3 | Methods

3.3.1 Sample

Teachers were sampled in primary and secondary schools in the United Kingdom, the Netherlands, Turkey, Lebanon, Malaysia and India. This questionnaire study was part of a larger research project investigating science education for 10 to 14 year old students. The primary school teachers all recently taught the last two classes of primary education. The secondary school teachers had experience in teaching the first two classes of middle school or high school. The selection of schools was done by local teams of researchers and attention was paid to variety in school location (urban, suburban or rural) and population (social economic status) to ensure a sample which is indicative of the diversity of teachers within a country. A total of 331 teachers completed the questionnaire. The number of teachers per country and the ratio of primary and secondary teachers varied. The Netherlands and Lebanon only had a small number of respondents while Malaysia and Turkey had many (Table 3.1). Similar large differences between the countries existed in the distribution of less and more experienced teachers and of male and female teachers. In all countries, secondary school teachers had had more formal education and more education in science than the primary school teachers.

Several matters further complicated the data collection. In India, all teachers that completed the questionnaire were from schools in the Mumbai region as it was not possible to collect data in the entire country. These schools did teach students from a variety of different social and economic backgrounds. In several countries, such as the Netherlands and Lebanon, it turned out to be very difficult to find primary school teachers who wanted to participate in the research project. In order to take the aforementioned differences between samples into account, teacher background variables were included in the analyses as covariates.

Table 3.1
Number of respondents

	Number of teachers	Percentage of total number of teachers	Primary school teachers	Secondary school teachers	Less than 10 years of experience	10 years or more of experience	Female	Male
United Kingdom	34	10.3 %	13	21	29	5	18	16
The Netherlands	21	6.3 %	2	19	9	12	10	11
Turkey	94	28.4 %	30	64	24	70	56	38
Lebanon	24	7.3 %	4	20	13	11	17	7
Malaysia	110	33.2 %	35	75	60	50	83	27
India	48	14.5 %	6	42	11	37	41	7
Total	331	100.0 %	90	241	146	185	225	106

3.3.2 Instrument

A questionnaire was designed to include a large number of different questions about personal views on the Nature of Science, teaching goals and perception of teaching practice. In order to enable measurement of this large variety of variables in a reasonably short period of time per teacher, it was decided to mainly use questions with a three to four point Likert-type answering scale. To find out the personal views of teachers on Nature of Science, 7 NOS statements were included on which teachers could indicate whether they agreed strongly, agreed, disagreed or disagreed strongly (see Table 3.2). Teaching goals were measured with 10 items about pursuing and meeting 5 different NOS goals such as teaching that science is an activity that involves creativity and imagination and teaching that science is tentative (for all statements, see Table 3.3). To measure how teachers perceived their own teaching practice, several adapted questions of the Constructivist Learning Environment Survey (CLES) (Johnson & McClure, 2004; Taylor, Fraser, & Fisher, 1997) were included in the questionnaire. Questions from a teacher version of the CLES (Johnson & McClure, 2004) were further adapted by omitting several superfluous items and slightly changing the wording of several items. For instance, all questions were phrased in such a way that they applied only to science lessons and not to all classes given by the teacher, thereby making the questionnaire applicable for primary school teachers. The questionnaire was originally in English. For use in countries where English was not the language of instruction (the Netherlands, Turkey and Malaysia), the questionnaire was translated into local languages by one researcher and translated back into English by another to check for possible mistranslations.

It was necessary for further analysis to condense the items into a smaller number of scales. Factor analysis was carried out in SPSS to construct and test scales. Factors were extracted with principal components analysis and varimax rotation with Kaiser normalization. The number of factors to be extracted from each factor analysis was determined by Scree plots. When the Scree plot showed that additional factors could not explain significantly more variance, no more factors were extracted. Factor analysis was first conducted with the entire international sample and later repeated with single country samples to check for cross-national stability. All single country factor analyses yielded factors that were composed of the same items as the overall factor analysis across all six countries. All items from which scales were constructed used a four point Likert scale. Several of these items were recoded so that the most positive (most agreeing with the statement, statement happening most often) gave the highest score of 4 and the most negative answer gave the score of 1. In the one case in which an item contributed to more than one factor, the item was added to the scale to which it contributed most.

A first round of factor analyses was done on the 7 items about the Nature of Science. Two factors were identified, one for constructivism and one for empiricism, showing that these two beliefs are not two mutually exclusive ends on a continuum (Table 3.2). A factor analysis which yielded only one factor could explain only 37% of all variance. The addition of a second factor increased the explained variance to 61%. The empiricism factor was composed of two items which were clearly empiricist and which contributed much to the factor and two more constructivist items which contributed far less to the factor. The item about technology was added to the constructivism scale.

Table 3.2
Views on the Nature of Science (rotated factor loadings)

Items	Factor	
	Constructivism	Empiricism
Science is about natural phenomena that are the same everywhere		.842
Eventually evidence will convince us which theory is correct		.836
Scientists bring different theories giving different interpretations		.422
Science is not value free because questions affected by funding agencies	.798	
Science is not value free because questions and methods affected by what scientists think are important	.845	
The way science is done is affected by the technology available	.648	.417
Scientists from different cultures consider different questions because of their background	.727	
Cronbach's alpha	.765	.626

Notes. The 2 factors explained 61.0% of all variance. Rotation converged in 3 iterations.

Two more factor analysis were done on a series of 10 items about teaching Nature of Science goals and on the 23 items of the Constructivist learning environment survey which measures to which degree the learning environment a teacher creates is constructivist or not. The items about pursuing and meeting 5 different Nature of Science goals were all put together in a single factor analysis (Table 3.3). On these items, teachers could indicate whether they always, frequently, rarely or never pursued and met the teaching goals. One single factor was extracted. This single factor shows that teachers pursued and met all NOS goals to the same degree and that there is no strong differentiation between the goals. There is thus no subset of goals that is only adopted by a particular set of teachers while other teachers adopt other goals. Further analysis indicated that the majority of teachers gave similar scores for corresponding statements about meeting and pursuing goals. A large number of teachers gave themselves lower scores for meeting goals than for pursuing goals.

Table 3.3
Pursuing and Meeting Nature of Science Goals (rotated factor loadings)

Items	Factor Pursuing and Meeting Nature of Science Goals
Pursuing the teaching goal 'Science is an activity that involves creativity and imagination'	.622
Meeting the teaching goal 'Science is an activity that involves creativity and imagination'	.639
Pursuing the teaching goal 'Students should be taught cultural/historical background of the development of science'	.716
Meeting the teaching goal 'Students should be taught cultural/historical background of the development of science'	.766
Pursuing the teaching goal 'Students should be taught that science uses a range of methods'	.758
Meeting the teaching goal 'Students should be taught that science uses a range of methods'	.801
Pursuing the teaching goal 'Students should know that science is tentative'	.778
Meeting the teaching goal 'Students should know that science is tentative'	.811
Pursuing the teaching goal 'Students should know that science is often the result of group activity'	.799
Meeting the teaching goal 'Students should know that science is often the result of group activity'	.810
Cronbach's alpha	.915

Notes. 1 factor was extracted which explained 56.7% of all variance

The last factor analysis was done on the items belonging to the adapted version of the Constructivist Learning Environment Survey (Table 3.4). On these items, teachers could indicate whether the statements occurred, always, frequently, rarely or never. The extracted factors were composed of exactly the same items as in previous studies that used the CLES and could be given the same names; personal relevance, uncertainty, critical voice, shared control and student negotiation (Taylor et al., 1997). Personal relevance is the degree to which teachers connect out-of-school experiences of the students with school science. The uncertainty scale assesses whether the teacher provides opportunities for students to experience science as knowledge derived from theory-laden inquiry that is influenced by culture and values and that changes over time. The critical voice scale measures whether the teacher provides an environment in which students feel free to question the teachers' pedagogical plans and methods and express concerns about impediments to learning. The shared control scale assesses the extent to which the teacher shares control with the students of the learning environment, including the learning goals, the design and management of learning activities and the assessment criteria. Student negotiation measures to which degree the teacher provides opportunities for students to talk to other students, explain their ideas and listen to other students.

Table 3.4
Constructivist Learning Environment Survey Factors

In my class…	Factor				
	Personal Relevance	Uncertainty	Critical Voice	Shared Control	Student Negotiation
… new learning starts with problems about the world outside the classroom	.590				
… students learn how science can be part of their out-of-school life	.826				
… students get a better understanding about the world outside school	.774				
… students learn that science has changed over time		.693			
… students learn that science in influenced by people's values and opinions		.737			
… students learn that different sciences are used by people in different cultures		.609			
… students learn that modern science is different from the science of long ago		.726			
… students learn that science involves inventing theories		.575			
… it's OK for the students to ask why do I have to learn this			.724		
… it's OK for the students to question the way they are being taught			.770		
… it's OK for the students to complain about activities that are confusing			.800		
… it's OK for the students to complain about anything that prevents them from learning			.791		
… it's OK for the students to express an opinion			.468		
… students help me to plan what they are going to learn				.735	
… students help me decide how well they are learning				.602	
… students help me decide which activities are best for them				.775	
… students help me decide how much time they spend on activities				.729	
… students talk with other students about how to solve problems					.627
… students explain my ideas to other students					.765
… students ask other students to explain their ideas					.752
… students listen carefully to another's ideas					.735
… students share examples from their own experience					.693
Cronbach's alpha	.649	.750	.802	.833	.832

Notes. 5 Factors were extracted which explained 60.0 % of all variance. Rotation converged in 7 iterations.

3.3.3 Analysis

Analysis of the data for the first two research questions was done with a combination of comparisons of mean scale scores and analyses of variance (ANOVA). All data was entered in the computer program SPSS. The data contained a small percentage of random missing data, which was added with the help of the expectation maximization function in SPSS.

In order to answer the third research question about the relationship between views on the Nature of Science and teaching practice in the six participating countries, multilevel analysis of variance was performed. Multilevel analysis makes use of statistical hierarchical linear regression models. The models are hierarchical in the sense that they employ different levels. The models employed in this study make use of three different levels: country, school and individual teacher. Each teacher belongs to a school which is situated in a country and these higher levels partially determine the practice and beliefs of that teacher. Multilevel analysis calculates the percentage of variance which can be attributed to each level. Multilevel analysis was carried out with the computer program MLWin.

For the multilevel analysis of each of the analyzed scales, an empty model was constructed as well as a significant model in which all explanatory variables that improved the explanatory power of the model were included. In the empty model, no possible explanatory variables were added to the model. This model assumes that all respondents would have the same scores for the end variables, irrespective of their background or the answers that were given on other questions. This is, of course, not a good description of reality since teachers had scores that are higher or lower than this predicted score. Therefore the model shows a large degree of variance at each level and a high value for the model to data difference denoted by -2 loglikelihood.

The explanatory power of the model increases by addition of explanatory variables. Here, constructivism and empiricism (as NOS views) were added to the model, as well as the type of school the teacher worked in (primary or secondary education) and the years of experience a teacher had (more or less than 10 years of experience). Experience was included in the model because we suspected that more experienced teachers would teach differently than inexperienced teachers for instance by succeeding to meet more goals in their teaching. Not all of these explanatory variables improved the model and only those contributing significantly were included in the end model.

Table 3.5.
Multilevel Analysis Models

	Empty model	Significant model
Factors under analysis	- Pursuing and meeting NOS goals	- Pursuing and meeting NOS goals
	- Personal Relevance	- Personal Relevance
	- Uncertainty	- Uncertainty
	- Critical Voice	- Critical Voice
	- Shared Control	- Shared Control
	- Student Negotiation	- Student Negotiation
Explanatory variables		- Empiricism
		- Constructivism
		- Primary/Secondary Education
		- Experience

3.4 | Results

3.4.1 International differences on views on the nature of science

To find out how views on the Nature of Science differed around the world, we compared the mean country scores for the constructivism and empiricism scales with each other (Figure 3.1). In Figure 3.1, a score of 4 means strong agreement with all the items of the scale, a score of 1 strong disagreement. From figure 3.1, one can learn that teachers generally tend to agree with the statements put forth, since the mean scores are all over 2.50. Nonetheless, there are large differences between the countries. An East-West division seems to be present among the countries. The teachers from the two Western European countries, the United Kingdom and the Netherlands are the most constructivist and least empiricist. The two most eastern countries, Malaysia and India are the least constructivist and Lebanon and Turkey score in between. While India has a very high score for empiricism, this is not the case for Malaysia. Analysis of variance showed statistically significant differences between countries for both constructivism ($F(5,325)=3.82$, $p=.002$) and empiricism ($F(5,325)=6.47$ $p=.000$). Post hoc Scheffé test were used to find out which countries differed statistically significantly from one another. For constructivism, post hoc Scheffé tests showed that, at $p<0.05$, the UK scored significantly higher than India. For empiricism, it was found that the UK scored significantly lower at $p<0.05$ than Lebanon, Turkey and India.

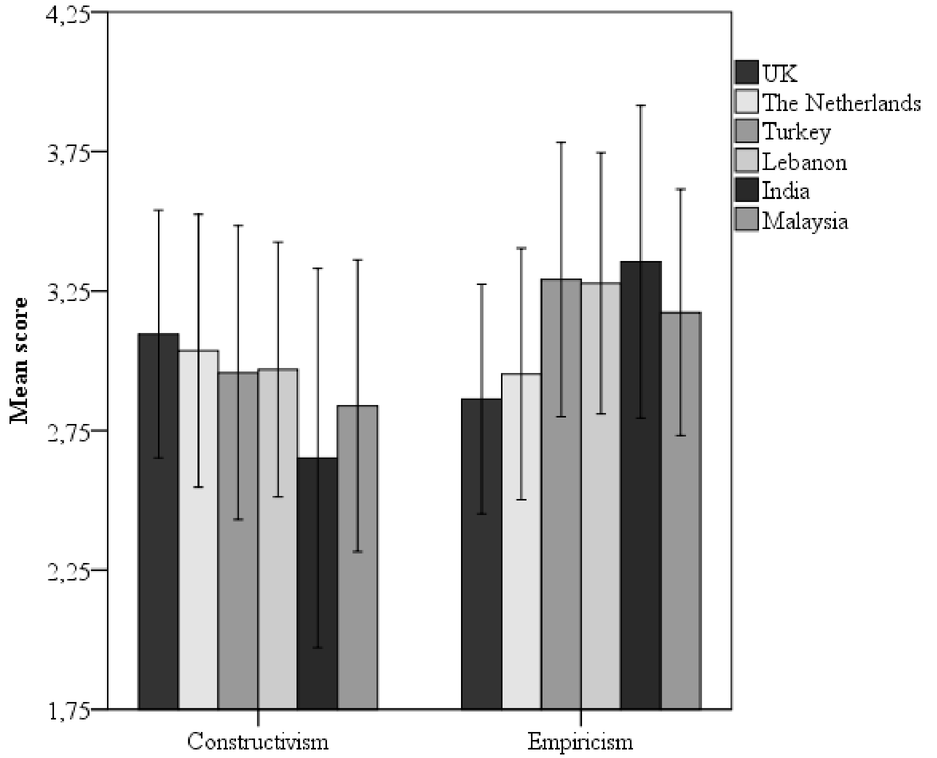

Figure 3.1. Views on the Nature of Science
Mean scale scores for teachers belonging to one of the six partner countries. Scales were constructed with items that appeared in the same factor in factor analysis. The error bars represent 1 standard deviation.

3.4.2 International differences in teaching goals and perceived teaching practice

In order to find out how teaching style differed around the world, the mean country scores for the scale for pursuing and meeting NOS goals and the five scales of the constructivist learning environment survey were compared with each other (Figures 3.2 and 3.3). Figure 3.2 shows that most countries scored somewhere between rarely and frequently for pursuing and meeting NOS teaching goals. The United Kingdom, Lebanon and Malaysia all found themselves around the international mean. Turkish and Indian teachers indicated they pursue and meet goals such as teaching the tentativeness of science and teaching about the cultural and historical background of science to a greater extent than teachers from any of the other countries. Out of the four countries that scored below the international mean, the Netherlands stood out as the country in which teachers incorporated the least NOS goals in their teaching. ANOVA showed statistically significant differences between countries ($F(5,325)=16.92$, $p=.000$). Post hoc Scheffé tests showed that (at $p<.05$), the Netherlands scored significantly lower than all other countries, and that the UK scored significantly lower than both Turkey and India.

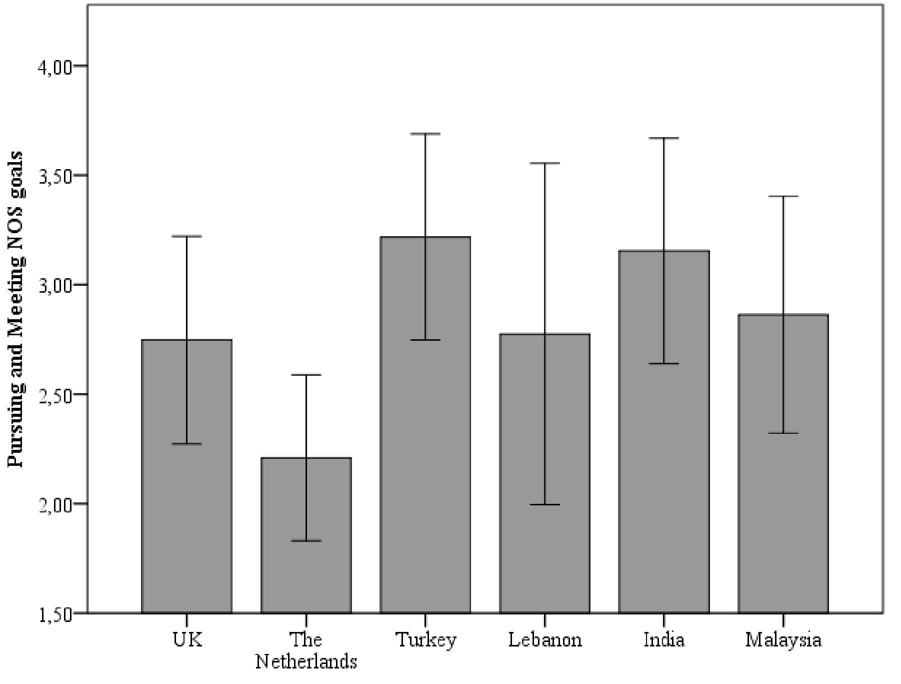

Figure 3.2. Pursuing and meeting NOS goals.
Mean scale scores for the scale for pursuing and meeting NOS goals. The error bars represent 1 standard deviation.

There is not a single clear pattern in the international results for the perceived teaching practice (Figure 3.3). Overall, not one country can be singled out for having particularly constructivist learning environment which contradicts the findings about the views teachers have (Figure 3.1) and the degree to which they incorporate NOS teaching goals. There are, however, some interesting outlying scores. The Netherlands, for instance, scored high on allowing critical voice and low on sharing control with students, negotiating with students and teaching about the uncertainty of science. ANOVA showed statistically significant differences between countries for *personal relevance* (F(5,325)=4.15, p=.000), *uncertainty* (F(5,325)=5.21, p=.001), *critical voice* (F(5,325)=3.54, p=.004), *shared control* (F(5,325)=4.98, p=.000) and *student negotiation* (F(5,325)=3.96, p=002). Post-hoc Scheffé tests showed that (at p<.05), the Netherlands was the country which scored significantly different from the others countries. For *personal relevance*, it was significantly lower than Lebanon, for *uncertainty* lower than India and Turkey, for *critical voice* higher than Malaysia and Turkey, for *shared control* lower than India and the UK and for *student negotiation* lower than Lebanon, the UK and India.

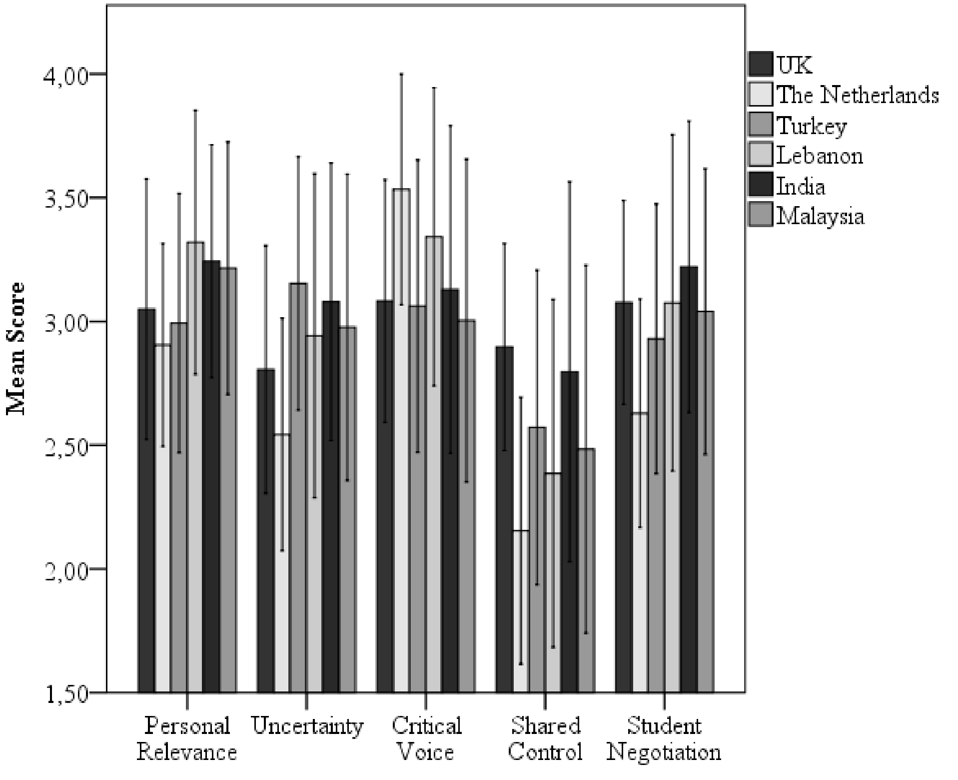

Figure 3.3. Constructivist Learning Environment Survey scales.
Mean scale scores for all CLES factors for all six participating countries. The error bars represent 1 standard deviation.

3.4.3 Relationships between views on the nature of science and perceived teaching practice

From the previous analyses, it does not seem apparent that there would be a straightforward relationship between having a particular view of science and teaching according to that view. After all, the teachers in the countries that appeared most constructivist in their approaches to NOS (the United Kingdom and the Netherlands, see Figure 3.1) did not incorporate the most NOS teaching goals or perceived themselves to provide the most constructivist learning environment in their classes (see Figure 3.2). If anything, there seems to be an inverse relationship. Multilevel analysis was used to find out whether there was a statistically significant relationship between views on the Nature of Science (empiricism and constructivism) on the one hand, and teaching the Nature of Science (teaching NOS goals) and the learning environment (the 5 CLES scales) on the other. In the multilevel analysis, the behavior in the classroom, the teaching goals and the 5 CLES scales, were used as the resulting end variables in the models. The personal views of the teachers (constructivism and empiricism) and their personal characteristics (experience and school type) were used as input in these models to explain classroom behavior.

The empty models in Table 3.6 show that most variance in teaching practice can be found at the individual teacher level (67 to 89%) and that a smaller percentage of the variance is identified with the school level (0 to 13%) or the country level (2% to 23%). This means that despite the country differences found in previous analyses (Figures 3.2 and 3.3), there is an even larger variation in teaching style among teachers from the same country. Of all the scales, the one for pursuing and meeting NOS goals appeared to show most variance at the country level.

The addition of background and NOS variables to the significant model improved the models over the empty models. In Table 3.6, it can be seen, that teachers with more than 10 years of experience had a scale score for 'Critical Voice' that is on average 0.225 higher than those with less than 10 years of experience. A higher score of 1 on constructivism means that the teacher scored 0.165 higher on the scale for 'Critical Voice'.

Empiricism turned out to have a larger impact on most scales in the significant model than constructivism did. Empiricism had a significant effect on 5 of the 6 scales (NOS goals, personal relevance, uncertainty, shared control and student negotiation) while constructivism had a significant effect on only one scale (critical voice). Surprisingly, in the cases where empiricism had an effect, those with empiricist views turned out to be more constructivist in their teaching. The only exception was ‘Critical Voice’ where having constructivist views led to more constructivist teaching.

Generally, the addition of NOS variables to the model had a relatively small impact on the self-rated scores for learning environment, as can be seen by the modest reductions in variance and -2 log likelihood. The largest effect was that of empiricism on teaching NOS goals, which was able to explain 13% of its variance, about half of the explained variance at the country level and the other half of the variance at the individual teacher level. In comparison, personal relevance could only be explained by empiricism for about 3%.

School type had an impact on two learning environment variables, shared control and student negotiation. In both cases, teachers from secondary schools perceived themselves as less constructivist than teachers from primary schools. Experience played a role in teaching the uncertainty of science, dealing with critical voice and student negotiation. In all these cases, the more experienced teachers had a more constructivist perception of the learning environment.

Table 3.6.
Multilevel analysis of NOS goals and constructivist learning environment survey scales

Empty model	Pursuing and meeting NOS goals	Personal Relevance	Uncertainty	Critical Voice	Shared Control	Student Negotiation
Country	0,085(0,055) 23,3%	0,012(0.010) 4,5%	0,027(0.022) 7,8%	0,009(0.011) 2,3%	0,031(0,026) 6,3%	0,009(0,011) 2,8%
School	0,034(0,016) 9,3%	0,000(0.000) 0%	0,028(0.017) 8,0%	0,031(0.019) 8,1%	0,032(0,023) 6,5%	0,043(0,019) 13,1%
Teacher	0,246(0,021) 67,4%	0,257(0.020) 95,5%	0,293(0.025) 84,2%	0,344(0.030) 89,6%	0,429(0,037) 87,2%	0,275(0,024) 84,1%
-2 log likelihood	522.580	496.494	566.025	613.313	687.652	553.509
Significant model						
Emp.	0,331(0,058)	0,174(0,057)	0,172(0,064)		0,145(0,076)	0,209(0,062)
Constr.				0,165(0,060)		
Secondary					-0,381(0,090)	-0,209(0,073)
Experience			0,208(0,065)	0,225(0,070)		0,131(0,064)
Country	0,060(0,040) 16,4%	0,010(0,009) 3,7%	0,008(0,010) 2,3%	0,012(0,012) 3,1%	0,024(0,021) 4,9%	0,013(0,013) 4,0%
School	0,033(0,015) 9,0%	0,000(0,000) 0%	0,034(0,018) 9,8%	0,025(0,018) 6,5%	0,036(0,023) 6,5%	0,022(0,015) 6,7%
Teacher	0,224(0,019) 61,4%	0,250(0,020) 92,9%	0,278(0,024) 79,9%	0,329(0,028) 85,7%	0,402(0,035) 81,7%	0,270(0,023) 82,6%
Percentage explained	13,2%	3,3%	8,0%	4,7%	6,9%	6,7%
-2 log likelihood	491.897	487.410	549.579	597.522	667.980	533.938
Reduction in -2 log likelihood	30.683	9.084	16.446	15.791	19.672	19.571

Notes: Experience and school level are dichotomous categories (low and high experience, primary and secondary education) and the effect is shown here for high experience (more than 10 years) and secondary education. Standard errors are given between brackets.

3.5 | Conclusions and discussion

Our international study on the views and the teaching practice of teachers in six different countries has yielded several seemingly contradictory findings. Teachers in countries outside Western Europe were found to have more empiricist and less constructivist views on the Nature of Science than Dutch and British teachers (Figure 3.1). The teachers from the UK were significantly more constructivist than Lebanese, Turkish and Indian teachers. The opposite was the case for the incorporation of NOS goals in teaching. Here, the Netherlands scored significantly lower than all other countries and the UK scored lower than Turkey and India (Figure 3.2). In almost all cases, countries scored above the scale medium on the scales of the constructivist learning environment survey (Figure 3.3), which is comparable to the findings of a previous international study using the CLES (Aldridge et al., 2000). However, no clear pattern in this study between the countries could be identified for these scales.

Multilevel analysis confirmed this relationship between having an empiricist view of science and pursuing and meeting teaching goals that are essentially constructivist in their nature, such as teaching that science is creative and teaching that science uses a variety of methods (Table 3.6). Furthermore, empiricism had an effect on more scales of the constructivist learning environment survey than constructivism (5 vs 1), further showing that having empiricist and not constructivist views on the Nature of Science leads to more constructivist perceptions of one's own teaching. The multilevel analysis also showed that most variance could be attributed to the individual level which is fairly typical for multilevel analysis. This finding suggests that teachers are individuals who greatly differ from their colleagues in their own school. Nonetheless, part of the variance could be identified at the school and country levels, showing that there are similarities between teachers with the same background.

How should we interpret these findings? The finding that teachers in Turkey, Lebanon, India and Malaysia had views that were more empiricist and less constructivist than the Dutch and British teachers are in line with other studies which have found empiricist views among teachers outside Western Europe (Iqbal et al., 2009; Irez, 2006). These results are also comparable with findings of the student data of the SED project (chapter two) which displayed a similar pattern among *students* with Turkish, Lebanese, Indian and Malaysian students being more empiricist and less constructivist than Dutch and British students. Students from Western Europe were, for instance, more likely to see scientific explanations as tentative than students from outside Western Europe. Students and teachers from the same country are thus comparable to each other in their beliefs on the Nature of Science.

According to the questionnaired teachers, teaching Nature of Science and teaching science in a constructivist way however, is a more prominent goal of science education in for instance, Turkey and India than in the Netherlands. This is the opposite of what one would expect. Constructivism as a learning theory originated in the United States and Western Europe so Dutch and British teachers are more likely to have been most exposed to the principles of constructivism. In a similar way, research on Nature of Science has primarily taken place in the United States and Europe and in those countries, the call for integrating Nature of Science in the curriculum has been the strongest. Moreover, Dutch and British teachers had personal opinions that were rather constructivist and which were not clearly reflected in their perceptions of the extent to which they pursued and met constructivist NOS goals. This was most particularly the case for teachers from the Netherlands, where constructivist personal opinions appeared to contradict less constructivist teaching goals.

One possible drawback of this study lies in the fact that we had to rely on self-report. Because it was impossible to do extensive classroom observations for all teachers who participated in the study, we had to rely on how teachers themselves perceive their own teaching. It has been found that teachers perceive their own classes very differently than how their own students perceive them (den Brok, Bergen & Brekelmans, 2006). Teachers also have a more positive perception of the classroom environment than their students (Fraser, 1994). Teachers may thus report on how they believe they teach or how they believe they should teach rather than on what they actually do in the classroom. The degree to which the perception of teachers matches the reality may even differ per school or per country, further complicating the interpretation of the results that were found.

One possible explanation for the results lies in the fact that the teaching methods and books used by the teachers in the Middle East and Asia are adapted from or heavily influenced by curricula that originated in the

United States or Western Europe (Cobern, 1996; Tobin, 2011). Science textbooks are therefore remarkably the same over the world, not only due to colonial legacies but also due to neoliberal tendencies to make education comparable around the world (Tobin, 2011). Constructivism has been proposed as a way of making science education more independent of Western culture (Cobern, 1996), although the degree to which curricula in different countries have adopted constructivist teaching approaches is not yet clear. If teaching materials were adapted from Western European or American sources which were constructivist in nature, this could explain the disconnect between personal beliefs and teaching practice as teachers would teach in more constructivist ways than their beliefs would prescribe, and therefore perceive their own teaching as very constructivist.

Teachers and students in the same country thus have similar views on the Nature of Science (chapter two). However, as teachers do not teach according to their own views, it is unlikely that students shape their beliefs directly by what they are taught in class. A possible explanation why teachers and students seem to share comparable views is that both share a similar culture that is present in the country and that stresses a certain view of science. This does, however, not imply that teaching has no impact on the views of students and several studies have found that explicit training in teaching the Nature of Science can change both personal opinion and class practice (Akerson et al., 2000; Schwartz & Lederman, 2002).

The most difficult finding to explain is why multilevel analysis shows that teachers with empiricist views scored higher on pursuing and meeting NOS goals and four of the five scales of the CLES (Personal Relevance, Uncertainty, Shared Control and Student Negotiation). Of the five CLES scales only one, the Uncertainty scale, is truly about teaching aspects of the Nature of Science. The other scales are about teaching style and should be seen as aspects of constructivism as a learning strategy rather than a particular view on how science works. Apparently, teachers who believe that science is certain and unchangeable, pay attention to the personal relevance of their lessons and share and negotiate control with their students.

The correlation between empiricism and NOS teaching that was found in multilevel analysis is even harder to grasp. If teachers would not teach according to their own convictions but according to an approved curriculum, as it is often the case (Tobin & McRobbie, 1997; Water-Adams, 2006), one would expect a lack of correlation. It further needs to be stressed that we found that constructivism and empiricism were not two direct opposites on a linear scale. According to the factors that were found in this study, teachers could be at the same time constructivist as well as empiricist, believing that science is in principle stable, universal and unchangeable, yet at the same time realizing that there are cultural and social impacts on science.

The finding that more experienced teachers turn out to be more constructivist in their teaching when it comes to teaching about uncertainty and allowing student critique (Table 3.6), is in line with a study by Tsai (2002), who found that more experienced teachers succeed more often in teaching according to their own views and were better at meeting the many different demands of the curriculum. It is more difficult to explain why primary school teachers were shown to negotiate more and share more control with their students than secondary school teacher. Perhaps this is because the structure of primary school lacks strict timeslots for each course which may allow teachers to be more flexible and student centered. A further possibility is the increase in high-stakes testing in Science for secondary students which means that teachers are likely to restrict student control in order to ensure the required syllabus is covered.

One of the limitations of this study is, as stated before, that teachers may have given socially desirable answers to the questions, stating that activities take place more often than they really do. The teachers' perceptions of what is desirable is interesting data in itself, revealing differences between beliefs about the NOS and what is believed to be desirable in relation to teaching approaches. However, given that the tendency to give socially desirable answers may differ with nationality, age and school type and given that our sample is very diverse, it is difficult to suggest *how* socially desirable answers may have impacted the data. A possible follow up study would include interviews and perhaps observations of classroom practice to validate whether teachers really teach according to their own statements.

Another limitation of the study is that, even by including over 300 teachers, the sample contained only a small number of primary school teachers from some of the countries. This could mean that the sample is not representative for each country. The different ratio of primary and secondary school teachers does not affect the multilevel analysis because school type was included as a possible explanatory variable.

This study has several implications for science education research. First of all, it shows that constructivism and empiricism are not two mutually exclusive categories which need to be placed at the extremes of a continuum and that teachers can hold simultaneously both constructivist and empiricist views. This means that teachers who agreed with empiricist statements do not necessarily disagree with constructivist statements, calling into question previous studies on Nature of Science of teachers that placed people on a continuum with empiricism and constructivism at its ends (Deng et al., 2011). It further adds to the research on science education outside Western Europe and the United States and how education there differs from the American and European practice.

The study has some further implications for science education itself. It calls into question the assumption that teachers teach according to their own views and stresses the importance of not only providing teachers with tools and strategies to bring teaching NOS in their classrooms, but also by changing their personal views and getting them acquainted with contemporary views of the Nature of Science. These two goals are both challenging as there is often little time available in the curriculum to devote to teaching NOS and attempts at changing personal beliefs will surely meet with resistance. However, previous studies have shown that it is possible to achieve both these goals (Akerson et al., 2000; Schwartz & Lederman, 2002).

CHAPTER 4

Interest in science and ideas about science among 10 to 14 year old Dutch students[1]

ABSTRACT

Concerns have been raised in the Netherlands about the low number of primary and secondary school students interested in taking science classes. In order to make science education more appealing for Dutch students, it is necessary to better understand the interests in and views of science that different groups of students within the Dutch student population have. The present study focuses on Dutch students in the age group of 10 to 14 years and aims to find out whether they hold an interest in science, how students can be profiled according to their interest and whether the groups of students with different profiles differ in their views on science. A total of 40 primary and secondary school students were interviewed about, among others, reasons why they liked or disliked science courses, the views they had of science and their opinions on scientists and the role of science in society. We divided students into four different groups: students interested in the content of science, students interested in activities related to science, students disinterested in science and a fourth group of students who neither liked nor disliked science but who were mostly unfamiliar with science. Of all the groups identified, this fourth group was the largest. Students of this group typically liked particular topics or activities but disliked other aspects of their science classes. This last group of students also had limited views of what science is and what scientists do and by addressing these views in education, their interest in science could be increased.

---

[1] This article has been submitted for publication as:
van Griethuijsen, R. A. L. F., & van Eijck, M.W., Haste H. & den Brok, P. J. (submitted). *Interest in science and ideas about science among 10-to 14 year old Dutch students.*

4.1 | Introduction

In the Netherlands, as in many other countries around the world, there is a concern among educators and policy makers that young students are not sufficiently interested in science and technology. Several studies suggest that among Dutch students, interest in science is lower than among students of other comparable countries. This has been found both in studies that compare the number of students enrolled in science tracks or science studies (Organization for Economic Co-operation and Development (OECD), 2012; Ministry of Education, 2009) and in other surveys in which interest in science, or more specifically interest in school science, has been investigated in multiple countries (Programme for International Student Assessment [PISA], 2007). It is not well understood why so many students in the Netherlands seem to lack an interest in science or science courses.

The Programme for International Student Assessment (PISA) study in 2006 included several questions about interest in science (PISA, 2007). On questions about interest in various science disciplines such as astronomy, chemistry and physics, Dutch students finished last among all countries that participated in the study. They also agreed less with statements such as 'I like reading about science' and 'I am happy doing science problems' than students from any other participating country (PISA, 2007). The Netherlands performed well in the PISA test that measured competence in science, ranking a ninth place, well above the average for OECD countries. Similar low levels of interest were found for interest in obtaining an education in science. A study by the Organization for Economic Co-operation and Development (OECD) ranked the Netherlands last among 37 countries for the percentage of 15 year olds planning a career in engineering or computing. The country had a slightly better 22nd place for students planning a career in health services (OECD, 2012).

Low interest in science and science studies is also reflected in the number of students entering science studies. As a percentage of the total number of students, the Netherlands has one of the lowest number of science and technology graduates and very low numbers of female graduates in sciences such as physics or engineering (Ministry of Education, 2009). In a previous paper that drew its data from the same research project as this chapter, it was found with questionnaire data that Dutch students were statistically significantly less interested in science than British, Turkish, Lebanese, Indian or Malaysian students (chapter two).

The low position of the Netherlands in international comparative studies on interest in science and school science begs the questions whether one can speak of a “Dutch case” and whether Dutch students are exceptional in their lack of interest in science education (Bosch, 2002). In some ways, the Netherlands is not exceptional and is comparable to other countries in the Northwestern part of Europe such as Sweden and Finland, which also display low interest in science among secondary school students (PISA, 2007). From a socioeconomic point of view, these countries are also comparable to the Netherlands. Nonetheless, Dutch students appear still considerably less interested in science than their counterparts in neighboring countries such as Belgium and Germany which are in many other ways comparable to Dutch students.

To better understand the Dutch situation, it may be necessary to look beyond a simple categorization of students as either interested or disinterested in science. As such, several studies have identified different groups of students with different types of interest in science. Haste (2004) found four types of students among 11 to 21 year olds. Apart from the young people that were oriented towards science and those that were alienated from science, there were groups of students that were specifically interested in green topics and in technology and new developments in science. A popular model among practitioners to classify Dutch students into interest groups is the ‘BètaMentality model’ (Platform Bèta Techniek, 2010) that distinguishes between four groups: science students who are mainly intrinsically interested in science, the career-oriented science students who are primarily interested in science because of the careers they can have after taking science courses, students who are interested in science because they want to help people to have a better life (society-oriented students) and the students who are explicitly not interested in science. While this model is popular among teachers, it is not based on any scientific research. In these models, interest in science is inextricably linked with a specific view of science. Those who are interested in science classes because of the opportunities science offers to solve problems likely have a more optimistic view of science than the students who dislike all aspects of science.

In the study described in this chapter, interviews were conducted with Dutch students in the age group of 10 to 14, in order to find out empirically which groups of students can be discerned in the Dutch student population in terms of interest in science and school science. Students were asked not only whether they found their science courses interesting but also whether they enjoyed extracurricular activities related to science and whether they would be interested in having a job related to science. We further asked questions about views on science, the nature of the job of a scientist, the usefulness of science and the importance of science. This was done in order to obtain a comprehensive view on variables related to interest in and views of science.

In the background section, we further discuss what is currently known about interest in science among primary and secondary school students, the role gender plays in interest in science and the role of the transition between primary and secondary education. Furthermore, the situation in the Netherlands is discussed, including a discussion on whether the Netherlands is exceptional in its disinterest in science and which explanations have been provided for the Dutch situation thus far.

4.2 | Background

4.2.1 Interest in science among primary and secondary school students

Generally, interest in science decreases when students become older. Studies from different countries have shown that the most important phase when students lose interest in science is between the ages of 10 and 14 (Barmby, Kind & Jones, 2008; Bennett & Hogarth, 2009; George, 2006; Krapp & Prenzel, 2011; Osborne, Simon, & Collins, 2003). It has been found that this is also the case for school science in the Netherlands (van Amelsvoort, 1999). Among 10 year old students, opinions on science are generally favorable, as are the opinions on other courses. However, during a period of 4 years, students become more critical of their classes and for many students, science classes fall out of favor. From age 14 on, interest in science seems relatively stable. This time period corresponds roughly with the last two years of primary education and the first two years of secondary education.

4.2.2 Explanations for decreasing interest

Several studies have looked into the changes between primary and secondary school that lead to a decrease in interest among students. A number of explanations have been given for decreasing interest in science and many of these explanations deal with the transition between the two school types and the accompanying changes in instruction (Braund & Driver, 2005; Ferguson & Fraser, 1998; Logan & Skamp, 2008). For instance, students disliked losing the close student-teacher relationship they had during their primary school years (Speering & Rennie, 1996). Furthermore, students enjoyed the teaching methods that were employed by their new teachers less than those in primary school. Generally speaking, secondary school science classes involve more note-taking, copying from a textbook and listening to the teacher and include less hands-on experiments (Logan & Skamp, 2008; Speering & Rennie, 1996). Many students often describe science classes as boring, referring not only to the teaching methods but also to the topics that are discussed in class, indicating that the more factual and mathematically oriented approach to science is not liked by all students and that students do not consider the science classes they receive relevant (Speering & Rennie, 1996). It has also been shown that in some schools and classes in which student interest is taken into account and in which opportunities are created to do many experiments, students do not lose their interest in science (Logan & Skamp; 2008; Vedder-Weiss & Fortus, 2011).

However, it is not possible to attribute the decrease in interest in science entirely to the transition from primary to secondary education. As several researchers have pointed out, even before students move to secondary school they start losing interest in science (Murphy & Beggs, 2003; Pell & Jarvis, 2001). Additional factors play a role, such as perceived ability to achieve good grades in a course, whether studying science fits well with one's identity and how peers perceive science classes (Logan & Skamp, 2008).

Van Amelsvoort (1999) found that the decrease in interest in science among Dutch students happened regardless of the quality of instruction provided by the teachers. In other words, even in classes where teachers were successful in making science appealing for their students, some decrease in interest took place. Some of the features of the Dutch school system can partially explain why few Dutch students end up studying science. Dutch students have to choose at a younger age (around 14 or 15 years old) whether or not they want to continue with their science courses than in surrounding countries and once the decision has been made not to take science courses, the possibility of entering science education is severely limited (van Langen & Dekkers, 2005).

4.2.3 Gender differences in interest in science

A gender effect is noticeable between girls and boys in their appreciation of science courses in secondary education (Jones et al., 2000). In secondary education, interest in science decreases more among girls than among boys. Moreover, girls and boys tend to be interested in different aspects of science. Girls tend to have a preference for biological topics and boys for physical sciences and technology (Jones et al., 2000). For some secondary school girls, science classes are only taken because they enable a further career in health care (Miller et al., 2006).

Part of the overall low interest in school science in the Netherlands stems from the low participation of girls and women in science education. Whereas in almost all countries there are fewer girls than boys who share an interest in science, especially in the 'harder' sciences such as physics or engineering, the Netherlands turns out to be a country in which exceptionally few women study science (Ministry of Education, 2009). While several explanations have been offered, there is not a clear single explanation for this phenomenon (van Langen & Dekkers, 2005). The early choice for a science stream at an age at which girls are in puberty and most susceptible for peer pressure has been argued to be an explanatory factor for this phenomenon. Another possible argument is that science jobs have an image of being difficult and demanding which will scare away female students, especially in the Netherlands where few women work full-time (van Langen & Dekkers, 2005). Historical and cultural explanations have also been given for the Dutch situation, linking the absence of Dutch women in science to Dutch Protestantism and religious segregation (Bosch, 2002).

4.2.4 Students' views on science

A popular explanation for disinterest in science is that students have stereotypical and negative views of science and scientists. There have been a large number of studies into the views primary and secondary school students have of science and of scientists (Christidou, 2011; Finson, 2002). Most of these studies found that students generally have incorrect or incomplete ideas about what science is. Studies that have looked into the Nature of Science (NOS) views of primary and secondary school students have routinely found that these students do not have views of science that are in line with contemporary understandings of NOS. Students often do not know the difference between laws and theories, think of scientific theories as unchangeable and true and think of science as distinct from the society in which it is practiced. There are, however, also several studies that have found students do have a good understanding of several aspects of science. Silver and Rushton (2013) have shown that primary school students perceive a difference between science and technology and Zhai, Jocz and Tan (2014) found that students know rather well that there is a difference between science as it is learned in school and as practiced by scientists in a lab. Students also realize that one needs different skills for being a successful scientist and for being good in science in school (Shanahan & Nieswandt, 2011).

Students neither have contemporary ideas about scientists and the type of work that scientists do. The well-known 'Draw-a-scientist' experiment has, since the late 1950s, routinely shown that students have stereotypical views of scientists (Finson, 2002). Scientists are usually drawn as male, middle-aged, bearded, eccentric and wearing glasses and a white lab coat and holding beakers. Scientists are seen as working solitary and their jobs are seen as mainly involving mixing chemicals with the possibility of creating explosions. This perception of a scientist has been found among students from different genders, ethnic groups, nationalities and age groups (Finson, 2002).

A possible explanation for the Dutch situation is that Dutch students have more negative perceptions of science and scientists than their counterparts in other countries. A previous paper that drew on the data of the SED project of which this paper is also a part, found a connection between interest in science and views about science (chapter two). Those students that were most interested in science believed that science was able to solve most problems in life and thought that scientists worked in teams and worked creatively. Furthermore, students that were interested in science had a broader concept of what science is, regarding more aspects of natural, social and applied science to be part of science. This large study into interest in science among 10 to 14 year olds that took place in the United Kingdom, the Netherlands, Turkey, Lebanon, India and Malaysia, found that students in countries outside Western Europe were generally more interested in the science courses they received in class (chapter two). Furthermore, these students were also more interested in having a job related to science and technology and in extracurricular activities related to science, such as visiting science museums and watching TV programs about science. In addition, a positive correlation between interest in science and having a particular view of science as more broad and optimistic was found. Students who believed that science could solve most problems in life, a view that is more predominant in countries outside Western Europe, were on average more interested in school science than other students. Students who believed that the job of a scientist was creative and collaborative had a more positive stance towards science courses and even were more interested in having a job related to science themselves.

Most of the studies discussed here investigated student interest in science and school science quantitatively and did not make a distinction between school science and science as it is practiced outside school or between different types of interest in science. It is not clear whether there are really very few students in the Netherlands interested in science or whether there are groups of students who hold an interest in science that are not or only partially met in their science classes.

4.2.5 Research Questions

The goal of this paper is to find out which types of students can be identified among Dutch 10 to 14 year old students and to find out how students in these groups view science. To find this out, we conducted interviews with 40 students in both primary and secondary education. The first research question is: *what interest in science has the group of interviewed students and are there differences between the genders and between primary and secondary students?* The second research question is: *how can the interviewed students be grouped according to their interest in science?* The third and last research question is: *are there differences in the views on science that the different groups of students hold?* By investigating views of science and scientists, attention is paid to those areas in which previously have been found to impact interest in science such as the usefulness of science, the view of science as collaborative and creative and the broadness of scientific disciplines (chapter two).

4.3 | Method

4.3.1 Sample

We sampled 40 students in the age group of 10 to 14 year old and therefore selected students in the last two classes of primary school en the first two classes of secondary school to participate in this study. Two primary schools and two secondary schools took part in the study (see Table 4.1). It was attempted to create a sample that represented the diversity found within the Dutch school population. Two non-religious as well as one Catholic and one Protestant school were included in the sample. Students came from a range of socioeconomic backgrounds. The Dutch secondary school system divides students in several different streams according to academic aptitude in the first year of secondary education. Students from all the three different streams[2] were included in the sample.

Table 4.1

Interview sample

	Number of students interviewed	Female students	Male students
Primary School 1	11	3	8
Primary School 2	9	5	4
Secondary School 1	10	5	5
Secondary School 2	10	5	5
Total	40	18	22

Interviewers had no pre-existing knowledge about the interviewed students. Students were selected for the interviews by their teachers, who were instructed to select a subset of their students that was representative of their classes in terms of interest and achievement (to avoid a sample of only high achieving students in science or students uninterested in science). A roughly

[2] Secondary education in the Netherlands is split into different streams, pre-vocational education, higher general secondary education and pre-university education. Students are placed into one of these streams according to their abilities.

equal number of primary and secondary and male and female students were interviewed (Table 4.1). Both the students and their parents had received letters about the study and given permission for the interviews. The interviews were confidential and were conducted in private rooms so that what was being said could not be overheard by other students or teachers. Interviews were recorded on audiotape and transcribed verbatim.

4.3.2 Interviews

Interviews were conducted according to a structured interview protocol. The interview protocol was originally developed in English by an international team of researchers and has been translated into Dutch by the authors. To check the translation, the interviews were also translated back into English. After the development of the interview protocol, it was tested with two 10 year old Dutch students for comprehensibility.

The interview protocol contained open-ended questions about various forms of interest in science: interest in science courses students followed in school, interest in visiting science museums and interest in working with science in a future job. Students were asked what their favorite course was and why and what their least favorite course was and why. Furthermore, students were asked directly whether they liked their science courses, what they liked about their science courses and whether they liked all of their science courses or whether there were specific activities and topics they preferred. To investigate whether interest in extracurricular science activities differed from interest in school science, students were asked whether they enjoyed visiting science museums and whether they preferred learning in science museums over learning about science in school. Students were also asked what kind of job they would like to have when they are adults, whether that job was related to science or not and whether they liked or disliked having a job related to science. Additionally, four questions were asked about how students saw scientists. Students were asked whether they could give reasons why they would or would not want to become scientists themselves and whether they would or would not like it if they were married to a scientist.

Several questions about views on science were included in the interview protocol. We focused on several aspects of science that had proven salient in a previous study (chapter two): the work of a scientist and the usefulness and importance of science. Students were asked whether or not they found science useful and if they could give examples why science is useful. In a similar way, students were asked whether they found learning science important and if they could give reasons why learning science is important. To explore the views on scientists in greater detail, several questions were included about the work of a scientist. Students were asked to describe the work that a scientist does on a daily basis. Furthermore, students were asked whether they believed that scientists work alone or in a group and if such a group would have a leader or not. To find out what students considered to be science, students were asked to think of courses that resembled or in some way were related to science. All the student interview questions that have been used for this study are listed in Table 4.2.

4.3.3 Analysis

All interviews were transcribed verbatim. A coding scheme was developed on the basis of the transcribed interview data via the constant comparative method (Strauss & Corbin, 1990). The data was analyzed per question. For each question, the 40 responses by students were gathered and 3 to 6 codes were identified. After coding all the interviews, the student data with the accompanying codes were transferred to a matrix in which every row contained the data of one student and every column stood for one of the codes. This allowed ultimately for the identification of four different groups on the basis of the codes assigned to different questions about various interests in science. The coding and grouping procedure was discussed and verified by a senior researcher who agreed with the codes and groups that were identified. After identification of the groups, the scores of the different groups on all codes were checked for statistical significance with Chi-square analysis.

Table 4.2
List of student interview questions used in this study

Number	Question
1	What is your favorite lesson?
2	What do you like in that lesson?
3	Tell me about something that you did in class that you enjoyed very much.
4	Which class do you like least?
5	What do you think about nature and technology, science, biology, physics and chemistry?
6	Do you like all classes of science of just a couple?
7	Do you think it is important to learn about science? Why or why not?
8	Do you learn about science outside school, by visiting science museums or science centers?
9	Do you like this way of learning about science? Is it more interesting than science class at school? Why?
10	Can you think of something that you have learned at school that is for things outside school?
11	Do you think that science is useful outside school?
12	When you are grown-up, what kind of job would you like to have? Why would you like to have that job?
13	What would you like to do daily during work?
14	Do you think that the job you mentioned is related to science? In which way?
15	Would you like to have a job which is related to science?
16	When I give you the sentence “I would like to be a scientist, because …” How would you finish that sentence?
17	Now suppose I said, complete the sentence, “I would not like to be a scientist because…”?
18	Now supposing I said, complete the sentence, “I would like to marry a scientist because…”?
19	Supposing I said, complete the sentence, “I would not like to marry a scientist because…”?
20	Imagine a typical day in the life of a scientist, what would they be doing each day?

4.4 | Results

4.4.1. Interest in school science

In total, 12 of the 40 students said they had a science course as their favorite course. Out of these 12 students, 2 students had 2 or more favorite courses of which science was one of them. An additional 4 students said that arithmetic or mathematics was their favorite course. In primary school, the science course that was picked most often as a favorite course was technology whereas in secondary school, the most picked science course was biology.

In some schools, interest in science courses was greater than in other schools. In one primary school, 4 students named a science course as their favorite while in the other school only 2 did so (all 6 students named technology as their favorite course). In one secondary school, 4 out 10 interviewed students had a science course as their favorite (biology for all four of them) and in the other secondary school only 2 students had as science course as their favorite (a combined course in physics and chemistry). The preference for different courses thus strongly depended on the school environment. The reasons for liking science courses also differed per school subject. Technology was primarily liked because of the activities involved while biology was mainly liked because of its content.

Interviewer:	What is your favorite course?
Student:	I like technology the most. The courses, yes, I like that the most. And mathematics. And for the rest, I like them but not more than the others.
Interviewer:	And what do you like about those courses?
Student:	With technology, you make everything yourself. You can carry out your own fantasies. You can simply make everything. People think that it is boring but it is not boring at all. Everybody can discover something about technology. (12yr old boy, primary education)

Interviewer:	What is your favorite course?
Student:	Biology. I am just good in it and I enjoy learning what people are made of. Sexual education, which we had some time ago, was interesting. Simply, what animals and people are made of. (14 year old girl, secondary education)

Only three students said that a science course was their least favorite course and an additional 6 students had mathematics as their least favorite course. Science was disliked because it was considered to be difficult, because of the teaching style of the teacher and because it included many calculations. Mathematics was primarily disliked because it was considered to be difficult.

Interviewer: What is your least favorite course?
Student: Physics. Because you have to make a lot of calculations. And you have to just understand it and if you do not understand it, there is not much you can do. (14 year old boy, secondary education)

Interviewer: What is your least favorite course?
Student: Science, because the class is very disorganized and he does not really explain very much. (14 year old girl, secondary education)

Students were also asked whether they liked all of their science classes and whether there were certain topics that they enjoyed more than other topics. Few students disliked all of their science classes.

Interviewer: What do you think of your science classes?
Student: Boring.
Interviewer: Ok and why do you find it boring?
Student: I don’t know, I have nothing with technical things and putting stuff together. No, it is not my thing.
Interviewer: And what about biology or about molecules, and things like that?
Student: Molecules? What are those?
Interviewer: The particles of which everything is made.
Student: No, it is not interesting to me.
Interviewer: So even if you do not have to put things together, you do not like it?
Student: No. (13 year old girl, primary education)

When prompted to say whether they disliked all of their science lessons, even students who had a science course as their least favorite course, admitted that they liked some aspects of their science classes. More specifically, students told that they enjoyed doing experiments and they were generally more favorable towards biology than physics or chemistry. In some cases, students made a selection of different topics within a subject that they liked.

Interviewer: Do you like all science classes or just a few?
Student: No, not really all.
Interviewer: Which ones do you like and which do you not like?
Student: For example, when it is about animals and people and the human body. But about molecules and so, that I do not understand and I find it boring. I do not like that so much. (12 year old boy, primary education)

Interviewer: Do you like all science classes or just a few?
Student: Chemistry and physics I like the most. I also like biology but I am a bit behind at the moment but I also find it interesting. It is just different than the normal courses, mathematics, Dutch. You have to find out things on your own and do experiments. (13 year old girl, secondary education)

Interest in science learning activities outside school was greater than interest in learning science in school. Three quarters of the students said that they had visited a science museum in their life. Most of the students were enthusiastic about their visits to science museum and described them as interesting and offering them opportunities to do experiments.

Interviewer: Have you ever learned about science by going to science museums or science centers?
Student: Yes, I like that.

Interviewer: And what is fun about going there?

Student: Mmmm, it is a bit science made fun for children. You can do things, discover things on your own. That is fun.

Interviewer: More fun than at school?

Student: Yes.

Interviewer: Why?

Student: Because at school, you have to sit in a chair all day and you have to listen to the teacher. That is a lot less fun than walking around on your own in a museum and discovering things on your own. (boy, 14 years old, secondary education)

The question about jobs related to science revealed that not all students who enjoyed science in school were interested in having a job related to science. Out of the 40 students, 10 students were interested in a science-related job. An additional 8 students would like to have a technology related job in the future.

Interviewer: When you are an adult, what kind of job would you like to have?

Student: Archeologist or something with technology.

Interviewer: And what do you like about those jobs?

Student: As an archeologist, you go to other countries and you find fossils and then you can show people where you have been and what you have done. And with technology, you improve the world and most of the time you have made an invention and then you can show it to people and you have done something good for the world. (12 year old boy, primary education)

4.4.2 Grouping of students according to their interest in science

Based on inspection of the qualitative case matrix, four groups of students could be discerned on the basis of their interest in science: (1) students who hold an interest in science mainly because of the *content* of science, (2) students who are interested in science mainly because of the *activities* related to science, (3) students who are *disinterested* in science or even dislike science and (4) students who are interested in *some but not all aspects* of science. The composition of the groups is outlined in Table 4.3. Chi square analysis showed that the four groups differed statistically significantly from each other in the number of boys and girls (Pearson Chi square 9.99, significance of 0.02) with the groups interested in content and interested in activities of science having more boys. There was no statistical significant difference in the number of primary and secondary school students between groups. Furthermore, the groups differed statistically significantly from each other in the degree to which science courses were chosen as favorite courses (Pearson Chi square 9.77, significance of 0.02), the degree to which students liked or disliked science courses (Pearson Chi square 36.91, significance of <0.01), whether they wanted to have a job in science or in technology (Pearson Chi square 13.17, significance of 0.01) and whether they would enjoy learning new things (Pearson Chi square 8.55, significance of 0.04). All these codes were more often present in the answers of the groups of students that were interested in the content or interested in the activities related to science. There were differences in other codes, but due to the small number of interviewed students, these were not statistically significant. The four groups are discussed in greater detail below.

Table 4.3
Composition of the 4 groups of students discerned on the basis of their interest

	Students interested in science content	Students interested in science activities	Students disinterested in science	Students partly interested in science
Number of students	11 (27.5%)	9 (22.5%)	6 (15.0%)	14 (35.0%)
Number of primary school students	5 (45.5%)	6 (66.7%)	2 (33.3%)	8 (57.1%)
Number of secondary school students	6 (54.5%)	3 (33.3%)	4 (66.7%)	6 (42.9%)
Number of male students	8 (72.7%)	8 (88.9%)	1 (16.7%)	6 (42.9%)
Number of female students	3 (27.3%)	1 (11.1%)	5 (83.3%)	8 (57.1%)

Students interested in the content of science

There were 11 students who were mainly interested in science because of the topics they learned about in school and in their spare time. This group was mostly made up of boys. There were both primary and secondary school students in this group. Many of the students in this group had a science course as their favorite course and said that they liked all or most of their science classes. Almost all students in this group were also interested in having a job related to science.

Content was a running thread in the interviews with these students. Many of these students had a science course as their favorite course and for most of them the content of the course was the reason why they picked that course. When further asked what they enjoyed about their science classes, these students typically responded with a science topic such as the human body. The same is true for the answers to questions in which students were asked to describe something in school they recently enjoyed. Science museums were typically described as interesting or a good opportunity to learn new things. The students in this group did not exclusively give answers about content. There were a number instances in which students said that they enjoyed something, e.g. visiting a science museum, because of the related activities. However, answers about content predominated. The work of a scientist was also predominantly viewed through the lens of content. When asked what they would consider appealing about the work of a scientist, many students answered that they enjoyed discovering new things and a few students said that they would enjoy learning new things.

Students interested in the activities of science

There were 10 students who were primarily interested in science because of the activities related to science they did in school or as extracurricular activities. For many of these students, technology was their favorite course and when asked why they liked technology, they responded with a description of an activity. The majority of the students in this group were also interested in having a job that was related to technology, such as a designer of cars or a software engineer. This group was mainly made up of boys and with 8 boys and only 1 girl (see Table 4.3), giving it a gender distribution that was even more skewed than that of the group that was primarily interested in science for content reasons. There were mainly primary school students in this group.

The students in this group and those in the group of students interested in the content of science shared an interest in science and technology but there were important differences between the two groups. When asked whether they enjoyed visiting science museums, students in the content group described science museums as interesting due to its content while students in the activities group said that they enjoyed science museums because of the hands-on activities. Similar trends were found in the answers to the question what the students would enjoy about being a scientist. Again, not all answers were strictly about activities, there were students who answered with a topic or said that they found science museums interesting. However, there were few of these instances, even fewer than the cases in which content-oriented students admitted to enjoying activities.

Students disinterested in science

The students who were disinterested or strongly disliked science were the smallest group with only 6 students. These students either said that they strongly disliked science or that they were simply not interested in science. All but one of the students in this group were female.

None of these students had a science course as their favorite course and several said that a science course was their least favorite course or that they disliked all science courses. Out of the six students, three said that they enjoyed some aspects of science courses, but these were only minor aspects of science, such as specific lessons about the human body. The students gave more examples why they did not like other science courses, for instance by stating that they disliked any class involving experiments or formulas. None of the students in this group had any interest in having a job related to science.

Students with a mixed interest in science

The group of students who held a mixed interest in science were with 14 students the largest group of students in this study. This group had more or less equal numbers of girls and boys and of primary and secondary school students (Table 4.3). Unlike the groups that were either interested or disinterested in all aspects of science, the interest in science of the students in this group depended strongly on the course, topic or activity. There were a few students in this group that had a science course as their favorite course, but at the same time had another science course as their least favorite course. Several of the students said that they found science to be difficult or that studying science took much effort and that this decreased their interest in science. A large number of students in this group (6 out of 14) said that they had never visited a science museum. Those who had visited a science museum liked those primarily because of the activities.

Most students in this group did not yet have a clear idea about their future. None of the students in this group said that they were planning to have a job that was related to science. However, as a group, the students were not entirely dismissive about science jobs when asked to list positive aspects of being a scientist. Several students said that doing research would be enjoyable. In addition, there were students who were externally interested in the work of a scientist, mainly because of the associated money and fame.

4.4.3 Relationship between interest in science and views on science

It was found that there were differences that approached statistical significance between the four groups in how students perceived the usefulness (Pearson Chi square 6.53, significance of 0.09) and importance of science (Pearson Chi square 7.54, significance of 0.06). Both codes were most often present in the answers of the group that was interested in the content of science and least in the answers of the group that held no interest in science. No differences were found in the way students viewed the work of scientists.

The answers to the questions about the work of a scientist were remarkably the same for all four groups. Almost all students said that they believed that scientists would mostly work in groups and that these teams would normally have a leader. In some cases, students said that scientists would work on their own on problems, but they would still be part of a team to which they would present and discuss their results when doing so. The descriptions of what the work of a scientist entailed were also very similar for students from the four different groups. Most students said simply that scientists would do research or would invent new machines. Many students had difficulties with giving more elaborate descriptions of the work of a scientist. When prompted to describe how exactly scientist would perform their research, students typically failed to give any further descriptions.

Students were asked whether they found science important or not. Most students, even those disinterested in science, said that they found science important. The students interested in science content found science the most important. They responded that science was not only important for careers but also as general knowledge.

Interviewer: Do you consider learning science to be important?

Student: Yes, it is important because you learn how to calculate something. And you can do a lot with it if you continue studying it. You can do important things, for instance calculating the size of the galaxy. (Boy, 14 year old, secondary education, content group).

Interviewer: Do you consider learning science to be important?

Student: A little bit.

Interviewer: A bit. Not so much and why a bit?

Student: I hope that I will not need it so much later on but you always need it a little bit. Always.

Interviewer: As for instance… For what would you need it?

Student: For instance, if you become a doctor, then you have to know what has happened and where something has happened. Or as a firefighter, that is different. (Boy, 12 year old, primary education, mixed group).

Similar answers were given to the question whether science is useful. Students in the content and activities groups were mostly likely to say that science was useful, either for use in and around the home, as general knowledge or as career preparation. Students in the disinterested group said that science had very little use and the students in the mixed group mainly thought of science as useful in and around the home.

Interviewer: Do you think think that science is useful for your life or that of your family?

Student: Yes, enough. Mmm, let’s think. The logical thinking about normal events. The insight. Yes, because I want to continue with science and I like explaining how things have originated. (Girl, 14 years, secondary education, activities group)

Interviewer: Do you think that science is useful for your life or that of your family?

Student: About technology and everything, yeah. Yes, I don't really know.

Interviewer: Not something that you have learned at school of which you think, when I am at home, I can do something with that knowledge?

Student: Well, a few things about technology, about how things are made, I looked that up on the internet a few times. Yes, that's it pretty much.

Interviewer: And the other sciences?

Student: Yes, a little bit, but not for me because, I don't know.

Interviewer: Not for you? Why not for you?

Student: No, because I really like sports more and those things and then I am more …. I don't know, I just don't like it.

Interviewer: But for other people, it is useful?

Student: Yes, for people who like those things. (Boy, 11 year old, primary education, mixed group)

4.5 | Conclusions and discussion

Four different groups of students were identified in this study: students interested in the content of science, students interested in activities related to science, students disinterested in science and students interested in some aspects of science but not in others. Students were grouped into these groups on the basis of their answers to a variety of questions about interest in science. For the groups who liked science for the content or the activities, content and activities were running threads in their answers. This means, for instance, that students, who liked their science courses for their content, also enjoyed learning new content in science museums and would enjoy being a scientist because this would enable them to learn new things. Students disinterested in science strongly disliked all aspects of science and would drop science courses as soon as possible. Students of the fourth group were interested in some aspects of science such as biology and doing experiments and not in others such as physics. The existence of a this large fourth group of students shows that interest in science is not as black and white as one would expect. The science education these students receive is likely not sufficient to keep these students interested in science but the right curricula and activities could help to maintain or increase interest.

Other studies have identified similar groups of students when investigating interest in science. A British study also identified 4 different groups of students among 11 to 21 year old students (Haste, 2004). Three of these groups, the “science-oriented”, “techno-investor” and “alienated from science” correspond roughly with the content, activities and uninterested groups identified in this study. The main difference was the presence of a “green” group in the study of Haste (2004) that was mainly concerned with nature instead of the group with a mixed interest in science. The BètaMentality model, used by a Dutch organization that has promoting science and technology as a goal, includes 4 different groups: concrete technology oriented students, career oriented science students, non-science students and people-oriented generalists (Platform Bèta Techniek, 2010). These groups partly correspond with the four groups found in this study. The most important difference is that the group of career oriented science students has taken the place of the group of students who are intrinsically interested in the content of science. This could be the case because an older subset of students was described in the BètaMentality model (12 to 24) and job prospects could be a more important factor for these students than for the students in the age group of 10 to 14.

This study confirmed the existence of gender differences in interest in school science with male students being the most interested in school science (Bennett & Hogarth, 2009; Jones et al., 2000; Osborne et al., 2003). The two groups with the students that were most interested in school science both had far more male than female students. The group that strongly disliked school science was mostly made up of girls.

Furthermore, the study confirmed that many students have stereotypical ideas about science and scientists or no ideas about science at all. This was true for those students who are uninterested in science or have a mixed interest but also, to a lesser degree, for those students who hold an interest in science. Most students could not give reasons why science differs from other subjects or could not give adequate descriptions of what a scientist does. When asked to describe the work of a scientist, most students said that a scientist would work in a lab and do experiments. When pressed to describe the activities in more detail, most students could not say what areas of research scientists were working in or what their experiments would be like. A large number of students gave stereotypical descriptions of scientists. Scientists were, for instance, described as overly occupied with work and antisocial. Older students did give more elaborate descriptions of the work of a scientist but did not have less stereotypical ideas about scientists. There was no gender division in this respect.

As a group, the interviewed students in this sample were generally more interested in science than could be expected on the basis of previous studies. For instance, about 40% of the students said that a science course was their favorite course whereas this was only the case for 22% of the students in a related questionnaire study (chapter two). International surveys and the percentage of students taking science courses also point towards a smaller interest in science among Dutch students than this study suggests (Ministry of Education, 2009; PISA, 2007).

A possible explanation for the relatively positive findings in the present study is that students are more positive about their science courses when interviewed than when they fill in an anonymous survey. When giving students the time to talk about their courses, most of them mentioned aspects of science that they enjoyed. The interviewed students were also given the possibility to name more than one course as their favorite course. There were very few students in the group that disliked science altogether. The largest group that was identified in this study was the group of students with a mixed opinion of science. These students did not love every aspect of science or disliked science as a discipline altogether, but rather picked certain topics or activities that they enjoyed or not. The positive view on school science in this study could also be attributed to the sampling procedure. Teachers may have selected students that were not representative in terms of interest or achievement. Another possibility is that students tend to be more positive about science and more hesitant to utter negative statements when sitting opposite a researcher being interviewed than filling in a questionnaire anonymously.

The findings in this study have several implications for science education. The study implies that interest in science depends on the views students have of science and scientists. These views can be shaped by teachers and curriculum developers by including or excluding elements in their courses that students enjoy. It was found that many students have stereotypical views of scientists and this can be easily addressed in class. This is particularly important for the large group of student with a mixed interest in science. The students who are uninterested in science will probably not continue with science courses and those students who are very interested are not likely to completely lose their interest. With the right instruction and interventions, student in the mixed group may maintain or increase their interest in science. Students in this group said that they enjoyed experiments and mentioned that they would want to do even more experiments. A large number of students in this group said that they had never visited a science museum and therefore never had an experience that could have increased their interest in science. There were also a number of students in this group that were interested in science for extrinsic reasons rather than intrinsic reasons. Several students said that they would like to have the job of a scientist for the associated money and the extrinsic benefits of jobs related to science and technology may not always be discussed well enough in science classes. Furthermore, this study made clear that most students have stereotypical or very limited views of science and scientists and that there is a need to counter stereotypes in class.

CHAPTER 5

Teachers' views on teaching science and diversity

Abstract

Teachers in primary and secondary education face the task of making science and technology education appealing for a diverse group of students with very different interests in science. In the Netherlands, a large group of students is neither very interested nor disinterested in science classes and only have a limited understanding of what science is and what scientists do. Whether these students will lose or gain an interest will depend strongly on the view of science developed in school. The research presented here was conducted to find out how teachers in the Netherlands think of diversity in their classrooms and how they present science in their classes. A total of 14 Dutch primary and secondary school teachers were interviewed for this purpose. Teachers generally did not view the diversity of their students along gender and ethnic lines but rather saw individuals with their own interests and needs. Teachers said that they did generally not adjust their teaching to appeal to different groups of students. The teachers indicated to use a variety of measures to make their classes interesting such as conducting projects or experiments. Only half of the teachers considered gender when teaching and almost none of the teachers considered making any adjustments to account for ethnic or religious differences between students. Better knowledge among teachers of the existence of different groups of students within their classes and the development of strategies on how to cater to these groups of students could greatly help in increasing the number of students interested in science.

5.1 | Introduction

Teachers are an important factor in whether students become interested in a particular school course or not and this is especially the case for science courses which attract the interest of few students (Osborne et al., 2003). The Science Education for Diversity (SED) project was set up to investigate student interest in science and in science education in primary and secondary education in six different countries: the United Kingdom, the Netherlands, Turkey, Lebanon, India and Malaysia. Previous studies which drew from the data collected in this project (see chapters two, three and four) provided the following findings: (1) Interest in science is lower in the Netherlands than in other countries that participated in the research. This is particularly the case for interest in science as a school subject and interest in having a job related to science, but also, to a smaller extent, for interest in science-related extracurricular activities such as visiting science museums and watching TV shows about science. (2) There is a strong correlation between interest in science and school science and the view of science a student has. Students with views of science as a way of solving many societal problems and who believed that scientists work in teams and have creative jobs tend to be more interested in science. These views are more prevalent outside the Netherlands and the United Kingdom than within these two countries. (3) Interviews with Dutch students revealed 4 different profiles with regard to their interest in science and technology: (A) students interested in the content of science, (B) students interested in the activities related to science, (C) students with no interest in science whatsoever and (D) students with a partial interest in science and whose enjoyment of science depends strongly on the topic or activity. This large fourth group of students appeared neither very interested nor disinterested in science, and these students had no view or a very limited view of what science is and what scientists do. It is unclear to which degree Dutch teachers realize that there are different groups of students with different interests in their classrooms and how these teachers adjust their teaching to the needs and interests of this group of students.

This study investigates how teachers think of the diversity in their classrooms in relation to science. Diversity is thus addressed not only in the form of gender diversity, which has long been an important factor in studies concerning interest in science among school students, but also in the form of the diversity of science interests and needs of students. Furthermore, it is investigated how teachers present science in their classrooms and how they respond to the various interests of students. Both primary and secondary school teachers were included in this study in order to investigate teaching practices in both school environments. It was also chosen to include both primary and secondary schools because previous studies found that in upper primary and lower secondary education, many students will lose interest in science (Andre et al., 1999; Murphy & Beggs, 2003).

5.2 | Background

5.2.1 Interest in school science among students

Interest in science among school students has long been a topic of research (Krapp & Prenzel, 2011). A distinction can be made between interest in school science and science as it is experienced outside school in science museums and science centers and via television shows (see chapter four) and even between different subjects and topics (Krapp & Prenzel, 2011). In this study, in which the focus is on how teachers present science in their classes and how this may impact the interest of the students in their class, we focus primarily on school science.

It has been established that, for many children, interest in school science decreases between the ages of 10 and 14 (Barmby et al., 2008; Bennett & Hogarth, 2009; George, 2000; George, 2006). In primary education most students hold an interest in science, but when students age and enter secondary education, this interest decreases and does so to an even greater degree than interest in other school subjects (Osborne et al., 2003).

There are many different factors that impact a student's interest in school science. One important factor is the science teacher and how the teacher represents science in his or her classes (George & Kaplan, 1998). According to a study by Raved and Assaraf (2011), students had more positive attitudes towards science when they perceived their classes to be addressing real-life problems, containing practical knowledge and managing to increase their curiosity about science. Furthermore, according to this study, the ideal teacher would use a varied approach to teaching and use a variety of different teaching methods.

5.2.2 Diversity of school students and interest in school science

Interest in science varies greatly between genders and between students from different ethnicities and religions. There is a gender difference in the appreciation of science in secondary education (Jones et al., 2000), with girls being generally less interested in science and technology than boys. In a large cohort study in the Netherlands, gender was found to be the most important variable for predicting whether a secondary school student would pick up science courses or not (Uerz, Dekkers & Béguin, 2004). Not all girls lose their interest in science. Those who keep their interest in science tend to favor other topics and courses than boys, preferring biological topics over the more technology oriented and computational topics such as physics. The gender difference appears to be more pronounced in the Netherlands than in other comparable countries with fewer girls taking up science courses (Ministry of Education, 2009). Various explanations have been given for this phenomenon such as government policies, labor market characteristics, social traditions and an education system that forces early choices for science tracks (van Langen & Dekkers, 2005).

Classrooms in the Netherlands have become increasingly diverse in terms of religion and ethnicity even while the teachers in the country remain predominantly white and middle class and often lack the experience of teaching multicultural classrooms (den Brok, van Eerde & Hajer, 2010). Several studies have looked into what teachers believe are the most appropriate ways of dealing with diverse students (Bryan & Atwater, 2002). One of the most commonly found and most persistent beliefs among teachers is that of colorblind teaching or "dysconcious racism", the belief that ignoring race or gender, ethnicity or class when teaching would serve students best (Bryan & Atwater, 2002; Ullicci & Battey, 2011). In many cases, teaching in such a way turns out to be problematic, because in reality teachers tend to teach in a way that appeals most to one particular group. In the case of science teaching this group is often a group of boys that already holds an intrinsic interest in science.

5.2.3 Diversity in science interest

There are other ways of looking at the student population, apart from separating groups into girls and boys and minority and majority ethnicities. Several studies have divided students into different groups based on their interest in science and technology (Haste, 2004; Platform Bèta Techniek, 2010). Haste (2004) identified 4 groups, students oriented towards science who like their science classes and spend their spare time on extracurricular activities, students interested primarily in technology and in how investments in science and technology can change their life, students who are alienated from science and dislike all science and a green group of students interested in the environment and in ethical issues. The BètaMentality model (Platform Bèta Techniek, 2010) classifies students as either technology oriented students who are primarily interested in practical applications of technology, generalists who are more theoretically interested in science, career-oriented science students who highly value career opportunities and students who are not interested in science. However, the empirical evidence for this latter distinction, though often regarded as recognizable by teachers, is limited.

The present study draws on the Dutch data of the SED project. Analysis of the student data of this project led to the identification of four different groups of students: those interested in the content of science, those interested in the activities related to science, those disinterested in science and those who have a mixed opinion about science (see chapter four).

Whereas the first two groups consisted of mainly boys and the third group of girls, the last group had equal numbers of boys and girls. This last group of students, which made up about 40% of all in the interviewed students, constitutes perhaps the most important challenge for teachers, when attempting to get more students interested in science. These students do not belong to the groups of students who are very interested in science or technology and will continue with taking these courses regardless of the instruction of the teacher nor to the group of students who are simply disinterested in science. Whether they will develop a further interest in science or not will depend for a large part on the science lessons they receive and the views of science these students will develop. The group includes students who are interested in some but not all aspects of science. For instance, some of the students were interested in doing experiments and in human related biology but disliked all other aspects of science. Some of the students in this group held an interest in science for extrinsic rather than intrinsic reasons, for instance by being interested in high paying jobs related to technology rather than the content of the courses being offered in school. As such, the group seems to include at least two of the four types distinguished by the Platform Bèta Techniek, the career and the practical oriented students.

This last group of students is also a difficult group of students for teachers. Whether their interest in science will increase or decrease will depend for a large part on the science classes these students will have in school. These students neither have a fully formed idea about what science is and what scientists do (see chapter four) and the classroom can play an important role in how the views of these students develop.

The questions remains what teachers can do to let groups of students who were hitherto not interested in science, develop an interest in science. There are considerable differences between the things students are interested in and what most science curricula prescribe (Christidou, 2006; Osborne & Collins, 2001) and including topics and elements in the curriculum that are in line with what students enjoy and what interests them may increase their overall interest in science. For groups of students specifically interested in technological applications, in the environment, or in ethical issues related to science, teachers may need to include examples and exercises related to these topics in their classes. Choi & Cho (2002) found that discussion of ethical issues among secondary school students increased both their interest in science and their perception of practicality of scientific knowledge. Other researchers have advocated connecting classroom activities more to the daily lives of students to increase interest in science (Hulleman & Harackiewicz, 2009). Activities and in particular, experiments tend to increase the interests of students (Osborne & Collins, 2001; Swarat, Ortony & Revelle, 2012). Furthermore, discussion of what scientists do and what impact science has on one's life may impact student interest in science (see chapter four).

5.2.4 Research questions

This study aims to find out how teachers think of a diversity of interests within their classroom and how they present science to their students. This knowledge is valuable because it will enable an evaluation of the classes and the degree to which science education caters to different groups of students and a recommendation of how to better serve a diversity of students.

In this study, we address several research questions. The first research question is: *to what degree are teachers aware of the diversity of the students in their class and the different interests in science that students have as described above?* The second question is: *what goals do teachers have when teaching science and how do they represent scientists, history of science, ethical issues related to science and environmental issues in their classes?* The third question is: *what strategies do teachers employ to make science appealing for their students and if they do so, how do they differentiate for different subgroups of students within their classes?*

5.3 | Methods

To answer the aforementioned research questions, teachers were interviewed about their classroom practice and their views on teaching. The sampling procedure, the development of the interview protocol and the analysis of the interview data are described below.

5.3.1 Sample

A total of 14 primary and secondary school teachers from 6 different schools were interviewed. Of these 14 teachers, 6 taught in primary education and 8 in secondary education. The secondary school teachers taught biology (2), chemistry (2) and physics (4). Several of the secondary school teachers also taught a general science course in the first few years of secondary education. There were 6 female teachers of which 3 worked in primary schools and 8 male teachers of which also 3 worked in primary education. The most experienced teacher had 38 years of experience while the teacher with least experience had 1 year of experience and was still following a teacher training program.

The secondary school teachers were all specialized science teachers, whereas the primary school teachers taught many courses among them science and technology courses. This difference was also apparent from the amount of formal education in science teachers had had. All the secondary school teachers held Masters Degrees in science and had entered a university based teacher training program. All primary education teachers had followed the teacher training program for primary school teachers which is required in the Netherlands and which enables teachers to teach all classes in primary schools. As the school subject technology is a relatively recent addition to the Dutch primary school curriculum, most of the primary school teachers had followed professional development courses to give technology lessons a few years before the interviews were conducted.

All schools that were included in the sample were situated in the south of the Netherlands except for one secondary school which was located in the middle of the country. The schools were part of the network of schools related to the university teacher education program the authors of the study are affiliated with. One secular, one Catholic and two Protestant schools were included in the sample. All teachers taught classes with boys and girls. In most cases these classes were evenly mixed although in some cases boys or girls represented more than half of the class. Most of the schools that were included in the study had mainly Dutch-born students but one primary and one secondary school were included which had a large percentage of students from minority ethnicities that are present in the Netherlands (mostly Turkish and Moroccan children).

All the teachers had given their permission to be interviewed and audiotaped. All interviews were recorded on audiotape and transcribed verbatim. Interviews lasted between 20 and 40 minutes.

5.3.2 Interviews

Interviews were conducted according to a structured interview protocol. The interview protocol contained questions about personal characteristics such as experience, educational background and the classes that the teacher taught. Furthermore several questions were included about the composition of the classes, e.g. the number of boys and girls and the diversity of students in terms of religion and ethnicity. Teachers were asked questions on their opinions on diversity within their classes and whether teaching materials and practice should be adjusted in any way to accommodate for the differences among students. Teachers were further asked questions about their own teaching practices, what their goals in teaching were and how they achieved those goals and whether they discussed history of science and ethics in class. The questions are displayed below in Table 5.1.

Table 5.1
List of teacher interview questions

Number	Question
1	Can you describe a typical science class that you teach?
2	What do you think every child should know about science by the time they finish their education?
3	What would you say were your own goals in teaching science?
4	Do you make any adjustments in your teaching to account for boys' and girls' different interests?
5	Do you think that the program you are expected to teach in science and the materials available to you, meet the needs of different genders?
6	In your teaching, do you find it useful to cite any scientists as examples?
7	Many science teachers think it is useful for students to have some understanding of the history of science. What is your view? Why?
8	Many teachers have the experience of a pupil expressing worries about moral issues around things they are studying in science. Have you ever experienced this? What did you do? Why did you respond in this way?
9	One area where many people recognize a link between science and values is the environment. Do you deal with the relationship between science, technology and the environment in your teaching? How?
10	Can you give me examples of what you think would be particularly good teaching in relation to anything we have talked about in this interview?
11	What would be examples of bad teaching, in your view?

5.3.3 Analysis

All interviews were transcribed verbatim. A coding scheme was developed on the basis of the transcribed interview data. The data was analyzed per question. For each question, the 14 responses from the teachers were gathered and via the constant comparative method 3 to 6 codes were identified based on conceptual differences and similarities between answers (Strauss & Corbin, 1990). These codes enabled the identification of themes within the answers given by teachers, which in turn allowed for answering the research questions. The coding procedure was discussed and the findings and their interpretations were verified by a senior researcher. The senior researcher agreed with the codes and groups that were identified. In the results section, the major codes or themes are discussed and, at various places, illustrated with representative fragments. The codes that were identified are italicized when they are first introduced in the results section.

5.4 | Results

The answers to the three research questions are presented below in different subsections.

5.4.1 Teachers ideas about diversity and interest in science

The majority of the teachers generally did not think of diversity among their students along the lines of gender or ethnicity. Teachers stressed that *individual differences* between students were more important than *gender differences* and that they did not want to lump students into groups based on this criterion. Gender differences were also perceived to be minor. One secondary education teacher said that he had not yet seen any differences in interest in chemistry between boys and girls in his classes, despite his 34 years of experience teaching this subject.

Their views on diversity informed the way the interviewed teachers said to teach their classes. About half of the teachers said that they did not make any differences in their science classes when teaching to boys or girls. The majority of these teachers were primary school teachers. Other teachers stressed that they perceived some minor differences between male and female students concerning the science topics they are interested in, in the age group that they taught and but these differences diminished over time.

Interviewer: Do you take differences in interest of boys and girls into account when teaching science and technology?

Teacher: In this group there are few differences. This is the second year in which we are having the technology classes in the afternoons. I think the difference is only

> diminishing. For instance, building with Knex or legos[1]. There are a lot of boys doing that but you also see more and more girls who enjoy doing these things. Because it is very hands on. I do not see much differences in my own classes. (Teacher primary education)

Other primary school teachers stressed that all students were supposed to have *similar experiences* in class and that differentiating would make possible differences larger. A secondary education teacher stressed that the *universal nature of science* led him not to make adjustments in his teaching to address either boys or girls. In the cases in which teachers taught in an ethnically diverse school, teachers were even more adamant in stating that they treated all students equally and that they did not adjust their classes to specific groups of students.

> Interviewer: Do you take differences in interest of boys and girls into account when teaching science and technology?
>
> Teacher: Little, maybe with… I am thinking of a specific topic. I don't think so, no, actually not.
>
> Interviewer: Why not?
>
> Teacher: Why not? Maybe science is too hard for that. It is above that. You deal with science as a human being and whether you are a boy or a girl, you have to look at both sides. There are two sides, so why would you leave out some aspects. I can imagine that with languages, you would give texts about specific topics, but with biology no. With procreation, you can't really only discuss the male side for the boys and the female side for the girls. (Biology teacher, secondary education).

[1] These are both brick-like toys for children.

Interviewer: Do you take differences in interest of boys and girls into account when teaching science and technology?

Teacher: No, especially not with technology. When we teach science and technology, I do not make a distinction. Because otherwise you would create even greater differences. I find it important that they all get to have the same classroom experiences. And how it later crystallizes out, we will find that out later, but for now I do not make a distinction between boys and girls. (Teacher primary education).

The remaining teachers, about half of the interviewed sample, said that they differentiated in some way to account for the diversity within their classes. However, in almost all cases, the adjustments that were made were relatively minor. Most of these teachers differentiated to account for differences in interest between boys and girls. This was mostly done by offering *different examples* for girls and boys. One teacher said that when discussing radioactivity, he not only included the atomic bomb in his lessons but also medical applications of isotopes because many girls in his class were interested in medicine. For similar reasons, another teacher mentioned after discussing that bulletproof vests were made from oil that panty hoses were also made from oil. Only two teachers remarked that when students were given the opportunity to choose their own experiments or projects, girls would choose different projects or take up different roles within a group while performing an experiment. Adjustments not always took the form of differentiating in interest. Some teachers said that they had to give male students more 'structure' as girls in their opinion were more organized than boys.

Interviewer: Do you take differences in interest of boys and girls into account when teaching science and technology?

Teacher: Yes, I really try to adapt the examples to what they like. Even if I do not always succeed in that. And you notice that when you have a class with a lot of boys that you tend to address boys things. But I think it is an advantage that I am not a boy myself and that I can easily put other examples forward.

Interviewer: Why do you do this?

Teacher: Because I want to increase interest among girls and I also want to increase interest among boys. It is not just one or the other, I try to reach both. And when I know the students a bit better, especially in a class where you had them for several years, then you know their interests. You know you have one who did a lot with electronics, so you reach out for that one. When you do gymnastics, I try to explain things with gymnastics. So not only boys and girls but also interests, then you reach out to them well. (Physics teacher, secondary education)

Furthermore, the teachers generally believed that the *teaching materials* that they used were appropriate for all the students in their class. Teaching materials were not seen as biased towards any group (gender or ethnic group) but suitable for all students.

5.4.2 Goals of teaching science

Teachers were interviewed about their personal goals in teaching, what they believed that every student should know about science upon leaving school and whether they taught history of science and ethical issues related to science in their classes. This was done to find out what teachers stressed in their classes and how they represented science.

When asked what they believed that every student should know upon leaving school, all teachers answered that students must obtain certain *factual knowledge*. There were also several teachers that stressed *scientific ways of thinking*.

Teacher: Of course, they must obtain some knowledge. What I also find important and I hope they'll do is that they start thinking in a certain way, scientific thinking, thinking in concepts. But of course, they must be able to do the physics they learned, but it is not purely learning knowledge, it is also a way of thinking you must master (Physics teacher, secondary education)

Many teachers saw the teaching of factual knowledge as one of their personal goals as well. Other personal goals of teachers were more revealing of their individual opinions on teaching. Different teachers stressed that they believed that students should learn to *enjoy science*, have a good understanding of *how science works* and know which *jobs* they could have and which *studies* they must take in order to get a job in science and technology. One teacher stressed that he found it most important that students would have a good understanding of the *impact of science on their daily lives*.

Teacher: My personal goal is that students understand that all science courses have enormous impact on how they live, on the stuff they use and on how we think the world works. And especially the developments that lead to the newest game computers and the newest products for your hair and everything, that there is a very technical story behind how these things were made. The understanding of the impact of science disciplines and technology on their own life, I consider it very important that they know that. That they have this view of the

> science courses that they are not necessarily difficult and they can be interesting and fun. It is especially important for the earlier classes because you want that many of those students will end up choosing those courses later in their school career. (Physics teacher, secondary education)

Most of the teachers included the history of science in their teaching although this was more common among primary school teachers than secondary school teachers. Generally, teachers were not concerned so much with dates of specific *scientific discoveries* but wanted to give students an impression of how science has *developed over the years*. The primary education teachers barely mentioned the names of *famous scientists* but the secondary education teachers did mention them. However, most secondary school teachers did not pay much attention to these scientists, only mentioning them when discussing the law or discovery named after them. Only one teacher said that he specifically included discussion of scientists in his classes to make clear that science is practiced by human beings and to place famous scientists in the context of their time.

> Interviewer: Do you teach the history of science?
>
> Teacher: If you are speaking purely of history, of years and dates, I do not find that important. If you are talking about dates.
>
> Interviewer: And what do you find important about history of science?
>
> Teacher: That in the course of years, science again and again yields new insight. It is not so that those insights are written in stone, they are never 100% solid. In science, you have, in physics for instance Newton's laws, those are laws that for a physicist are certain but I always have questions about them. If you would look a

hundred years into the future, it turns out that a law is not 100% correct. So I always leave an opening, science develops itself. It can go in a very different direction than you think, that is the interesting part about it. To not hold on too tight to certainties, that's science. (Physics teacher, secondary education)

In contrast to history of science, ethics were hardly discussed in class. None of the teachers paid regular attention to ethical issues in their classrooms. Teachers even stated that their students never or rarely brought up ethical discussions themselves and that today's youth are barely interested in these discussions. On the other hand, all teachers said that they included lessons on the environment in their science classes and that this was an important part of the curriculum.

5.4.3 Attempts to make science appealing for students

The interviewed teachers displayed a consensus about what they considered to be good and bad teaching of science. When asked what they considered to be bad teaching, the interviewed teachers unanimously said that they disliked lessons in which the teacher only gives *whole class instruction* and in which it is the teacher who mainly speaks during class, not giving students the opportunity to say anything.

Interviewer: What do you consider bad teaching?

Teacher: Well, according to me, only telling how things are and not leaving any opening for discussion or thinking on your own. Not even creating space for exercises, just you have to accept this as I tell you, then nothing will stay with them. (Chemistry teacher, secondary education)

The answers to the question what good teaching entailed varied more but most answers stressed the importance of *captivating the students' minds* and *activities* in which students could learn and actively think of solutions. A majority of teachers stressed that students should actively participate in the class by asking questions and doing their own experiments.

Interviewer: What do you consider good teaching?

Teacher: I like it when all the children are actively participating. When all children are involved, the end result of the work doesn't necessarily have to be good but you must have the feeling that they all did a good job and that they all realized what they were working on. Well, we have worked on that, it may not have turned out the way we thought it would. But they were actively involved and at the end of the lesson you think that they have learned something. It is not always measurable whether they have learned something. (Primary school teacher)

Interviewer: What do you consider good teaching?

Teacher: I find it very important, especially with physics, to connect with the students, understand what happens in the heads of those students, what happens in everyday life and you have to connect your physics to that. And then you notice that some aspects are less interesting for students. For instance when we discuss light and calculations, light and mirrors. You can give some examples but after that it becomes a very theoretical story and they lose interest. When you are discussing forces in cars and safety and aerodynamics in sports, I always connect it to those things. Yes, they all find it great. (Physics teacher, secondary education)

When teachers were asked to discuss how they taught their own classes, many teachers further stressed the importance of doing experiments and capturing the minds of their students. Teachers said that their favorite classes were either those in which they could do one of their favorite experiments with their students such as making soap (primary education), testing insulating materials (secondary education) or determining blood groups (secondary education) or in which they discussed a topic that had been in the news, such as nuclear energy, or that they could connect to the daily lives of students, for instance electricity.

> Teacher: When I am doing these classes, I consider it important that they enjoy it, they must be having fun. And I think that when they are enjoying themselves, at a certain moment, the interest will increase. You notice that after doing a few science classes, they come up with ideas themselves. Like "that is also nice to do" and "you can also do that with it". And then it starts to capture their minds more. (Primary school teacher)

5.5 | Conclusions and discussion

Regarding the research questions that were addressed in this study, the following conclusions can be drawn. (1) The teachers that were interviewed for this study did not see the diversity within their science classrooms along gender or ethnic lines and neither made a clear distinction into groups with different interests. (2) Teachers saw the teaching of factual knowledge to their students as their main goal, nonetheless many teachers also paid attention to the role of science in society, history of science, the environment but not to ethics of science in their classes. (3) Teachers did employ different strategies to make their classes appealing to a diverse audience of students. However, the choice of strategies differed strongly per teacher and none of the teachers seemed to have extensively analyzed what the needs and interests of different groups of students were before employing strategies to increase interest. These conclusions are discussed in greater detail below.

The teachers that were interviewed for this study did not think in terms of gender and ethnicity when discussing the diversity of students within their science classes. Teachers even stressed that they did not want to lump students together and see them as a group in which all the members have the same identity but rather see their students as individuals. Furthermore, when teachers did discern differences between the genders, this was often in terms of how boys and girls should be instructed and whether or not they needed order and not in terms of differences in interest. The answers given in this study show that teachers are likely to be insufficiently critical of diversity issues and of their own handling of these issues. Most teachers gave relatively short answers to questions about possible differences between boys and girls and between students of different ethnicities and did not appear to have thought extensively about these issues. All of the interviewed teachers considered the teaching materials they used appropriate for all students despite evidence that this is still not the case in many countries (Blumberg, 2008).

It is true that the division of students into groups which are either interested, not interested or partly interested in science and technology does not run strictly along ethnic or gender lines (see chapter four). But many studies have found that male students tend to appreciate science and technology classes in primary and secondary education more than female students and that boys and girls are often interested in different aspects of science (Brotman & Moore, 2008; Jones, et al., 2000). While teachers said that they viewed students as individuals, they did not elaborate much on how these individuals differed from each other or how and if they perceived different groups within the student population and how they would adjust their teaching towards these individuals or groups.

There is a possibility that the views teachers have would lead to colorblind teaching or dysconcious racism (Bryan & Atwater, 220; Ullicci &

Battey, 2011), teaching with the intention to appeal equally to all students, but which in reality favors one particular group of students. About half of the teachers did not consider the differences between boys and girls when teaching and almost none of the teachers made any adjustments in their teaching to accommodate for students of different religions or ethnicities or other groups. Teachers often justified their statements by stressing that they did not perceive great differences between their students and that they believed that it would be best to teach every student in the same way. These ideas were more prominent among primary school teachers than among secondary school teachers. Together with the strong focus on teaching factual knowledge, this would mean that the classes of these teachers would appeal most to those students who are predominantly interested in the content of science. In chapter four, results were presented of interviews with students that were taught by a number of the interviewed teachers. It was found that this group of students that are primarily interested in the content of science consists of about a quarter of all students and that most of the students in this group were boys.

Not all teachers included in the study appeared to teach in a colorblind way. Those who did make differences in their classes to accommodate differences between genders often did so by offering different examples and in a few cases, teachers gave students the opportunity to do different projects. However, the adjustments these teachers made were often small. The findings of this study are in line with the findings of many studies that have been conducted in the United States and that have found that it helps when teachers follow courses (during a teacher training program) to become responsive to the needs of a diverse group of students (Kumar & Hamer, 2012; Lee, Hart, Cuevas & Enders, 2004; Villegas & Lucas, 2002).

The teachers in the present study found the teaching of factual science knowledge paramount in their teaching and stated that every student should leave school having learned basic knowledge about science. Nonetheless, the teachers had broader personal goals in teaching such as making students familiar with the impact science has on their lives and showing them which jobs and fields of study are related to science. It is remarkable that all teachers that were interviewed said that they paid some attention to the history of science and that in all cases teachers discussed the environment in their science classes but hardly included any conversations about ethics in their lessons. This shows that despite a focus on scientific content, teachers do attempt to present science as a human endeavor that has an impact on the daily lives of students and that can be used to solve the world's problems.

There was a remarkable consensus between the interviewed teachers on what they considered to be good and bad teaching. Whole class instruction as the dominant method of teaching was considered to be bad teaching whereas the inclusion of many different teaching methods such as experiments and projects, allowing student input and captivating the mind of the student were considered to be good teaching. Many of the approaches that teachers list as examples of good teaching are often reported as recommendations in studies on making science more appealing for groups of students who are normally not interested in science (Raved & Assaraf, 2011; Osborne et al., 2003). Such approaches include doing experiments in class, using examples that connect to the daily lives of students and involving students in discussions about science.

The picture that emerges from the answers that the teachers have given to the three research questions is one in which teachers do different things in their classes which, in principle, must make science more appealing to their students. However, these things are not yet done after an in-depth analysis of what groups of students are present in their classes and what interests and needs these students have. The result of this is that the science classes that are offered will likely interest some of the potential interest groups present in the classroom but not all. A teacher who pays much attention to the environment and to ethical issues in class may turn off student that are more interested in technological application or information about jobs in science and technology. Which students will lose or gain an interest thus depends for a large part on the teaching style and the strategies employed by the teacher they have during their school career. To increase interest among all possible groups of students who could possibly be interested in science, teachers would need to develop strategies to cater to these different groups of students. Since most teachers will have difficulties doing this on their own and perhaps lack an inventory of strategies for each possible group of students, it may be helpful to include such strategies in teacher training programs and in continuous professional development for teachers.

There are some limitations to this study. First of all, the sample of 14 interviewed teachers is rather small. Whereas we have no reason to suspect that the sample is in any way not representative of the Dutch teacher population, it is still not possible to generalize from such a small sample. A more important limitation is that this study is entirely based on self-report of the teachers and there have not been any observations of classes to find out whether the teachers really behaved according to what they have said in the interviews. As the topics that were discussed in the interview do not present themselves during every class, confirmation of the interviews by observation would require multiple observations for each teacher. If the study would contain a bias, it is more likely that the teachers would have overrepresented how much they would do to make science attractive to their students rather than underrepresented it (den Brok et al., 2006).

CHAPTER 6

Conclusions and discussion

6.1 | Introduction

In this chapter we will start by summarizing the most important conclusions of each of the four studies in this dissertation. Two of the four studies compared questionnaire data from six different countries and investigated the perceptions, views and attitudes of students and teachers. The two other studies focused more on the Dutch context and described more in-depth the views, attitudes and perceptions of students and teachers as collected via interviews. The summary of the four studies is followed by a discussion section, in which some observations that emerge when looking across the four studies are discussed. This chapter ends with a discussion of the limitations of the studies, followed by suggestions and implications for future research as well as for practice.

6.2 | Conclusions

The most important conclusions of each of the four studies in this dissertation are summarized in the following subsections.

6.2.1 Global patterns in students' views of science and interest in science

The first study focused on the answers of students on a questionnaire that was completed by over 9000 students in the six countries that participated in the SED study and that attempted to answer the questions (a) how interest in science and (b) views on science differed between students from the six countries and (c) how interest in science and views on science were related to each other. It was shown that there was a clear division in interest in science between the Netherlands and the United Kingdom on the one hand and the other four countries on the other: Turkey, Lebanon, India and Malaysia. Students from the latter four countries displayed a greater interest in science than Dutch and British students. Students from India appeared to be the most interested of the countries involved and Dutch students the least. The difference in interest in science did not only manifest itself in a greater interest in science as it is taught in school but also in a greater interest in having a job related to science and technology later in life and in participating in extracurricular activities related to science.

There were also international differences in how students from different countries viewed science and scientists. Students outside Western Europe tended to see science more positively, as a tool for solving many problems, than students in Western Europe. There was also greater confidence in science among students in Turkey, Lebanon, India and Malaysia, and students from these countries saw the job of a scientist more often seen as creative and collaborative. Multilevel analysis showed an association between interest in science and views related to science, especially the view that science can solve many problems.

Multilevel analysis also revealed that, despite large differences in interest between the different countries, by far the greatest variation in interest could be identified at the student level, meaning that there were large differences in interest between students who attended the same school within one particular country. The different interest in science variables appeared associated differently with background variables in the multilevel analyses. There were gender differences for all constructs with girls being less interested in science than boys, but these differences were small for school science and science as an extracurricular activity and larger for science jobs and extracurricular activities related to technology. The scores for all interest in science variables were lower for older students and were lower in secondary education as compared to primary education, except for interest in having a science job which remained stable.

6.2.2 Teachers' views on nature of science, teaching goals and practice of teaching the nature of science around the world

The second study focused on the perceptions and beliefs of teachers who taught the students of the first study and focused on the question which views these teachers had of science and whether these views had an impact on their teaching practice. Patterns between nationalities and views of science for the teachers appeared similar as those for students in the previous study: teachers from countries outside Western Europe had views on the nature of science that were more empiricist and less constructivist than those of Dutch and British teachers. This means, for instance, that teachers from Turkey, Lebanon, India and Malaysia believed to a greater extent that science is unchangeable and free from cultural influences.

Strangely, these views did not have their reflection in the degree to which these teachers said to pursue and meet teaching goals that were related to teaching the nature of science, such as teaching that science is an activity that requires creativity and imagination or teaching that scientific explanations are tentative. There were neither clear national differences in the degrees to which teachers from different countries indicated to employ constructivist teaching methods such as allowing student criticism during class or sharing control with students over the learning process.

Multilevel analysis actually showed that there was a correlation between having empiricist views and teaching in a way that is essentially constructivist. Thus, students and teachers seemed to share similar views about science, but these views did not appear to be transferred during teaching in class.

6.2.3 Interest in science and ideas about science among 10 to 14 year old Dutch students

The third study investigated in greater detail what Dutch primary and secondary school students thought of science and how this related to their interest in science. Dutch students that were interviewed were divided into four different groups based on their interest in science: students who were very interested in the *content* of science, students who were also interested in science but mostly in *activities* related to science and in technology, students who had *no interest* in science whatsoever and students who had *not yet made up their mind* about science and who held an interest in *some aspects of science* but not in other aspects. For the content and activities interested groups, content and activities were running threads in their answers on why they liked school science, what kind of job they would like to have in the future and even on why they enjoyed visiting science museums. The fourth group of students consisted of students who had an interest in some topics, such as the human body but not in physics or chemistry on the whole. The fourth group of students had more limited views regarding what science is and what scientists do as compared to the first two groups. Most students in this fourth group could not give any reasons why science differed from other school subjects and could not give any adequate descriptions of what a scientist does for a living. Descriptions of scientists were often stereotypical and scientists were often described as solitary and overly occupied with their work. The first two groups consisted mostly of boys, the third group mostly of girls and the fourth group was evenly split between boys and girls.

6.2.4 Teachers views on teaching science and diversity

The fourth study investigated how teachers in the Netherlands thought of diversity in their classrooms and how they indicated to teach science to their students. It was revealed for a sample of 14 teachers that these teachers tended to think that there were no large differences in interest in school science between boys and girls or students of different ethnicities. On the whole, the interviewed teachers thought it was best to treat all students the same regardless of gender or ethnicity, in the literature also referred to as so-called 'color-blindness'. When teachers did indicate to differentiate for gender in their classes, this was usually in the form of offering different examples that appealed specifically to boys or girls, or by giving boys more guidance. Teachers did not appear to be aware of the existence of possible groups of students with different interests in science. From their statements no or little instances of differentiation to account for different groups of students with different interests in science could be inferred.

Nonetheless, teachers indicated to apply strategies that in the literature have been advocated for creating greater interest in science, such as connecting science to the daily lives of students, doing experiments and the inclusion of environmental and historical issues in the curriculum. In contrast, ethical issues concerning science topics were hardly reported to be discussed in class. From their answers it seemed that teachers did not analyze the interests and needs of students before applying the aforementioned strategies.

6.3 | Discussion of the main results and conclusions across the four studies

In this section we will discuss some prominent observations that can be made by looking across the results of the four partial studies. A first notable observation is that the studies in this dissertation not only showed that there were differences in interest in science between students from different countries, but that there were even larger differences in interest between individual students within the same country. This was not only apparent from the multilevel analyses in chapter two in which a large portion of the variance was identified at the individual level, but also from the results of the fourth chapter, where four different types of interest were found within a sample of 40 interviewed students. This is an important finding. One of the prominent factors that explained differences in interest between students in the multilevel analyses next to students' age, was student gender. This is not a new finding, as previous studies on gender and interest in science have displayed similar results (Jones, Howe & Rua, 2000; Murphy & Whitelegg, 2006). Girls tend to have a generally smaller interest in science as compared to boys and tend to be interested in other aspects of science, most notably in biological subjects (Jones et al., 2000). Our study found that the size of the gender gap may depend on the kind of specific interest that is being measured. The difference between boys and girls in interest in school science was relatively small, but the study in chapter two confirmed that already at a young age far fewer girls than boys were interested in a job in science (see also Sadler, Sonnert, Hazar & Tai, 2012). What the studies in this dissertation have added to the debate on gender and science is the finding that there is also a gender gap in countries outside Western Europe. Furthermore, the division of students in groups in chapter four showed that there were fewer girls in the groups of students that were intrinsically interested in science at a young age and that there were more girls in the group that had not yet made up their mind or that were interested in parts of science. Thus, the gender gap may not be as sharp as often reported and may partially be related to an uninformed or incomplete image of science, rather than simply a negative or stereotypical image of science.

A second interesting observation is that whereas the study in chapter two indicated that there was generally less interest in science among Dutch students than among students from other nations, the finding that there was a large variation of interests within the country gives hope that sufficient numbers of Dutch students would continue studying science and technology if properly motivated in class. It also suggests that the situation in the Netherlands is not as 'black and white' as international comparative studies seem to suggest (PISA, 2007). Interest in science is very nuanced and can vary strongly per topic and whether science is experienced in school or outside school. There are many variables that may play a role in why a student develops an interest in science or not, such as the home situation, the jobs and level of education of their parents, their exposure to television programs on science, books and science museums. In this dissertation, it was found that interest in science is strongly correlated to how a student perceives the nature of science. There appears thus to be an important role for teachers in shaping students' views on science and interest in science. However, the study in chapter three revealed that while students and teachers in the same countries often shared similar views about science, these views did not appear to be transmitted through teaching. The study in chapter five further revealed that teachers mostly seemed not to be aware of individual differences in interest between students and did not indicate to differentiate their teaching for these different students.

Third, there seem to be some mixed findings in this dissertation in relation to the question *how motivated* students in the Netherlands actually are. The study in chapter two found that there was little interest in science among Dutch students whereas the study in chapter four found that about 40% of the interviewed students were either interested in the content of science or the activities related to science and that only a small group of students were not interested in science at all. These differences may relate to the sampling procedure or the greater anonymity of a questionnaire study which could give students the opportunity to give more negative statements about science. Another explanation may be that by allowing students to talk freely about their interest, these students were more likely to mention science and mention aspects of science they enjoy. Still, after putting the two studies next to each other, the question remains how great the interest in science actually is among Dutch students. It is clear that interest in science in the Netherlands is not as great as for instance in countries such as India.

Fourth, it is not completely clear what students exactly think of scientists and the work they do. From the studies in chapters two and four, it appeared hard to classify the views that students had of scientists as either negative or positive. On the whole, the views of scientists could best be described as simple or incomplete. The first study in chapter two showed that many students thought of the job of a scientist as solitary and uncreative. The interview study in chapter four, however, showed that most Dutch students had little idea of what the job of a scientist entailed. Nonetheless, when asked whether they could picture themselves as scientists, only a few Dutch students said they did not want to have such a job, for example because of the negative stereotypes of scientists they had seen in the media. The response of students on how they see scientists may thus depend strongly on the exact wording of the questions that are asked to them. When asked whether they find the work of a scientist important, most students will answer very positively (Jenkins & Nelson, 2005; DeWitt et al., 2013). When asked to draw a picture of a scientist, students will draw from stereotypical images they found in the media (Finson, 2002). And when asked whether the students can picture themselves as scientists, they will think of more practical problems related to a job as a scientist such as the necessity to study for many years and work long hours (this study, chapter four).

Fifth, one of the original ideas behind the SED project was to find out what could be learned from countries outside Western Europe in order to improve science education in countries such as the Netherlands and the United Kingdom. What the findings in chapter two and three suggested is that the high levels of interest in science among students in countries such as India is not per se the result of specific features of the Indian educational system. This means that copying features of foreign curricula is not the answer to the question of how to deal with low levels of interest. Doing so might even be counterproductive. The findings from this dissertation suggest that the problem of lower interest in science in the Netherlands should thus not be solved by looking at other countries, but rather at by taking another look at the Dutch situation and at what causes individual students to become interested in science, which was done in this study in chapters four and five. The results of the study presented in chapter five suggest that there are still many things that can be done by teachers to improve interest in science among students in the Netherlands. Large groups of students are interested in at least some aspects of science, but their interests seem not to be sufficiently met by the education they receive. In addition, the interviewed teachers reported to employ many strategies that should make their science classes more appealing to their students, such as discussing the history of science or discussing everyday topics related to the environment. From the account of teachers, however, this appeared not to be done consistently or after an analysis of what different groups of students need, and interest in science may be increased if this were more the case. The findings of this study may even be interpreted as a cautionary tale for those countries that have a large proportion of their student population interested in science and which are undergoing rapid economic development and cultural change. It is remarkable that despite a far higher level of general interest in science, the same trends appear to take place in countries outside Western Europe: boys displayed a greater interest in science than girls and interest in science tended to drop with students' age. If interest in science is tied to culture and possibly to the state of development of a country (Sjøberg & Schreiner, 2005), this could mean that interest in science in these countries may drop in the future and measures such as those in the Netherlands may need to be taken in order to ensure that a large proportion of students keep their interest in science.

Finally, the larger SED project that formed the context of this dissertation had two seemingly opposing goals. One was to find out how to make science more attractive to those students who had no or little interest in science, a 'science for all' approach based on the idea that Europe needs a scientifically literate population in the future that can make democratic decisions on which directions science should take. The other goal was to find out how to get more students interested in science because there is a need for a greater number of scientists within the European economy. Or, as the title of a report written for the European Union states: 'Europe needs more scientists' (Gago et al., 2004). Based on the findings from this dissertation, the first goal seems to be more easily achievable than the second one. The interview studies found that there was a large group of students who were partly interested in science and who had no or very limited ideas about science. The right kind of curricular changes and teacher training could very well make science more appealing to these students, resulting in the end in a more scientifically literate population. The second goal seems far more difficult to fulfil and draws out the question what is possible to achieve. Can we really expect that large numbers of students who are not or barely interested in science at the age of 10 to 14 are to develop a great interest in scientific subjects and eventually become science graduates or even scientists themselves? Is it wiser to invest more energy in those who already at a young age hold an interest in science in order to avoid that they may lose their interest? If the need for scientists is most acute for the physical sciences, how reasonable is it to expect that students from the group of students who have so far only displayed an interest in some aspects of science, mostly very different ones than those of the hard sciences, will end up choosing to study physics in a few years? This last question is especially important considering the gender differences in science. Many studies have found that young girls have a greater interest in biological topics, whereas boys tend to be more interested in physics (Brotman & Moore, 2008) and that there is no gender gap anymore concerning biology and medicine graduates (Osborne et al., 2003). The much higher percentages of female graduates in the hard sciences in other countries than the Netherlands suggest that it must be possible to increase the number of female science students.

6.4 | Limitations

The research presented in this dissertation used questionnaires and interviews. In those questionnaires and interviews, students and teachers were asked what they did in the classroom and how they would respond in certain situations. Although the overall SED project included some classroom observations, these were not extensive enough to include in this dissertation and to find out whether the teachers really behaved according to what they claimed to do in the interviews and questionnaires (see appendices). The topics and situations which were included in the questionnaire and interviews for the teachers do not typically occur during every lesson. Not every science lesson will have the opportunity to discuss one of the tenets of the nature science. The questionnaire included several scenarios on which the teachers could indicate how they would react, such as a student telling the teacher that the content of the science class contradicted her religious beliefs. Several of these scenarios were so rare for the Dutch context that a large proportion of the surveyed teachers indicated that they had never experienced these situations, making them risky candidates for observation studies. There might thus be some instrument-related bias in the answers of the teachers but, as has been stated in the discussion section of chapter three, given the large and comprehensive sample, we believe that the answers that were given are at least still indicative of the ideals these teachers have about teaching.

International comparative studies often have more challenges when it comes to their reliability and validity than studies that take place in a single country (Hui & Triandis, 1985; Wubbels 1985). Translation of questionnaires, interview and observation protocols can easily lead to errors and misunderstandings. Concepts might be interpreted differently in different countries. Researchers from different nationalities may judge observations or interview questions in completely different ways. What may be considered state-of-the-art science teaching in one country may already be considered old fashioned in another country. Furthermore, when Likert scales are included in a questionnaire, some students and teachers have the tendency to use the most extreme answers on the scale whereas others tend to use the middle answers. These are not only issues for the SED study but also for comparable studies such as PISA, ROSE and TIMMS. The answer to this problem is not to abandon international comparative studies but to take as many measures and strategies as possible to avoid problems with validity and reliability and present the results in such a way that the reader is aware of how the data was gathered and how to interpret them. We took several precautions to avoid biases in this study. All questionnaires and protocols were translated from English into foreign languages and translated back into English by another author to avoid translation errors. The term *science* gave us many problems because its translations in many languages have different connotations than the English term science. For instance, the Dutch word *'wetenschap'* can also refer to the social sciences. '*Natuurwetenschappen'* is a better translation of the word science but most 10 year old Dutch students will be unfamiliar with this word. For this reason, questions were included in both the teacher and the student questionnaire in which teachers and students were asked to classify items as belonging to the realm of science or not.

Nonetheless, some of the surprising findings might be caused in part by such cross-cultural issues. For example, on the basis of what is known about international differences in interest in science from previous studies (PISA, 2007; Sjøberg & Schreiner, 2005a), we did expect that Dutch students would score lower than students from India, but the differences in answers to the questions still were much larger than expected. Could it be the case that Indian student tended to tick off the outer boxes whereas Dutch students were only ticking off the middle ones? There are, nonetheless, reasons to believe that the differences that were seen in the variables are trustworthy, as reliability coefficients and factor analysis results appeared stable between countries. In addition, whereas the international differences in interest in school science and interest in having a job related to science were more dramatic, this was much less the case for interest in extracurricular activities. The large difference between the Netherlands and India could also be seen in answers to the question what a student's favorite course was, a question in which Likert scales played no role and in which about 60% of all Indian students responded that mathematics or a science course was their favorite, compared to 20% of all the Dutch students.

In addition, the results presented in the second chapter of this dissertation rely strongly on the outcomes of four different questions on views on science, three of which were statistically significantly related to different forms of interest in science in a multilevel analysis. Nevertheless, this is a small set of questions and a more comprehensive set of questions may result in a more comprehensive and stable measurement of views on science.

Another limitation of the study in this dissertation was that while the interview studies and the questionnaire studies were administered in the same schools, it was not possible to make direct links between answers of respondents collected with the help of different instruments. It was known which students and teachers came from which school, but for the questionnaire data there was no information about which student got science classes from which teacher. Questionnaires were completed anonymously and it was not possible to link the questionnaire and interview answers of the students and teachers that were included in both these studies. This is something to consider in the design of future studies.

There are other limitations due to the international nature of the research project and the requirements that were posed by the European Union to the project. The research instruments were made with a team of international researchers and were made to study international differences in education. This means that all partners had their say in what kind of questions would be included in the questionnaires and the interview protocols. There was no or very little room for inclusion of questions that were specific for educational settings in one specific country. The classes in which science is taught differed in each country and therefore the questionnaires did not refer to specific classes but rather to science as a general school subject or to specific topics within science. The materials that were designed for this study were rather extensive (see appendices). Completing questionnaires and conducting interviews took up most of the time that was available for research in schools. There was thus no or limited opportunity to add additional questions pertaining to the Dutch situation to the questionnaires or interviews, although this would certainly yield interesting data. For example, there were no questions in the study about the choices students would make in the future on continuing with science courses or not. There were neither questions on recent changes in the Dutch science curriculum, such as the introduction of the school subject of Technology in primary education.

Another limitation is the relatively low number of schools, teachers and students that participated, in particular in the interview studies. There were a large number of respondents for the student questionnaire but these came from a low number of schools. The teachers who completed the teacher questionnaire came from the same set of schools as these students. Only four schools were involved in the interview studies. In future research, larger numbers of both students and teachers would be needed in order to confirm the trends that have been found in these studies.

6.5 | Recommendations for further research

The studies that are presented in this dissertation were derived from a dataset that was collected for the international Science Education for Diversity research project. This dataset is very extensive and the four studies presented here have not yet exhaustively described all trends and findings of the SED research project. Before the studies in this dissertation were written, the student questionnaire data was analyzed in an explorative way in which many different student characteristics and school characteristics were looked at. It was during this phase of the analysis that the correlation between interest in science and views on science was discovered that led to the first study which in turn inspired the subsequent studies. Below are several recommendations for further research that could be done by a further analysis of the data that was collected for the SED project as well as recommendations for research that would warrant new studies.

The four studies presented in this dissertation could be criticized for looking primarily at diversity through the lens of nationality, gender and age. The studies focused on these student characteristics because in the initial exploratory analysis, these showed the largest differences between subgroups and countries, more than, for instance, ethnicity, religion and social economic status on which data was collected as well. For the Dutch data, this study actually confirmed the patterns for take-up of science courses and studies showing that gender is a more important explanatory factor than ethnicity (Ministry of education and sciences, 2009). Whereas the current studies have not investigated ethnicity, religion and social economic status, these student characteristics could be investigated in follow up studies. Studies in Australia and the United Kingdom have shown that social economic status and cultural capital of the parents of a child can have an important impact on aspirations in science and the decision to take up science courses (DeWitt et al., 2013; Gorard & Huat See, 2009; Lyons, 2006). It is also overly simple to look at gender, ethnicity, religion and social class in isolation. In future studies, these attributes should all be taken together in one analysis to reveal the possible interactions between them.

In a similar vein, the first two studies could be criticized for consistently lumping together two Western European countries and four other countries which are usually referred to as non-Western European and failing to investigate the differences within these two groups of countries in greater detail. It was mentioned in chapter two that Dutch students were even less interested in school science than British students and that Indian student were even more interested in school science than Turkish, Lebanese and Malaysian students, but no further analysis of differences between individual countries could be presented in this dissertation. This is a valid point of critique and there are many ways in which the countries that are lumped together in the first study differ from one another. The two studies presented in chapters two and three are among the first studies to be published on the data of the SED project and it was decided to present some of the most important trends in the data that were found during a period of exploratory analysis that took place before these studies were written. Future studies on the SED data should make it clearer how the six partner countries differ from each other in terms of science education, diversity issues and views on science.

The student questionnaire included only four questions about views on the nature of science. It was during the initial exploration of the data that it was found that the answers to these questions were strongly related to the various constructs on interest in science. Despite the difficulties involved in asking students as young as ten years old questions about their views on science, it would be valuable to ask students more questions about how they view science in order to find out in greater detail which views are related to higher interest in science. The item with the greatest explanatory power in the multilevel analyses in chapter two was the one about what problems science can solve. This item was related to the tenet about the limits of what science can achieve (see McComas, 2008), but probably revealed more about the very positive way science is seen in countries outside Western Europe. It would be interesting to know more about how science is viewed outside Western Europe and what expectations students from these countries have of science.

Another drawback of the Science Education for Diversity study is that it did not employ longitudinal data, making it impossible to follow students over the course of time. Students in primary education and in secondary education completed the questionnaire and were interviewed around the same time. Because the analysis of the quantitative data showed that students in secondary education were on the whole less interested in science than students in primary education, it is possible to make the claim that interest in science decreases as students age. This study has, however, no account of a student who was interested in science in primary education and later lost this interest in secondary education. In the discussion of the results of chapters four and five, it was assumed that the students who are mostly interested in the content of science are most likely to persevere and continue with their science education, while the students with a mixed interest in science are more likely to drop their science courses. This assumption was made on the basis of the idea that the currently employed curricula in Dutch education will appeal most to students who are interested in the content of science and on the answers of the teachers in chapter five, but the data of the SED project does not offer the possibility to check whether this is actually true. Perhaps highly interested students suddenly lose all their interest in science after entering secondary education, while other students who were previously not interested in science become interested in science. It is neither clear what would happen with the students who are primarily interest in activities related to science as they age. Over time the experiments students do in their classes become less playful and exploratory. A longitudinal study in which students are followed over the course of years could reveal better how interest develops as students age.

After presenting the studies in this dissertation at Dutch and international conferences, we have often received the comment that economic reasons could be an important factor in explaining why students in countries outside Western Europe tend to be more interested in science and technology.

The assumption many people have is that students in India and in other countries outside Western Europe and North America would be more interested in science and technology because those studies would offer more opportunities for well-paying jobs and possibilities to work abroad than studies in other domains. We have not found any indication in our study that this is the case. There were no items in which students were directly asked whether their school interests were determined by job opportunities and money. However, no differences were observed between students who held an interest in school science and those who did not in an item about wanting a job that paid a lot of money. It is possible that money could become a more important reason for being interested in science for older students. During interviews, students between the ages of 10 and 14 in the Netherlands tended to pay little attention to money when discussing what jobs they would like to do in the future and the youngest students appeared not to be aware of which jobs were well paid and which jobs were not. However, this dissertation did not investigate if this was the case in other countries. Further studies could elucidate the possible role of jobs and money in pursuing science studies among older students.

6.6 | Implications for practice

The first two studies presented in this dissertation were primarily conducted in order to understand why students in different countries in the world were or were not interested in science. The two studies presented in chapters two and three therefore have few implications for the practice of science teaching in the Netherlands. The studies showed that many students in the Netherlands did not have an adequate understanding of what science is and what it is that scientists do. However, this has been found several times before and a call for more attention to be paid to the nature of science in science curricula has also been made before (Lederman, 1992). What the study in chapter two did show is that students in the Netherlands and the United Kingdom may not be sufficiently aware of the impact science and technology has on their daily lives, likely to a far lesser extent than students in countries where many technological developments have occurred more recently.

The third and fourth studies presented in this dissertation do have more direct implications for the practice of teaching science. Above all, the third study showed the necessity for understanding what drives different groups of students away from science or towards science. Without the understanding that different groups of students hold different interests in science, any attempt to increase interest in science will be ad-hoc and may not reach the intended students. It may be impossible to know the interests and preferences of around 30 individual students but the knowledge of the existence of possible groups of students is of value for teachers and curriculum developers. The Platform Bèta Techniek (2010) has made the same claim for a slightly older age group of students.

Current teaching methods are most likely geared towards the group of students that is mostly interested in the content of science and to a lesser degree towards the students who are primarily interested in technology and the activities related to science. The large group of students who are somewhat interested in science but who lack a good understanding of what science is, are probably not served best by the current curriculum. Teachers do employ many strategies to make science appealing but the extent to which these are used and the choice of which strategies are used depend strongly per teacher. A better analysis of the students and their interests present in the classroom, made possible with the instruments created for this study, could enable teachers to identify all groups of students present in their classes. More attention to experiments and to what science is, to what scientists do and to how science is part of life could also increase interest in science among different groups of students.

References

American Association for the Advancement of Science (1990). *The liberal art of science: Agenda for action*. Washington, DC: Author.

American Association for the Advancement of Science (2009). *The Nature of Science.* Project 2061: Benchmarks Online. Retrieved from http://www.project2061.org/publications/bsl/online/index.php?chapter=1

Abd-El-Khalick, F. (2005). Developing deeper understandings of nature of science: the impact of a philosophy of science course on preservice science teachers' views and instructional planning. *International Journal of Science Education*, 27, 15-42.

Abd-El-Khalick, F., & Lederman, N.G. (2000). Improving science teachers' conceptions of nature of science: A critical review of the literature. *International Journal of Science Education, 22,* 665-701.

Aikenhead, G. S., & Ryan, A. G. (1992). The development of a new instrument - Views on science-technology-society (VOSTS). *Science Education*, *76,* 477-491.

Aikenhead, G. S. (1997). Student views on the influence of culture on science. *International Journal of Science Education*, *19,* 419-428.

Aikenhead, G. S. & Otsuji, H. (2000). Japanese and Canadian teachers' views on science and culture. *Journal of Science Teacher Education, 11,* 277-299.

Akerson, V.L., Abd-El-Khalick, F. & N. G. Lederman, N.G.(2000) Influence of a reflective explicit activity-based approach on elementary teachers' conceptions of nature of science. *Journal of Research in Science Teaching, 37,* 295-317.

Akkerman, S., & Eijck, M.W. van (2013). Re-theorising the student dialogically across and between boundaries of multiple communities. *British Educational Research Journal. 39,* 60-72.

Andre, T., Whigham, M., Hendrickson, A. & Chambers, S. (1999). Competency Beliefs, Positive Affect, and Gender Stereotypes of Elementary Students and Their Parents about Science versus Other School Subjects, *Journal of Research in Science Teaching*, *36,* 719-747.

Aldridge, J. M., Fraser, B. J., Taylor, P. C., & Chen, C. C. (2000). Constructivist learning environments in a cross-national study in Taiwan and Australia. *International Journal of Science Education, 22,* 37-55.

Alexander, R. (2001). *Culture & Pedagogy - International comparisons in primary education,* Malden: Blackwell Publishing Ltd.

Aschbacher, P. R., Li, E. & Roth, E. J. (2010) Is Science Me? High School Students' Identities, Participation and Aspirations in Science, Engineering, and Medicine. *Journal of Research in Science Teaching, 47,* 564-582.

Barmby, P., Kind, P. M. & Jones, K. (2008) Examining Changing Attitudes in Secondary School Science. *International Journal of Science Education, 30*, 1075-1093.

Bennett, J., & Hogarth, S. (2009). Would you want to talk to a scientist at a party? High school students' attitudes to school science and to science. *International Journal of Science Education, 31,* 1975-1998.

Bybee, R., & McCrae, B. (2011). Scientific literacy and student attitudes: perspectives from PISA 2006 science. *International Journal of Science Education, 33,* 7-26.

Blickenstaff, J. C. (2005). Women and science careers: leaky pipeline or gender filter? *Gender and Education*, *17,* 369-386.

Blumberg, R. L. (2008). The invisible obstacle to educational equality: gender bias in textbooks. *Prospects*, *38,* 345–361.

Bosch, M. (2002). Women and Science in the Netherlands: A Dutch Case? *Science in Context*, *15,* 483-527.

Braund, M. & Driver, M. (2005). Pupils' perceptions of practical science in primary and secondary school: implications for improving progression and continuity of learning. *Educational Research, 47,* 77-91.

Brotman, J. S. & Moore, F. M. (2008). Girls and Science: A Review of Four Themes in the Science Education Literature. *Journal of Research in Science Teaching, 45,* 971-1002.

Bryan, L. A., & Atwater, M. M. (2002) Science Teacher Beliefs and Cultural Models: A Challenge for Science Teacher Programs. *Science Teacher Education*, 86, 821-839.

Bybee, R., & McCrae, B. (2011). Scientific literacy and student attitudes: perspectives from PISA 2006 science. *International Journal of Science Education*, *33,* 7-26.

Catsambis, S. (1995). Gender, Race, Ethnicity, and Science Education in the Middle Grades. *Journal of Research in Science Teaching*, *32*, 243-257.

Choi, K. & Cho, H-H. (2002). Effects of teaching ethical issues on Korean school students' attitudes towards science, *Journal of Biological Education*, *37,* 26-30.

Christidou, V. (2006) Greek Students' Science-related Interests and Experiences: Gender differences and correlations, *International Journal of Science Education*, *28,* 1181-1199.

Christidou, V. (2011). Combining students' voices with the voices of school Science, teachers, and popular science. International Journal of Environmental & Science Education, 6, 141-159.

Cobern, W. W. (1996) Constructivism and non-western science education research. *International Journal of Science Education, 18,* 295-310.

Debacker, T. K. & Nelson, R. M. (2000). Motivation to Learn Science: Differences Related to Gender, Class Type, and Ability. *The Journal of Educational Research*, *93,* 245-254.

den Brok, P., Bergen, T., & Brekelmans, M. (2006). Convergence and divergence between students' and teachers' perceptions of instructional behaviour in Dutch secondary education. In D. Fisher & M. D. Khine (Eds.), *Contemporary approaches to research on learning environments: world views* (pp.125-160). Singapore: World Scientific.

den Brok, P., van Eerde, D. & Hajer, M. (2010). Classroom interaction studies as a source for teacher competencies: the use of case studies with multiple instruments for studying teacher competencies in multicultural classes. *Teachers and Teaching: theory and practice*, *16,* 717-733.

Deng, F., Chen, D. T., Tsai, C. C., & Chai, C. S. (2011). Students' views of the nature of science: A critical review of research. *Science Education, 95,* 961-999.

DeWitt, J., Osborne, J., Archer, L., Dillon, J., Willis, B. & Wong, B. (2013). Young Children's Aspirations in Science: The unequivocal, the uncertain and the unthinkable. *International journal of Science Education, 35,* 1037-1063.

Dogan, N., & Abd-El-Khalick, F. (2008). Turkish grade 10 students' and science teachers' conceptions of nature of science: A national study. *Journal of Research in Science Teaching, 45,* 1083-1112.

Eccles, J. S. (1994). Understanding Women's educational and occupational choices; Applying the Eccles et al. Model of Achievement-related choices. *Psychology of Women Quarterly, 18,* 585-609.

Eijkelhof, H. M. C., & Kortland, J. (1988). Broadening the aims of physics education. In P.J. Fensham (Ed.), *Development and dilemmas in science education* (pp. 282-305). London: Falmer Press.

Fraser, B. J. (1994). Research on classroom and school climate. In D. GabeI (Ed.), *Handbook of research on science teaching and learning* (pp. 493-541). New York: Macmillan.

Ferguson, P. D. & Fraser, B. J. (1998). Student gender, school size and changing perceptions of science learning environments during the transition from primary to secondary school. *Research in Science Education, 28,* 387-397.

Finson, K. D. (2002). Drawing a scientist: What we do and do not know after fifty years of drawings. *School Science and Mathematics, 102,* 335-345.

Gago, J. M., Ziman, J., Caro, P. Constantinou, C., Davies, G., Parchman, I., Rannikmäe, I., & Sjøberg, S. (2004). *Europe needs more scientists: Report by the high level group on increasing human resources for science and technology in Europe.* Retrieved from http://ec.europa.eu/research/conferences/2004/sciprof/pdf/final_en.pdf

Gao, L. B. & Watkins, D. A. (2002). Conceptions of teaching held by school science teachers in P.R. China: identification and crosscultural comparisons. *International Journal of Science Education, 24,* 61-79.

George, R. (2000). Measuring Change in Students' Attitudes Toward Science Over Time: An Application of Latent Variable Growth Modeling. *Journal of Science Education and Technology*, *9,* 213-225.

George, R. (2006). A cross-domain analysis of change in students' attitudes toward science and attitudes about the utility of science. *International Journal of Science Education, 28,* 571-589.

George R. & Kaplan, D. (1998). A Structural Model of Parent and Teacher Influences on Science Attitudes of Eighth Graders: Evidence from NELS: 88. *Science Education, 82*, 93–109.

Gorard,S. & Huat See, B. (2009). The impact of socio-economic status on participation and attainment in science. *Studies in Science Education, 45,* 93-129.

Guzzetti, B. J. (1996). Gender, Text, and Discussion: Examining Intellectual Safety in the Science Classroom. *Journal of Research in Science Teaching*, *33,* 5-20.

Hagay, G., Baram-Tsabari, A., Ametller, J., Cakmakci, G., Lopes, B., Moreira, A. et al. (2013). The generalizability of students' interests in biology across gender, country and religion. *Research in Science Education, 43,* 895-919.

Hashweh, M. Z. (1996). Effects of science teachers' epistemological beliefs in teaching. *Journal of Research in Science Teaching, 33,* 47-63.

Haste, H. (2004). *Science in my Future: A study of values and beliefs amongst 11-21 year olds.* London: Nestlé Social Research Programme.

Hui, C.H. & Triandis, H.C. (1985). Measurement in cross-cultural psychology: a review and comparison of strategies. *Journal of cross-cultural psychology, 16,* 131-152.

Hulleman, C.S. & Harackiewicz, J. M. (2009). Promoting Interest and Performance in High School Science Classes. *Science, 326,* 1410-1412.

Iqbal, H. M., Azam, S. & Rana, R. A. (2009) Secondary school science teachers' views about the 'nature of science'. *Bulletin of Education and Research, 31,* 29-44.

Irez, S. (2006). Are we prepared?: An assessment of preservice science teacher educators' beliefs about nature of science. *Science Education 90,* 1113-1143.

Jayaratne, T. E., Thomas, N. G. & Trautmann, M. (2003). Intervention Program to Keep Girls in the Science Pipeline: Outcome Differences by Ethnic Status. *Journal of Research in Science Teaching*, *40,* 393-414.

Jehng J.-C., Johnson S. D., & Anderson R. C. (1993). Schooling and students' epistemological beliefs and learning. *Contemporary Educational Psychology, 18,* 23-35.

Jenkins, E. W. & Nelson, N. W. (2005). Important but not for me: students'attitudes towards secondary school science in England. *Research in Science & Technological Education, 23,* 41-57.

Johnson, B. & McClure, R. (2004). Validity and reliability of a shortened, revised version of the constructivist learning environment survey (CLES). *Learning Environments Research, 7,* 65-80.

Jones, M. G., Howe, A. & Rua, M. J. (2000). Gender differences in students' experiences, interests, and attitudes toward science and scientists. *Science Education*, *84,*180-192.

Kang, S. J., Scharmann, L. C., & Noh, T. (2005). Examining students' views on the nature of science: Results from Korean 6th, 8th, and 10th graders. *Science Education*, *89,* 314-334.

Kawasaki, K. (1996). The concepts of science in Japanese and Western education. *Science & Education*, *5,* 1-20.

Kind, P., Jones, K., & Barmby, P. (2007). Developing attitudes towards science measures. *International Journal of Science Education*, *29,* 871-893.

Krapp, A. & Prenzel, M. (2011). Research on Interest in Science: Theories, methods, and findings, *International Journal of Science Education, 33,* 27-50.

Kumar, R. & Hamer, L. (2012). Preservice Teachers' Attitudes and Beliefs Toward Student Diversity and Proposed Instructional Practices: A Sequential Design Study. *Journal of Teacher Education, 64,* 162-177.

Laplante, B. (1997). Teachers' beliefs and instructional strategies in science: Pushing analysis further. *Science Education, 81,* 277-294.

Lederman, N. G. (1992). Students' and teachers' conceptions about the nature of science: A review of the research. *Journal of Research in Science Teaching*, *29,* 331-359.

Lederman, N. G. (1999). Teachers' understanding of the nature of science and classroom practice: factors that facilitate or impede the relationship. *Journal of Research in Science Teaching, 36,* 916-929.

Lederman, N. G., Abd-El-Khalick, F., Bell, R. L., & Schwartz, R. S. (2002). Views of nature of science questionnaire: Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching*, *39,* 497-521.

Lee, O., Hart, J. E., Cuevas, P. & Enders, C. (2004). Professional Development in Inquiry-Based Science for Elementary Teachers of Diverse Student Groups. *Journal of Research in Science Teaching, 41,* 1021-1043.

Lee, O. & Luyckx, A. (2007). Science Education and Student Diversity: Race/Ethnicity, Language, Culture and Socioeconomic Status. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of Research in Science Education* (pp. 171-197). New York NY: Routledge.

Liu, S.-Y., & Lederman, N. (2002). Taiwanese gifted students' views of nature of science. *School Science and Mathematics*, *102,* 114-123.

Liu, S.-Y., & Tsai, C.-C. (2008). Differences in the scientific epistemological views of undergraduate students. *International Journal of Science Education, 30,* 1055-1073.

Logan, S. & Skamp, K. (2008). Engaging students in science across the primary secondary interface: Listening to the students' voice. *Research in Science Education, 38,* 501-527.

Lyons, T. (2006). The Puzzle of Falling Enrolments in Physics and Chemistry Courses: PuttingSome Pieces Together. *Research in Science Education, 36,* 285-311.

Markowitz, D. G. (2004). Evaluation of the Long-Term Impact of a University High School Summer Science Program on Students' Interest and Perceived Abilities in Science. *Journal of Science Education and Technology, 13,* 395-407.

Marks, G. N.(2008). Accounting for the gender gaps in student performance in reading and mathematics: evidence from 31 countries. *Oxford Review of Education, 34,* 89 — 109.

McComas W. F., & Olson, J. (2002). The nature of science in international science education standards documents. In W. F. McComas (Ed.), *The nature of science in science education: rationales and strategies* (pp. 41–52). Dordrecht: Kluwer Academic Publishers.

McComas, W. F., Clough, M. P., & Almazroa, H. (2002). The role and character of the nature of science in science education. In W. F. McComas (Ed.), *The nature of science in science education: rationales and strategies* (pp. 3-39). Dordrecht: Kluwer Academic Publishers.

McComas, W. F. (2008). Seeking historical examples to illustrate key aspects of the nature of science. *Science & Education, 17,* 249-263.

Mellado, V. (1998). The classroom practice of preservice teachers and their conceptions of teaching and learning science. *Science Education, 82,* 197-214.

Miller, P. H., Slawinski Blessing, J. & Schwartz, S. (2006). Gender Differences in High-school Students' Views about Science. *International Journal of Science Education, 28,* 363-381.

Ministry of Education, C. a. S. (2009). *Key figures 2004-2008 - Education, Culture and Science.* Kelpen: Hub. Tonnaer.

Ministry of Education, C. a. S. (2014). *Kerncijfers 2007-2013 – Onderwijs, Cultuur en Wetenschap.* Kelpen: Hub. Tonnaer.

Murphy, C. & Beggs, J. (2003). Children's perceptions of school science. *School Science Review*, *84,* 109-116.

Murphy, P. & Whitelegg, E. (2006). Girls and physics: continuing barriers to 'belonging'. *Curriculum Journal, 17,* 281-305.

National Research Council (2012). *A Framework for K-12 science education: Practices, crosscutting concepts and core ideas*. Washington D.C.: The National Academies Press.

Nosek, B. A., Smyth, F. L., Sriram, N. Lindner, N. M., Devos, T., Ayala, A., … Greenwald, A. G. (2009). National differences in gender–science stereotypes predict national sex differences in science and math achievement. *Proceedings of the National Academy of Science, 106,* 10593-10597.

NSTA (2000). NSTA Position Statement: The Nature of Science. Retrieved from http://www.nsta.org/about/positions/natureofscience.aspx [On-line].

Organisation for Economic Co-operation and Development. (2007). *PISA 2006: Science competencies for tomorrow's world. Volume 1: Analysis*. Retrieved from http://www.oecd-ilibrary.org/education/pisa-2006_9789264040014-en.

Organization for Economic Co-operation and Development (OECD) (2012). *Education at a glance: Highlights.* Paris: OECD Publishing.

Osborne, J. & Collins, S. (2001). Pupils' views of the role and value of the science curriculum: a focus-group study. *International Journal of Science Education, 23,* 441-467.

Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: a review of the literature and its implications. *International Journal of Science Education, 25,* 1049-1079.

Park, D.-Y. & Lee, B. L. (2009). Different conceptions of the nature of science among preservice elementary teachers of two countries. *Journal of Elementary Science Education, 21,* 1-14.

Pell, T. & Jarvis, T. (2001). Developing attitude to science scales for use with children of ages from five to eleven years. *International Journal of Science Education, 23,* 847-862.

Phillips, D. C. (2005). The good, the bad and the ugly: the many faces of constructivism. *Educational researcher, 24,* 5-12.

Platform Bèta Techniek (2010). *BètaMentality 2011-2016; Getting young people interested in science and technology.* The Hague: Platform Bèta Techniek.

Pomeroy, D. (1993). Implications of teachers beliefs about the nature of science - Comparison of the beliefs of scientists, secondary science teachers, and elementary teachers. *Science Education, 77,* 261-278.

Programme for International Student Assessment (2007). *PISA 2006 Science Competencies for Tomorrow's World: Volume 1: Analysis.* Paris: OECD Publishing.

Ramsden, J. M. (1998). Mission impossible?: Can anything be done about attitudes to science? *International Journal of Science Education*, *20,* 125-137.

Rasbash, J., Charlton, C., Browne, W. J., Healy, M., & Cameron, B. (2005). *MLwiN Version 2.02.* Bristol: University of Bristol, Centre for Multilevel Modelling.

Raved, L. & Assaraf, O. B. Z. (2011). Attitudes towards Science Learning among 10th-Grade Students: A qualitative look. *International Journal of Science Education*, *33,* 1219-1243.

Saad R. & BouJaoude, S. (2012). The Relationship between Teachers' Knowledge and Beliefs about Science and Inquiry and Their Classroom Practices. *Eurasia Journal of Mathematics, Science & Technology Education, 8,* 113-128.

Sadler, P. M., Sonnert, G., Hazari, Z. & Tai, R. (2012). Stability and Volatility of STEM Career Interest in High School: A Gender Study. *Science Education*, *96,* 411–427.

Schommer-Aikins, M., Duell, O. K., & Barker, S. (2003). Epistemological beliefs across domains using Biglan's classification of academic disciplines. *Research in Higher Education*, *44,* 347-366.

Schreiner, C., & Sjøberg, S. (2010). Science education and young people's identity construction - Two mutually incompatible projects? In D. Corrigan, J. Dillon, & R. Gunstone (Eds.), *Re-emergence of values in Science Curriculum* (pp. 231-247). Rotterdam: Sense Publishers.

Schwartz, R. S. & N. G. Lederman, N.G. (2002). "It's the nature of the beast": The influence of knowledge and intentions on learning and teaching nature of science. *Journal of Research in Science Teaching, 39,* 205-236

Science Education for Diversity (SED). (2013). *Science Education for Diversity website*. Retrieved from http://science-education-for-diversity.eu/

Shanahan, M. C. & Nieswandt, M. (2011). Science student role: Evidence of social structural norms specific to school science. *Journal of Research in Science Teaching, 48,* 367-395.

Silver, A. & Rushton B. S. (2013). Primary-school children's attitudes towards science, engineering and technology and their images of scientists and engineers. *Education 3-13, 36,* 51-67.

Sjøberg, S. (2003). Science and Technology Education Current Challenges and Possible Solutions. In E. Jenkins (ed.), *Innovations in Science and Technology Education Vol VIII* (pp. 201-228). Paris: UNESCO.

Sjøberg, S., & Schreiner, C. (2005a). *The ROSE Project: An overview and key findings.* Retrieved from http://roseproject.no./network/countries/norway/eng/nor-Sjoberg-Schreiner-overview-2010.pdf

Sjøberg, S., & Schreiner, C. (2005b). How do learners in different cultures relate to science and technology? *Asia-Pacific Forum on Science Learning and Teaching, 6,* 1-17.

Snijders, T. A .B., & Bosker, R. J. (1999). *Multilevel Analysis: An introduction to basic and advanced multilevel modeling.* London: Sage Publications.

Solomon, J. (1991). Teaching about the nature of science in the British national curriculum. *Science Education, 75,* 95-103.

Speering, W. & Rennie, L. (1996). Students' perceptions about science: The impact of transition from primary to secondary school. *Research in Science Education, 26,* 283-298.

Strauss, A. & Corbin, J. (1990). *Basics of qualitative research: Grounded theory procedures and techniques.* Newbury Park, CA: Sage Publications.

Swarat, S., Ortony, A. & Revelle, A. (2012). Activity Matters: Understanding Student Interest in School Science. *Journal of Research in Science Teaching, 49,* 515-537.

Taylor, P. C., Fraser, B. J., & Fisher, D. L. (1997). Monitoring constructivist classroom learning environments. *International Journal of Educational Research, 27,* 293-302.

Tobin K. (2011). Global reproduction and transformation of science education. *Cultural Studies of Science Education, 6,* 127-142.

Tobin K. & McRobbie C. J. (1997). Beliefs about the nature of science and the enacted science curriculum. *Science & Education, 6,* 355-371.

Tsai, C. C. (2002). Nested epistemologies: science teachers' beliefs of teaching, learning and science. *International Journal of Science Education, 24*, 771-783.

Tsai, C. C. (2007). Teachers' scientific epistemological views: The coherence with instruction and students' views. *Science Education, 91,* 222-243.

Uerz, D., Dekkers, H. & Béguin, A. A. (2004). Mathematics and language skills and the choice of science subjects in secondary education. *Educational Research and Evaluation*, *10,* 163-182.

Ullici, K. & Battey, D. (2011). Exposing Color Blindness/Grounding Color Consciousness; Challenges for Teacher Education. *Urban Education*, *46,* 1195-1225.

van Amelsvoort, J. (1999). *Perspective on instruction, motivation and self-regulation.* Doctoral dissertation [in Dutch]. Nijmegen: University Press.

van Langen, A. & Dekkers, H. (2005). Cross-national differences in participating in tertiary science, technology, engineering and mathematics education. *Comparative Education, 41,* 329- 350.

van Langen, A. , Rekers-Mombarg, L., & Dekkers, H. (2008). Mathematics and science choice following introduction of compulsory study profiles into Dutch secondary education. *British Educational Research Journal, 34,* 733-745.

Vedder-Weiss, D. & Fortus, D. (2011). Adolescents' declining motivation to learn science: Inevitable or not? *Journal of Research in Science Teaching, 48,* 199-216.

Villegas, A. M. & Lucas, T. (2002). Preparing Culturally Responsive Teachers: Rethinking the Curriculum. *Journal of Teacher Education, 53,* 20-32.

Water-Adams, S. (2006). The Relationship between understanding of the nature of science and practice: The influence of teachers' beliefs about education, teaching and learning. *International Journal of Science Education, 28,* 919-944.

Wubbels, T. (1985). Cross-national studies of learning environments. In B.J. Fraser (Ed.), *The study of learning environments, volume 7.* (pp. 112-120). Perth: Curtin.

Zhai, J., Jocz, J. A., & Tan, A.-L. (2014). 'Am I like a scientist?': Primary children's images of doing science in school. *International Journal of Science Education, 36,* 961-999.

Appendix 1 Student questionnaire

The student questionnaire is displayed below. This is the English version of the questionnaire. A translated Dutch version was used for research in the Netherlands. The questions on ethnicity and language use were adapted in each country.

YOU AND THE WORLD AROUND YOU

These questions are about you and how you think about the world around you.

All your answers are confidential. This means that only the researchers will read your answers and know your name.

Your teacher will tell you how to fill in the questionnaire. Please do not start until you are told to do so.

SECTION 1: ABOUT YOU

First of all we would like to ask some questions about you.
Please remember that your answers are confidential.

1a	**What is your name?** ________________________ Please write first name and family name	
1b	**Are you a girl or a boy?** Please draw a circle round 'boy' or 'girl'	I am a: girl boy
1c	**How old are you?** Please draw a circle round your age.	9 10 11 12 13 14 15
1d	**Which school do you attend?** Please circle the name of your school	[name school 1] [name school 2]
1e	**Which school year are you in?** Please draw a circle round your school year	Primary school: 7 8 Secondary school: 1 2
1f	**What class are you in?** Please circle	[name class 1] [name class 2]

SECTION 2: ABOUT SCHOOL

Here are some questions about school.

2a **What is your MOST favorite lesson?**
Please write in ____

2b **Why is this your favorite? Here are some reasons why you might like it.**
Please tick the box that shows how true is each reason for why you like your favorite lesson.

		Very true	A bit true	Not true
2b.1	It is my favorite because it is about finding out how things work	☐	☐	☐
2b.2	It is my favorite because it is about what people feel and how they think	☐	☐	☐
2b.3	It is my favorite because I like the teacher	☐	☐	☐
2b.4	It is my favorite because I am good at it.	☐	☐	☐
2b.5	It is my favorite because I can use my imagination	☐	☐	☐
2b.6	It is my favorite because I learn things that are useful for my life	☐	☐	☐

2c **What is your LEAST favorite lesson?**
Please write in ____

2d **Why is this your least favorite? Here are some reasons why you might not like it.**
Please tick a box for each reason to show how much it is true for why you do not like this lesson.

		Very true	A bit true	Not true
2d.1	It is my least favorite because it is about boring things	☐	☐	☐
2d.2	It is my least favorite because it is not about people	☐	☐	☐
2d.3	It is my least favorite because I don't like the teacher	☐	☐	☐
2d.4	It is my least favorite because I find it too hard	☐	☐	☐
2d.5	It is my least favorite because I can't use my imagination	☐	☐	☐
2d.6	It is my least favorite because it has nothing to do with real life	☐	☐	☐

SECTION 3: WHAT I LIKE TO DO

3a **Here are some things that you might like to do.** Please tick the box next to each one to show if this is
something that you like to do A LOT,
or something that you like to do A LITTLE ,
or something that you DON'T like to do.

		I like doing this A LOT	I like doing this A LITTLE	I DON'T like doing this
3a.1	Going to science museums	☐	☐	☐
3a.2	Watching TV programs about animals and nature	☐	☐	☐
3a.3	Finding out how our bodies work	☐	☐	☐
3a.4	Watching TV programs about space and the planets	☐	☐	☐
3a.5	Finding out about new inventions and discoveries	☐	☐	☐
3a.6	Helping to look after people when they are sick	☐	☐	☐
3a.7	Using new machines and technology	☐	☐	☐
3a.8	Fixing things when they break	☐	☐	☐
3a.9	Thinking about ways that I and my family can help the environment	☐	☐	☐
3a.10	Cooking and preparing food	☐	☐	☐
3a.11	Making things out of wood or metal	☐	☐	☐
3a.12	Making or altering clothes	☐	☐	☐
3a.13	Talking to my parents about science	☐	☐	☐
3a.14	Watching TV programs or reading about how natural things like volcanoes, hurricanes and floods happen	☐	☐	☐
3a.15	Talking to my friends about science	☐	☐	☐

3b	**Think about your science lessons in school. How much do you like them and why do you like them or not like them?**			
		Very true	A bit true	Not true
3b.1	I like all science lessons in school	☐	☐	☐
3b.2	I like some science lessons but not all of them	☐	☐	☐
3b.3	I most like science lessons about living things	☐	☐	☐
3b.4	I most like science lessons about what the world is made of, like atoms and molecules	☐	☐	☐
3b.5	I don't like any science lessons	☐	☐	☐
3b.6	I don't like science because it ignores feelings and people	☐	☐	☐
3b.7	I like science because it has clear right answers	☐	☐	☐
3b.8	I don't like science because it is too hard	☐	☐	☐

SECTION 4: WHAT I BELIEVE

4a **When people talk about 'science' what do they mean?** Please tick the box to show whether you think each of the following are part of 'science' or not.

		Always part of science	Sometimes part of science	Never part of science	I don't know
4a.1	Making music	☐	☐	☐	☐
4a.2	Looking at fossils and dinosaurs	☐	☐	☐	☐
4a.3	Trying to predict whether you will be lucky in the future	☐	☐	☐	☐
4a.4	Finding out how to cure disease	☐	☐	☐	☐
4a.5	Exploring space	☐	☐	☐	☐
4a.6	Finding out about climate change	☐	☐	☐	☐
4a.7	Digging up old cities and temples	☐	☐	☐	☐
4a.8	Healing people who are sick	☐	☐	☐	☐
4a.9	Farming	☐	☐	☐	☐
4.10	Building a bridge	☐	☐	☐	☐
4a.11	Finding out why some countries are poor and some are rich	☐	☐	☐	☐
4a.12	Finding out why some people learn things more easily than others do	☐	☐	☐	☐
4a.13	Reading about people in the past who discovered or invented things	☐	☐	☐	☐

4b **Here are some things that some people of your age say. How much do you agree with each of them?** Please tick the box on each line to show if you agree A LOT, or if you agree A LITTLE, or you DON'T AGREE.

		I agree A LOT	I agree A LITTLE	I DON'T AGREE
4b.1	People of my age who like science are very intelligent	☐	☐	☐
4b.2	People of my age who like science make friends easily	☐	☐	☐
4b.3	People of my age who like science can only talk about a few things	☐	☐	☐
4b.4	People of my age who like science have friends who are mostly girls	☐	☐	☐
4b.5	People of my age who like science are interesting to talk to	☐	☐	☐
4b.6	People of my age who like science have friends who are mostly boys	☐	☐	☐
4b.7	People of my age who like science are 'cool'	☐	☐	☐
4b.8	People of my age who like science are friends with both boys and girls	☐	☐	☐
4b.9	People of my age who like science can talk about lots of different things	☐	☐	☐

4c **Here are some thing that you might believe, or things that you might do. How much is each one true of you? Is it VERY TRUE A BIT TRUE, or NOT TRUE?** Please put a tick in the box that shows how true each one is for you.

		Very true for me	A bit true for me	Not true for me
4c.1	I am worried about global warming	☐	☐	☐
4c.2	I am careful not to buy products that have been tested on animals	☐	☐	☐
4c.3	I try to do everything I can to help to save the environment	☐	☐	☐
4c.4	I am worried that scientists may discover or invent something that will cause a big disaster.	☐	☐	☐

4d Here are some pairs of ideas. Think carefully about each pair of ideas. Which one is closest to what YOU think?
There are four boxes between each pair. Please put a tick in the box that shows which idea is MOST CLOSE to what you think, and HOW close it is.

FOR EXAMPLE:

1. I prefer chocolate ice cream	■	☐	☐	☐	I prefer vanilla ice cream

This would show that you REALLY DO like chocolate ice cream a LOT more than you like vanilla ice cream

2. I prefer oranges	☐	☐	■	☐	I prefer bananas

This would show that you like bananas A LITTLE MORE than you like oranges.

Which idea is closer to what YOU believe?

4d.1	Science can help to solve most problems that people face in their life	☐	☐	☐	☐	Science is only useful for a small number of problems that people face in their life
4d.2	What we know today in science is just the best guess that scientists can make from what their experiments tell them	☐	☐	☐	☐	Science tells us what is completely true about the world around us
4d.3	Most scientific discoveries are made by a team of people working together	☐	☐	☐	☐	Most scientific discoveries are the work of one very intelligent person
4d.4	The best scientists use their imagination to help get good ideas	☐	☐	☐	☐	The best scientists stick to facts and proofs
4d.5	The government should make laws so that scientists don't discover or invent dangerous things	☐	☐	☐	☐	Scientists should decide where science should go, not the government
4d.6	I believe that using animals in experiments is always wrong	☐	☐	☐	☐	I believe that it is OK for scientists to experiment on animals in order to save human lives

SECTION 5: Today and the future

5a **Today, in 2010, which country in the world do you think is the most successful in science and discovery?** Please write here.

____

5b **Today, in 2010, which country in the world do you think is the most successful in computer technology? Please write here.**

____

5c **Imagine it is the year 2030, twenty years from now. How old will YOU be in 2030?** Please write here.

____

5d **In 2030, which country in the world do you think will be the most successful in science and discovery?** Please write here.

____

5e **In 2030, which country in the world do you think will be the most successful in computer technology? Please write here.**

____

5f **What will the world be like in 2030? Here are three ideas about what the world will be like then. Which idea do YOU think is MOST LIKELY to be true in 2030?**

Please tick one box below to show which of the three people you think is MOST LIKELY TO BE RIGHT about what the world will be like in 2030?

5f.1 JEM says: "Things will be much the same as they are today but we will have better phones and computers" ☐

5f.2 NAT says: "New inventions and technology will have solved most of the health and environmental problems that we have now" ☐

5f.3 LOU says: "Things will have got worse in the world, not better, and there will be more wars, crime and violence" ☐

5g **Here are some things that different people believe about where we come from.** Do YOU agree most with Dal, Jud or Oll? Please tick ONE box below to show which one **YOU** MOST agree with.

5g.1 DAL says: “Life on earth, including human life, has evolved over millions of years and some creatures, like dinosaurs, became extinct long before humans evolved” ☐

5g.2 JUD says: “Most life on earth evolved over millions of years but God created human life” ☐

5g.3 OLL says: “God created all life on earth at the same time, about 10,000 years ago” ☐

5h **Do you think most of your FAMILY would agree most with Dal, Jud or Oll?**

Please tick ONE box below to show which one you think most of **YOUR FAMILY** would agree with most.

5h.1 DAL says: “Life on earth, including human life, has evolved over millions of years and some creatures, like dinosaurs, became extinct long before humans evolved” ☐

5h.2 JUD says: “Most life on earth evolved over millions of years but God created human life” ☐

5h.3 OLL says: “God created all life on earth at the same time, about 10,000 years ago” ☐

5i **Do you think your SCIENCE TEACHER would agree most with Dal, Jud or Oll?**

Please tick ONE box below to show which of them you think your **SCIENCE TEACHER** would agree with most.

5i.1 DAL says: “Life on earth, including human life, has evolved over millions of years and some creatures, like dinosaurs, became extinct long before humans evolved” ☐

5i.2 JUD says: “Most life on earth evolved over millions of years but God created human life” ☐

5i.3 OLL says: “God created all life on earth at the same time, about 10,000 years ago” ☐

SECTION 6: ABOUT YOU

6a **When you grow up, what is the job that you would MOST LIKE to do?** Please write in the name of this job.

____

6b **What would be important to you when you choose your future job?**

Please tick the box on each line that shows if this is something you would like A LOT to have in your future job, something you would like A LITTLE to have in your future job, or something that you WOULD NOT LIKE in your future job.

		I would like this A LOT	I would like this A LITTLE	I would NOT like this
6b.1	I would like to have a job where I work with other people not just by myself	☐	☐	☐
6b.2	I would like a job where I can help people	☐	☐	☐
6b.3	I would like a job where people will look up to me and respect me	☐	☐	☐
6b.4	I would like a job where I can discover or invent new things	☐	☐	☐
6b.5	I would like a job that will make me well known	☐	☐	☐
6b.6	I would like a job that will get me a lot of money	☐	☐	☐
6b.7	I would like a job related to science or technology	☐	☐	☐

6c **Here are THREE things that might be true of this job. Which ONE is MOST true?**
Please tick ONE box that shows which is MOST true.

		MOST true
6c.1	This is a job that is mostly done by men	☐
6c.2	This is a job that is mostly done by women	☐
6c.3	This is a job that both men and women do	☐

6d **Here are some things about you and technology.**
Please tick the box to show which is true about you and which is not.

		True	Not true
6d.1	I have a mobile phone	☐	☐
6d.2	There is a computer at home that I can use	☐	☐
6d.3	There is a computer at school that I can use	☐	☐
6d.4	I am on Facebook	☐	☐

6e **How often do you do the following things?** Please tick a box on each line to show how often you do this.

		At least every day	At least once a week	At least once a month	Less often or never
6e.1	Call or text my friends on my mobile phone	☐	☐	☐	☐
6e.2	Use the internet to help me with my school work	☐	☐	☐	☐
6e.3	Play computer or video games	☐	☐	☐	☐

6f **What is your religion?** Please tick the box to show which is your religion

6f.1	Christian	☐
6f.2	Muslim	☐
6f.3	Sikh	☐
6f.4	Hindu	☐
6f.5	Buddhist	☐
6f.6	Jewish	☐
6f.7	I have no religion	☐
6f.8	I do not want to answer this question	☐

If you have another religion that is not on the list, please write it in ______________________________

6g **How often do you attend a religious service at the place of worship for your religion (church, mosque, temple)?** Please tick the box that shows which is MOST true for you.

		MOST true
6g.1	Every week	☐
6g.2	About once a month	☐
6g.3	Only on special religious days or festivals	☐
6g.4	Only for family events like weddings	☐
6g.5	Never	☐

6h **How often do you pray?** Please tick the box that shows which is MOST true for you.

		MOST true
6h.1	More than once a day	☐
6h.2	Once a day	☐
6h.3	Once a week	☐
6h.4	Sometimes, when I need to or want to	☐
6h.5	Never	☐

SECTION 7: TELLING ABOUT YOURSELF

7a **Imagine that a new person the same age as you came to your school and you want to make friends.**
When you meet them, what do you want them to know about you?
What would be VERY important to tell them, which would be A LITTLE BIT IMPORTANT to tell them and which would NOT IMPORTANT to tell them.
Please tick the box on each line to show what is important for your new friend to know about you. If something does not APPLY TO YOU, or is not true of you, tick that box.

		This would be VERY important to tell them	This would be A LITTLE BIT important to tell them	This would NOT BE important to tell them	Does NOT apply to me
7a.1	What sports you like	☐	☐	☐	☐
7a.2	What is your religion	☐	☐	☐	☐
7a.3	What TV programs you like to watch	☐	☐	☐	☐
7a.4	What country did your grandparents live in	☐	☐	☐	☐
7a.5	What is your favorite hobby	☐	☐	☐	☐
7a.6	That your family is Dutch	☐	☐	☐	☐
7a.7	That your family is Turkish	☐	☐	☐	☐
7a.8	That your family is Moroccan	☐	☐	☐	☐
7a.9	That your family is Surinamese	☐	☐	☐	☐
7a.10	That your family is Antillean	☐	☐	☐	☐
7a.12	That your family comes from another country – please write in the name of the country here ________________________	☐	☐	☐	☐

SECTION 8: LANGUAGE

8a The language you are reading now is Dutch
Some people speak different languages at home, at school, or with their friends.
Which language do you MAINLY speak at home with your family? Please write here.

____

8b **Are there any OTHER languages that you speak at home with your family?** Please write them here.

____

8c **Which language do you MAINLY speak with your friends?** Please write here.

____

8d **Are there any OTHER languages that you speak with your friends?** Please write here.

____

SECTION 9: BOOKS

9a **About how many books are there in your home? Don't include magazines**.
To help you guess the number, think of making a pile of books a metre high. That would be about 40 books.
Please tick the box that shows how many books are in your home

9a.1	Less than 10 books	☐
9a.2	Between 10 and 100 books	☐
9a.3	Between 100 and 1000 books	☐
9a.4	More than 1000 books	☐

SECTION 10: PEOPLE IN YOUR COUNTRY

10 **Here is a list of different groups of people who live in your country. Which group, or groups, describe you and your family?**
Please put a tick in the box next to **all** the groups to which you and your family belong.

10.1	Dutch	☐
10.2	Turkish	☐
10.3	Moroccan	☐
10.4	Surinamese	☐
10.5	Antillean	☐
10.6	Indonesian	☐
10.7	Chinese	☐
10.8	German	☐

From another country – please write the name of the country here

____

THANK YOU FOR ANSWERING ALL THE QUESTIONS

Appendix 2 Teacher questionnaire

The teacher questionnaire is displayed below. A translated Dutch version of this questionnaire was used for research in the Netherlands. The questions on ethnicity and language use were adapted in each country.

SCIENCE EDUCATION AND DIVERSITY

This is a questionnaire about your views on teaching science and how this is related to education and diversity.

It will be used for a research project funded by the European Union and called *Science Education for Diversity*.

All your answers are confidential.

SECTION 1: ABOUT YOU

First of all we would like to ask some questions about you.
Please remember that your answers are confidential.

1a Name ____

1b ☐ Female ☐ Male

1c Age _________

1d Number of years you have been teaching
☐ Less than 2
☐ 2 –5
☐ 6 – 10
☐ More than 10

1e Name of school ____

1f How would you describe your current teaching? Please tick one.
☐ I teach a wide range of subjects, of which science is one
☐ I mainly teach science but I teach several science subjects
☐ I am a specialist science teacher

1g Which of the following subjects do you currently teach? Please tick all that apply.

- ☐ Classroom teacher, no specific subject
- ☐ General science
- ☐ Physics
- ☐ Chemistry
- ☐ Biology
- ☐ Environmental studies
- ☐ Technology
- ☐ Mathematics
- ☐ Geography

1h What proportion of your teaching time do you spend teaching science? Please tick one.

- ☐ 10% or less
- ☐ 10-25%
- ☐ 25 –50%
- ☐ More than 50%

1i To what age students do you currently teach science? Please tick all that apply.

- ☐ 9 years old
- ☐ 10 years old
- ☐ 11 years old
- ☐ 12 years old
- ☐ 13 years old
- ☐ 14 years old
- ☐ 15 years old
- ☐ Over 15 years old.

1j Overall, in the science classes that you currently teach, are the students (Please tick one):

- ☐ All female
- ☐ All male
- ☐ More than 70% female
- ☐ More than 70% male
- ☐ Approximately equal number of males and females

1k Thinking overall of the students to whom you currently teach science, please estimate the proportion, as a percentage, of them who fall into the following ethnic, religious or social groups:

Dutch ______
Moroccan ______
Turkish ______
Surinamese ______
Antillean ______
Other, ___________ ______

SECTION 2: YOUR BACKGROUND

Please remember that your answers are confidential.

2a What is your highest academic qualification? Please tick one.

☐ Secondary/high school final examinations
☐ Tertiary college, non-degree qualification (e.g. certificate)
☐ Tertiary college/university, undergraduate degree
☐ Postgraduate qualification

2b What is your highest qualification in a science or technology subject? Please tick one.

☐ None
☐ Secondary/high school final examinations
☐ A major component of a tertiary college, non-degree qualification
☐ A minor component of a tertiary college, non-degree qualification
☐ A major component of a tertiary college/university, undergraduate degree
☐ A minor component of a tertiary college/university, undergraduate degree
☐ Postgraduate qualification

2c How would you describe your ethnic group?
☐ Dutch
☐ Moroccan
☐ Turkish
☐ Surinamese
☐ Antillean
☐ Other, ______________________________

2d How would you describe your social group, if not the same as your ethnic group?
☐ Dutch
☐ Moroccan
☐ Turkish
☐ Surinamese
☐ Antillean
☐ Other, ______________________________

2e How would you describe your religious beliefs? Please tick one.

☐ I am an active follower of my religion
☐ I am a believer but not very active
☐ I am a non-believer

2f Which of the following best describes your religious background?
☐ Protestantism
☐ Catholicism
☐ Islam
☐ Judaism
☐ Buddhism
☐ Hinduism
☐ Atheism
☐ Other, ______________________________

SECTION 3: SCIENCE TEACHING

3a Science education may have two goals. One is to produce specialist scientists who will be trained in science at university level. The other is to produce a 'scientifically literate' population. Scientific literacy might be seen as the desirable outcome of school science education.

To what extent do you consider each of the following to be one of the basic components of scientific literacy—what every child should leave secondary education knowing?

		Basic understanding and skills that all should have	Understanding and skills that should be expected of more able pupils	Understanding and skills required only for specialist future science training
3a.1	How to measure volume, mass, weight, size	☐	☐	☐
3a.2	The basic components of living and non-living things (atoms, molecules, cells etc)	☐	☐	☐
3a.3	The solar system	☐	☐	☐
3a.4	The relationship between disease and hygiene	☐	☐	☐
3a.5	How to conduct an experiment	☐	☐	☐
3a.6	How to assess whether a medicine or treatment is effective	☐	☐	☐
3a.7	The basic food groups	☐	☐	☐
3a.8	How to access the Internet to help with their school work	☐	☐	☐
3a.9	Key historical figures and events in the development of science	☐	☐	☐
3a.10	Human reproduction	☐	☐	☐

3b **When people talk about 'science' what do they mean?**

Please tick the box to show to what extent you think each of the following is part of 'science' or not.

		Always part of science	Sometimes part of science	Never part of science
3b.1	Making music	☐	☐	☐
3b.2	Looking at fossils and dinosaurs	☐	☐	☐
3b.3	Trying to predict whether you will be lucky in the future	☐	☐	☐
3b.4	Finding out how to cure disease	☐	☐	☐
3b.5	Exploring space	☐	☐	☐
3b.6	Finding out about climate change	☐	☐	☐
3b.7	Digging up old cities and temples	☐	☐	☐
3b.8	Healing people who are sick	☐	☐	☐
3b.9	Farming	☐	☐	☐
3b.10	Building a bridge	☐	☐	☐
3b.11	Finding out why some countries are poor and some are rich	☐	☐	☐
3b.12	Finding out why some people learn things more easily than others do	☐	☐	☐
3b.13	Reading about people in the past who discovered or invented things	☐	☐	☐

3c **Which of the following have you used as examples in your science teaching?**

		I often use this example	I sometimes use this example	I never use this example
3c.1	Making music	☐	☐	☐
3c.2	Looking at fossils and dinosaurs	☐	☐	☐
3c.3	Trying to predict whether you will be lucky in the future	☐	☐	☐
3c.4	Finding out how to cure disease	☐	☐	☐
3c.5	Exploring space	☐	☐	☐
3c.6	Finding out about climate change	☐	☐	☐
3c.7	Digging up old cities and temples	☐	☐	☐
3c.8	Healing people who are sick	☐	☐	☐
3c.9	Farming	☐	☐	☐
3c.10	Building a bridge	☐	☐	☐
3c.11	Finding out why some countries are poor and some are rich	☐	☐	☐
3c.12	Finding out why some people learn things more easily than others do	☐	☐	☐
3c.13	Reading about people in the past who discovered or invented things	☐	☐	☐

SECTION 4: MY SCIENCE LESSONS

This part of the questionnaire asks about some possible characteristics of your science lessons.

Please indicate to what extent this characteristic is present in your science lessons.

		Always	Frequently	Rarely	Never
4a	During my science lessons,				
4a.1	… new learning starts with problems about the world outside of school.	☐	☐	☐	☐
4a.2	… students learn how science can be part of their out-of-school life.	☐	☐	☐	☐
4a.3	… students get a better understanding of the world outside of school.	☐	☐	☐	☐

		Always	Frequently	Rarely	Never
4b	During my science lessons students learn…				
4b.1	… that science has changed over time.	☐	☐	☐	☐
4b.2	… that science is influenced by people's values and opinions.	☐	☐	☐	☐
4b.3	… about science used by people in different cultures.	☐	☐	☐	☐
4b.4	… that modern science is different from the science of long ago.	☐	☐	☐	☐
4b.5	… that science involves inventing theories.	☐	☐	☐	☐
4b.6	…that it is important to consider ethical issues as well as factual issues in science	☐	☐	☐	☐
4b.7	… about the nature of science and enquiry	☐	☐	☐	☐

		Always	Frequently	Rarely	Never
4c	During my science lessons it's OK for the students…				
4c.1	… to ask me "why do I have to learn this?"	☐	☐	☐	☐
4c.2	… to question the way they are being taught.	☐	☐	☐	☐
4c.3	… to complain about activities that are confusing.	☐	☐	☐	☐
4c.4	… to complain about anything that prevents them from learning.	☐	☐	☐	☐
4c.5	… to express their opinion.	☐	☐	☐	☐

		Always	Frequently	Rarely	Never
4d	During my science lessons students help the teacher…				
4d.1	… to plan what they are going to learn.	☐	☐	☐	☐
4d.2	… to decide how well they are learning.	☐	☐	☐	☐
4d.3	… to decide which activities are best for them.	☐	☐	☐	☐
4d.4	… to decide how much time they spend on activities.	☐	☐	☐	☐

		Always	Frequently	Rarely	Never
4e	During my science lessons, students…				
4e.1	… talk with other students about how to solve problems.	☐	☐	☐	☐
4e.2	… explain my ideas to other students.	☐	☐	☐	☐
4e.3	… ask other students to explain their ideas.	☐	☐	☐	☐
4e.4	… listen carefully to another's ideas.	☐	☐	☐	☐
4e.5	… present their work to the class	☐	☐	☐	☐
4e.6	… share examples or illustrations from their own experience	☐	☐	☐	☐
4e.7	…watch me demonstrate an experiment or investigation.	☐	☐	☐	☐
4e.8	… formulate hypotheses or predictions to be tested	☐	☐	☐	☐
4e.9	… design or plan experiments or investigations	☐	☐	☐	☐
4e.10	… put events or objects in order and give a reason for the organization	☐	☐	☐	☐
4e.11	… study the impact of technology on society.	☐	☐	☐	☐

SECTION 5: AIMS OF SCIENCE EDUCATION

This part of the questionnaire asks about some of your views on the aims or goals of science education. Each question of this section begins with a possible aim of science education. This aim may or may not fit with the school-demanded curriculum. Following each aim, the same series of four questions concerning the aim is posed.

Aim A:
Students should appreciate that science is an activity that involves creativity and imagination as much as many other human activities.

5a **To what extent do you agree with this aim of science education?** Please tick one of the answers below to indicate to what extent you agree.

I agree completely	I agree slightly	I disagree slightly	I disagree completely
☐	☐	☐	☐

5b **To what extent do you actively pursue this aim in your class?** Please tick one of the answers below to indicate to what extent you actively pursue this aim.

I pursue this aim always	I pursue this aim frequently	I pursue this aim rarely	I never pursue this aim
☐	☐	☐	☐

5c **To what extent do you meet this aim in your class?** Please tick one of the answers below to indicate to what extent you meet this aim.

I always meet this aim	I meet this aim frequently	I meet this aim rarely	I never meet this aim
☐	☐	☐	☐

5d If you **DO NOT** pursue this aim, please indicate which of the following are reasons why you do not, and how important they are. (If you DO pursue this aim, go to Question 5e)

		A very important reason	A somewhat important reason	Not a reason why I do not pursue this aim
5d.1	Students need to focus on logic, facts and proof in science	☐	☐	☐
5d.2	It is not part of the curriculum and I need to stick to the curriculum to be seen as a good teacher	☐	☐	☐
5d.3	There is no time to explore these ideas within my teaching even if I wanted to do so	☐	☐	☐
5d.4	It would confuse students	☐	☐	☐
5d.5	My fellow teachers or my principal would criticize me	☐	☐	☐
5d.6	Parents would criticize me	☐	☐	☐
5d.7	I would not know how to teach this	☐	☐	☐
5d.8	This aim is appropriate for older students but not the age group that I teach	☐	☐	☐

Aim B:
Pupils should be taught some of the cultural and historical background of the development of scientific knowledge.

5e **To what extent do you agree with this aim of science education?** Please tick one of the answers below to indicate to what extent you agree.

I agree completely	I agree slightly	I disagree slightly	I disagree completely
☐	☐	☐	☐

5f **To what extent do you actively pursue this aim in your class?** Please tick one of the answers below to indicate to what extent you actively pursue this aim.

I pursue this aim always	I pursue this aim frequently	I pursue this aim rarely	I never pursue this aim
☐	☐	☐	☐

5g **To what extent do you meet this aim in your class?** Please tick one of the answers below to indicate to what extent you meet this aim.

I always meet this aim	I meet this aim frequently	I meet this aim rarely	I never meet this aim
☐	☐	☐	☐

5h If you **DO NOT** pursue this aim, please indicate which of the following are reasons why you do not, and how important they are. (If you DO pursue this aim, please go to Question 5i)

		A very important reason	A somewhat important reason	Not a reason why I do not pursue this aim
5h.1	Students need to focus on logic, facts and proof in science	☐	☐	☐
5h.2	It is not part of the curriculum and I need to stick to the curriculum to be seen as a good teacher	☐	☐	☐
5h.3	There is no time to explore these ideas within my teaching even if I wanted to do so	☐	☐	☐
5h.4	It would confuse students	☐	☐	☐
5h.5	My fellow teachers or my principal would criticize me	☐	☐	☐
5h.6	Parents would criticize me	☐	☐	☐
5h.7	I would not know how to teach this	☐	☐	☐
5h.8	This aim is appropriate for older students but not the age group that I teach	☐	☐	☐

Aim C:
Pupils should be taught that science uses a range of methods and approaches and that there is no single scientific method or approach.

5i **To what extent do you agree with this aim of science education?** Please draw a circle around one of the answers below to indicate to what extent you agree.

I agree completely	I agree slightly	I disagree Slightly	I disagree completely
☐	☐	☐	☐

5j **To what extent do you actively pursue this aim in your class?** Please draw a circle around one of the answers below to indicate to what extent you actively pursue this aim.

I pursue this aim always	I pursue this aim frequently	I pursue this aim rarely	I never pursue this aim
☐	☐	☐	☐

5k **To what extent do you meet this aim in your class?** Please draw a circle around one of the answers below to indicate to what extent you meet this aim.

I always meet this aim	I meet this aim frequently	I meet this aim rarely	I never meet this aim
☐	☐	☐	☐

5l If you DO NOT pursue this aim, please indicate which of the following are reasons why you do not, and how important they are. (If you DO pursue this aim, please go to Question 5m)

		A very important reason	A somewhat important reason	Not a reason why I do not pursue this aim
5l.1	Students need to focus on logic, facts and proof in science	☐	☐	☐
5l.2	It is not part of the curriculum and I need to stick to the curriculum to be seen as a good teacher	☐	☐	☐
5l.3	There is no time to explore these ideas within my teaching even if I wanted to do so	☐	☐	☐
5l.4	It would confuse students	☐	☐	☐
5l.5	My fellow teachers or my principal would criticize me	☐	☐	☐
5l.6	Parents would criticize me	☐	☐	☐
5l.7	I would not know how to teach this	☐	☐	☐
5l.8	This aim is appropriate for older students but not the age group that I teach	☐	☐	☐

Aim D:
Pupils should appreciate that much scientific knowledge, particularly that taught in school science, is well established but other scientific knowledge is more open to doubt. It should be explained that current scientific knowledge is the best we have but may be subject to change in the future, given new evidence or new interpretations of old evidence.

5m **To what extent do you agree with this aim of science education?** Please tick one of the answers below to indicate to what extent you agree.

I agree completely	I agree slightly	I disagree Slightly	I disagree completely
☐	☐	☐	☐

5n **To what extent do you actively pursue this aim in your class?** Please tick one of the answers below to indicate to what extent you actively pursue this aim.

I pursue this aim always	I pursue this aim frequently	I pursue this aim rarely	I never pursue this aim
☐	☐	☐	☐

5o **To what extent do you meet this aim in your class?** Please tick one of the answers below to indicate to what extent you meet this aim.

I always meet this aim	I meet this aim frequently	I meet this aim rarely	I never meet this aim
☐	☐	☐	☐

5p If you DO NOT pursue this aim, please indicate which of the following are reasons why you do not, and how important they are. (If you DO pursue this aim, go to Question 5q)

		A very important reason	A somewhat important reason	Not a reason why I do not pursue this aim
5p.1	Students need to focus on logic, facts and proof in science	☐	☐	☐
5p.2	It is not part of the curriculum and I need to stick to the curriculum to be seen as a good teacher	☐	☐	☐
5p.3	There is no time to explore these ideas within my teaching even if I wanted to do so	☐	☐	☐
5p.4	It would confuse students	☐	☐	☐
5p.5	My fellow teachers or my principal would criticize me	☐	☐	☐
5p.6	Parents would criticize me	☐	☐	☐
5p.7	I would not know how to teach this	☐	☐	☐
5p.8	This aim is appropriate for older students but not the age group that I teach	☐	☐	☐

Aim E:
Students should be taught that developments in science are more often than not the result of collective group activity and collaboration, often of a multidisciplinary and international nature.

5q **To what extent do you agree with this aim of science education?** Please tick one of the answers below to indicate to what extent you agree.

I agree completely	I agree slightly	I disagree Slightly	I disagree completely
☐	☐	☐	☐

5r **To what extent do you actively pursue this aim in your class?** Please tick one of the answers below to indicate to what extent you actively pursue this aim.

I pursue this aim always	I pursue this aim frequently	I pursue this aim rarely	I never pursue this aim
☐	☐	☐	☐

5s **To what extent do you meet this aim in your class?** Please tick one of the answers below to indicate to what extent you meet this aim.

I always meet this aim	I meet this aim frequently	I meet this aim rarely	I never meet this aim
☐	☐	☐	☐

5t If you DO NOT pursue this aim, please indicate which of the following are reasons why you do not, and how important they are. (If you DO pursue this aim, please go to Question 6a)

		A very important reason	A somewhat important reason	Not a reason why I do not pursue this aim
5t.1	Students need to focus on logic, facts and proof in science	☐	☐	☐
5t.2	It is not part of the curriculum and I need to stick to the curriculum to be seen as a good teacher	☐	☐	☐
5t.3	There is no time to explore these ideas within my teaching even if I wanted to do so	☐	☐	☐
5t.4	It would confuse students	☐	☐	☐
5t.5	My fellow teachers or my principal would criticize me	☐	☐	☐
5t.6	Parents would criticize me	☐	☐	☐
5t.7	I would not know how to teach this	☐	☐	☐
5t.8	This aim is appropriate for older students but not the age group that I teach	☐	☐	☐

SECTION 6: COMMON CLASSROOM EXPERIENCES

Below are some common experiences that teachers have. Please consider each one and indicate in the next question how you dealt with this situation, if you have had this experience.

6a **A student tells you that the lesson you have just given conflicts with what he has learnt at home and what his religious leader teaches. He says that he will ignore what you told him because to him it is wrong.**

Have you had this experience? ☐ Yes ☐ No

If you have had this experience, go to Question 6b and then continue to Question 6c. If you have not had this experience go directly to Question 6c

6b.1	How did you respond to the student? Please tick all boxes that apply to you.	I did this
6b.2	I said, only, that in science we look for evidence and the scientific evidence supports what I said in the lesson	☐
6b.3	I said that religion is based on faith and tradition and that people may take lessons on how to live from these, but this is quite separate from scientific evidence which looks for facts and tests theories that are not related to religious beliefs	☐
6b.4	I said that many scientists hold religious beliefs but see no conflict between their religion and their science because they see them as different parts of their life	☐
6b.5	I said that many scientists have religious beliefs and that for them, the wonders they discover about the world through their science make them appreciate religious ideas, but they do not mix scientific explanations with religious explanations	☐
6b.6	I said that there are many ways of understanding the world. Religion and science are two of them. Everyone must make their own choice as to which they prefer	☐

If you gave a different response, please write it here
____
____
____
____

Now go to Question 6c

6c Thinking about your goals as a teacher, how satisfactory do you think each of the possible responses is to the student's comments?

Please complete this whether or not you have had the experience.

		Very satisfactory	Satisfactory	Unsatisfactory
6c.1	Say, only, that in science we look for evidence and the scientific evidence supports what I said in the lesson	☐	☐	☐
6c.2	Say that religion is based on faith and tradition and that people may take lessons on how to live from these, but this is quite separate from scientific evidence which looks for facts and tests theories that are not related to religious beliefs	☐	☐	☐
6c.3	Say that many scientists hold religious beliefs but see no conflict between their religion and their science because they see them as different parts of their life	☐	☐	☐
6c.4	Say that many scientists have religious beliefs and that for them, the wonders they discover about the world through their science make them appreciate religious ideas, but they do not mix scientific explanations with religious explanations	☐	☐	☐
6c.5	Say that there are many ways of understanding the world. Religion and science are two of them. Everyone must make their own choice as to which they prefer	☐	☐	☐

6d **A student tells you that she finds science boring and useless because the textbooks only have pictures of people who are male and Western, and that the examples used in the books having nothing to with real life or what interests her.**

Have you had this experience? ☐ Yes ☐ No

If you have had this experience, go to Question 6e and then continue to Question 6f. If you have not had this experience go directly to Question 6f

		I did this
6e	How did you respond to the student? Please tick all boxes that apply to you.	
6e.1	I said that the examples in the teaching materials are related to how the scientific evidence was developed, so they show how science is done and that is why they had to read them	☐
6e.2	I said that although the pictures show mostly white male scientists, there are many female scientists and scientists come from all social and ethnic groups, in all countries	☐
6e.3	I said that I would try to think of examples from everyday life and use them in the classroom, in addition to the teaching materials	☐
6e.4	I suggested that she should make a list of things that interest her and seem important to her, and think about the science behind them.	☐
6e.5	I suggested that she think about the ways that the things she learns in science could be applied to her life outside the classroom and in the future when she might be a parent and a worker.	☐
6e.6	I got the whole class to discuss their interests and hobbies and to consider how these contained science, or could have science applied to them	☐
6e.7	I got the whole class to think about how different cultures describe nature and the relationship between people and nature	☐

If you gave a different response, please write it here
____
____
____
____

Now go to Question 6f

6f Thinking about your goals as a teacher, how satisfactory do you consider each of the possible responses to be?

Please answer whether or not you have experienced this situation.

		Very satisfactory	Satisfactory	Not satisfactory
6f.1	Say that the examples in the teaching materials_are related to how the scientific evidence was developed, so they show how science is done and that so why they had to read them	☐	☐	☐
6f.2	Say that although the pictures show mostly white male scientists, there are many female scientists and scientists come from all social and ethnic groups, in all countries	☐	☐	☐
6f.3	Say that I would try to think of examples from everyday life and use them in the classroom, in addition to the teaching materials	☐	☐	☐
6f.4	Suggest that she should make a list of things that interest her and seem important to her, and think about the science behind them.	☐	☐	☐
6f.5	Suggest that she think about the ways in which the things she learns in science could be applied to her life outside the classroom and in the future when she_ might be a parent and a worker.	☐	☐	☐
6f.6	Get the whole class to discuss their interests and hobbies and to consider how these contained science, or could have science applied to them	☐	☐	☐
6f.7	Get the whole class to think about how different cultures describe nature and the relationship between people and nature	☐	☐	☐

6g You have just explained in class how pharmaceutical companies develop and test medicines. A couple of days later you develop a bad cold and headache, which is obvious to the class. Several students suggest remedies that their families use, to help cure your sickness. Most of these are 'alternative' or 'traditional' cures; several students say that the medicine you are taking (made by a well-known Western pharmaceutical company) contains dangerous chemicals and their family doesn't use them.

Have you had this experience? ☐ Yes ☐ No

If you have had this experience, go to Question 6h and then continue to Question 6i. If you have not had this experience go directly to Question 6i.

		I did this
6h	How did you respond to the students? Please tick all boxes that apply to you.	
6h.1	I thanked the students and made no comment	☐
6h.2	I thanked the students and said that many traditional or alternative medicines had never been tested by pharmaceutical scientists but many people believe that they work. It is time that scientists did proper research on them to find out just how they work, and whether they do work	☐
6h.3	I said that Western pharmaceutical products are properly tested and if they have bad side effects it is because they are not used properly	☐
6h.4	I said that often, medicines work because people believe in them, what is called the 'placebo effect', because our bodies heal better when we feel hopeful and confident, but that these medicines may have no real effects on the body or the disease.	☐
6h.5	I said that pharmaceutical companies do not always take account of local conditions and diets, and that some local methods of treatments work in that place but would not work in another country or location.	☐
6h.6	I said that some alternative or traditional methods of treatment use herbs or other ingredients that have a healing effect on the body, even though these have not been investigated by science, but other methods are based on belief in magic, and have no real basis; students should be aware of the difference between these and know how to make good judgments.	☐

If you gave a different response, please write it here
____
____
____
____

Now go to Question 6i

6i Thinking about your goals as a teacher, how satisfactory do you consider each of the possible responses to be?

Please answer, whether or not you have experienced this situation.

		Very satisfactory	Satisfactory	Not satisfactory
6i.1	Thank the students for their suggestions and make no comment	☐	☐	☐
6i.2	Thank the students and say that many traditional or alternative medicines have never been tested by pharmaceutical scientists but many people believe that they work. It is time that scientists did proper research on them to find out just how they work, and whether they do work	☐	☐	☐
6i.3	Say that Western pharmaceutical products are properly tested and if they have bad side effects it_is because they are not used properly	☐	☐	☐
6i.4	Say that often, medicines work because people believe in them; that is called the 'placebo effect', because our bodies heal better when we feel hopeful and confident, but that these medicines may have no real effects on the body or the disease.	☐	☐	☐
6i.5	Say that pharmaceutical companies_do not always take account of local conditions and diets, and that some local methods of treatments work in that place but would not work in another country or location.	☐	☐	☐
6i.6	Say that some alternative or traditional methods of treatment use herbs or other ingredients that have a healing effect on the body, even though these have not been investigated by science, but other methods are based on belief in magic, and have no real basis; students should be aware of the difference between these and know how to make good judgments.	☐	☐	☐

SECTION 7: SCIENCE AND DIFFERENCE

Here are some questions about science and about science education

7a Please show how much you AGREE or DISAGREE with each of the following statements

		Agree strongly	Agree	Disagree	Disagree strongly
7a.1	Because science is about natural phenomena, which are the same everywhere, the scientific method works universally	☐	☐	☐	☐
7a.2	Eventually, data and evidence will convince us which scientific theory is correct	☐	☐	☐	☐
7a.3	Because scientists come to the data with different theories, they will ask different kinds of questions and arrive at different interpretations of the data, so data alone do not provide the answer.	☐	☐	☐	☐
7a.4	Science is not value-free; the questions scientists ask in their research are affected by the agencies who fund the science	☐	☐	☐	☐
7a.5	Science is not value-free; the questions that scientists ask in their research and the methods they choose are affected by what they think are important problems to solve	☐	☐	☐	☐
7a.6	The way that a scientific study is conducted, and the kinds of questions asked, are affected by the technology that is available to the scientist	☐	☐	☐	☐
7a.7	Scientists from different nations and cultures are concerned about different long-term questions because of their background	☐	☐	☐	☐

7b Please show how much you AGREE or DISAGREE with the following statements

		Agree strongly	Agree	Disagree	Disagree strongly
7b.1	In order to help all my students understand science, I try to ignore gender, ethnic or religious differences amongst my students	☐	☐	☐	☐
7b.2	In order to help all my students understand science, I try to find examples that are relevant to different groups, such as boys and girls	☐	☐	☐	☐
7b.3	In order to help all my students understand science, I try to find examples that are relevant to different cultural experiences	☐	☐	☐	☐
7b.4	I have found that, whatever teaching method I use, girls in general are just not as motivated as boys to learn science or see its relevance.	☐	☐	☐	☐
7b.5	I have found that, whatever teaching method I use, members of some ethnic or cultural groups are just not as motivated as others to learn science or see its relevance.	☐	☐	☐	☐
7b.6	I have found that, whatever teaching method I use, members of some religious groups are just not as motivated as others to learn science or see its relevance.	☐	☐	☐	☐

7c In your view, to what extent do you think that the following kinds of students limit how you teach science?

		A lot	To some extent	A little	Not at all	Does not apply to me
7c.1	Students with different academic abilities	☐	☐	☐	☐	☐
7c.2	Students who come from a wide range of social, ethnic or religious backgrounds	☐	☐	☐	☐	☐
7c.3	Students with special needs, such as physical or psychological impairments	☐	☐	☐	☐	☐
7c.4	Uninterested students	☐	☐	☐	☐	☐
7c.5	Students with low morale	☐	☐	☐	☐	☐
7c.6	Disruptive students	☐	☐	☐	☐	☐

8a This question asks about the sources of your knowledge of the science that you teach and the sources of examples that you use to help you in your teaching. Please indicate whether each source is a MAJOR source, a MINOR source, NOT A SOURCE that you use, or a source TO WHICH YOU DO NOT HAVE ACCESS.

		A major source	A minor source	Not a source that I use	I do not have access to this source
8a.1	My own education in science and technology	☐	☐	☐	☐
8a.2	The textbook or teaching materials associated with the curriculum	☐	☐	☐	☐
8a.3	Other school science textbooks	☐	☐	☐	☐
8a.4	Popular science magazines	☐	☐	☐	☐
8a.5	Articles and reports in newspapers	☐	☐	☐	☐
8a.6	Television programs about science	☐	☐	☐	☐
8a.7	The Internet	☐	☐	☐	☐
8a.8	Magazines and journals aimed at science teachers	☐	☐	☐	☐
8a.9	Real life experience of science in the world outside school	☐	☐	☐	☐
8a.10	Current events related to science	☐	☐	☐	☐

Please write in the spaces below, details of the materials that you use to help you in your teaching

8a.10 The title and author of the main textbook used in your science teaching

____
____
____
____

8.a.11 The names of any science magazines or periodicals that you consult to inform your teaching

____
____
____
____

8a.12 Any material you draw upon that has been designed by government bodies, the education ministry, or institutions or organizations responsible for providing advisory material for science teaching

____
____
____
____
____
____
____
____

8a.13 Any websites that you regularly use in support of your science teaching

____
____
____
____

8a.14 Any additional resources that you regularly use

____
____
____
____
____
____
____
____

8b This question asks about how you use technology to help you in your teaching. Please indicate how frequently you make use of technologies, or whether they are unavailable to you

		I use this whenever possible	I occasionally use this	I rarely or never use this	I do not have the facilities for this
8b.1	Traditional school laboratory equipment that does not involve electronics or computers	☐	☐	☐	☐
8b.2	Students have access to a computer in the classroom for doing modeling, calculations etc	☐	☐	☐	☐
8b.3	Students have access to a computer in the school library for doing modeling, calculations etc	☐	☐	☐	☐
8b.4	Students are encouraged to work in groups using their personal electronic equipment for science projects	☐	☐	☐	☐
8b.5	Students use video games and simulations designed for science teaching	☐	☐	☐	☐
8b.6	Students are encouraged to use the Internet as a source of information relating to their science work	☐	☐	☐	☐
8b.7	I show videos/DVDs in class to illustrate scientific examples	☐	☐	☐	☐

END OF QUESTIONNAIRE

Appendix 3 Student interview protocol

1 I am going to ask you a couple of questions about what you like to, at school and outside school. We ask these questions to children in six different countries. Nobody but me and the other people that work on this project will know what you say in the interview.

I will record the conversation, so I can listen it properly again. Is that okay? Shall we start with telling who you are and to which school you visit

2 Are you a boy or a girl? How old are you?

3 For how long are you at this school now?

4 What is your favorite lesson?

What do you like in that lesson?

5 Tell me about something that you did in class that you enjoyed very much.

6 Which class do you like least?

7 (When the student has not mentioned science yet)
What do you think about nature and technology, science, biology, physics and chemistry?

7a ASK ANYBODY
Do you like all classes of science of just a couple?

8 Some lessons are science lessons. Are there also other lessons at school that resemble science, but are called differently, or are not carried out in separate science lessons?

8a Why do these classes resemble science?

8b (When they have not answered the previous question)
For example geography, is geography science, or not?

8c Is history like science?

9 Do you think it is important to learn about science? Why or why not?

10 About science class. Do you use the internet when you are working on those lessons?

10a (If yes) Do you use the internet for
[Ask separately]
Homework
Projects/Assignments
Preparation of tests?

10b Do you like to work online?
Why?

11 When you work in class, do you prefer to work alone or in a group? Why?

12 Do you learn about science outside school, by visiting museums or scientific institutes?

12a [If yes] Do you like this way of learning about science? Is it more interesting than science class at school?
Why?

13 Can you think of something that you have learned at school that is for things outside school ?

13a [When not answered in 13] Do you think that science is useful outside school?

14 Do you know a famous scientist?

14a Do you know a famous female scientist?

14b Can you think of something what these scientists did to become famous?

15 Do you know from which countries these scientists originated and where they have carried out their work?

16 When you are grown-up, what kind of job would you like to have? Why would you like to have that job?
(when a student mentions an unrealistic job such as a popstar or racecar driver, suggest that that is a job which is hard to get and ask for a more realistic alternative)

17 What would you like to do daily during work?

18 Do you think that the job you mentioned is related to science? In which way?

18a [if not] Would you like to have a job which is related to science?

19 When I give you the sentence “I would like to be a scientist, because …” How would you finish that sentence?

20 Now suppose I said, complete the sentence, “I would not like to be a scientist because…”?

21 Now supposing I said, complete the sentence, “I would like to marry a scientist because…”?

22 Supposing I said, complete the sentence, “I would not like to marry a scientist because…”?

23 Imagine a typical day in the life of a scientist, what would they be doing each day?

24 Do you think they would be working by themselves or would they be in a team?

24a If they were in a team, would there be a leader, or would they all be working as equals?

25 We all get sick from time to time. Let’s imagine you had a bad stomach-ache, what would you do?

25a What would your mother and father do to help you?

25b Tell me what they would do; tell me what they would give you to make you better.

26 Suppose you hurt yourself playing sports, you pulled a muscle or twisted something. What would you do to get better?

26a Who would your parents take you to in order to get you better

27 Suppose someone had a really bad disease, like cancer. What would they do to try to be made better?

27a Suppose that treatment didn't work. What do you think they would do next to try to get better?

28 In those questions just now, some of the people we talked about were doing healing, making sick people better. Do you think that when someone is a healer, they are also a scientist? Why/why not?

29 Let's consider a quite different question. Suppose you had a friend who said that their religious holy book explained the beginning of the earth and of human life very differently from what scientists said, and so your friend thought the scientists were wrong? What would you say to your friend?

30 That's all my questions. Thank you for answering them. Do you have any questions for me?

Appendix 4 Teacher interview protocol

1 Thank for you agreeing to be interviewed. We are exploring teacher's experience of the science curriculum and of teaching science to a range of pupil abilities and backgrounds. Your responses are confidential and will only be seen by the research team, but I hope you are happy that I record the interview so that I can have an accurate record for the research analysis. I also need to have some way of identifying you on the recording. Perhaps you could say the name of the school, and how many years you have been teaching? You don't have to give your own name unless you wish to do so.

2 Can you tell me about your current teaching of science? What science classes are you currently teaching?

3 What age group(s) do you teach?

4 Are your classes mixed or mostly boys or mostly girls?

5 In what language do you teach science? Is this the native language of the majority of your pupils?

5a What other languages do students in your classes speak?

6 Would you say that your students mostly come from one cultural group, or from more than one?
(This question can be omitted in a homogeneous context)

6a If from more than one, can you give examples?

7 How would you describe your own educational background in science; was science a major part of your college education, was it a minor part, or did you not study science at college level?

7a Did you choose to teach science or is it just part of what you have to cover as a classroom/homeroom teacher?

8 Do you find teaching science satisfying?
Why/why not?

9 Can you describe a typical science class that you teach? I'd like you think of a science topic that you often teach and you very much enjoy teaching. What might be such a topic?

9a Let's think first about your overall approach to your lessons.
Here are three ways that teachers might describe how they organizes their lesson; which one best describes the way you teach [that lesson];

1. I plan the lesson in detail including all the activities that the students do
2. I plan the lesson but students choose how they will complete the class task
3. I tell the students what the learning goal of the lesson and let them decide how to work towards that goal

9b What activities do you expect the students to engage in?

9c What apparatus do you use?

10 Generally in your science teaching, what would you say were your main resources? Would you say you mostly use the textbook or printed materials? Or do you mostly draw on your own knowledge and experience of teaching the subject? Do you consult the internet? Do you use scientific articles or science magazines?

(Ask this as one question but you may need to repeat the options. The interviewed teacher may say yes to more than one option)

11 What do you think every child should know about science by the time they finish their education?

12 What would you say were your own goals in teaching science?

12a What would you regard as examples of successfully achieving your teaching goals?

13 Can you think back to the way that you were taught science in school. In what ways do you think your teaching is the same as your teacher's or in what ways is it different?

14 What would you say were the main obstacles to achieving your teaching goals?

15 Do you make any adjustments in your teaching to account for boys' and girls' different interests?

15a Why/why not?

15b If you do, can you give examples of different methods or materials that you use?

16 Do you make any adjustments in your teaching to take account of cultural differences amongst your students?

(No need to ask this question if the context is culturally homogeneous)

16a If you do so, in what way. If you do not, can you say why you don't

17 In the community in which you teach, are you aware of examples of ways of thinking about the natural world that would not normally be regarded as 'scientific'?

17a An example might be about medicine or healing practices.

17b Another example might be beliefs about meteorological events like thunder, or rain.

18 If a student raised these examples in your class, how would you respond?

19 Have you encountered any challenges in teaching science to pupils because of their religious beliefs?

20 If a pupil said to you that what you taught in your science class was contradictory to what their religious leaders taught them, how would you respond?

21 If you have taught students from different cultural or religious backgrounds, what would you say you have learned from this experience, if anything?

22 Do you think that the program you are expected to teach in science and the materials available to you, meet the needs of different genders?

23 Do you think that the program you are expected to teach in science and the materials available to you, meet the needs of different cultural or religious groups in your class?

24 If you were able to advise trainers of teachers, what would you suggest that they include in teacher training to help teachers be more effective in teaching students from diverse backgrounds?

25 In your teaching, do you find it useful to cite any scientists as examples?

25a Do you ever use examples of women scientists?

25b Do you ever use examples of scientists of [own nation]?

26 Many teachers have the experience of a pupil expressing worries about moral issues around things they are studying in science. Have you ever experienced this?

26a [Probe with examples if necessary as appropriate to local conditions and age of students; Examples might be using animals in experimentation, cloning]

26b What did you do? Why did you respond in this way?

27 One area where many people recognize a link between science and values is the environment. Do you deal with the relationship between science, technology and the environment in your teaching? How?

28 Many science teachers think it is useful for students to have some understanding of the history of science. What is your view? Why?

29 There seem to be broadly two ways of teaching the history of science. One is to tell students about the heroic efforts of great scientists who struggled to find the right answer. The other way is to show how very differently scientists have thought about nature, at different times and in different places, so science isn't black or white, true or false, but is constantly changing. Which approach do you think you would choose to teach?

30 Can you give me examples of what you think would be particularly good teaching in relation to anything we have talked about in this interview?

31 What would be examples of bad teaching, in your view?

Summary

Interest in science and technology among students is a topic of considerable interest in the Netherlands and in many other countries in Europe. Regularly, articles appear in the media bemoaning a lack of interest in science among young students or low enrolment of students in scientific disciplines at universities. Studies reporting on international comparisons in science education suggest that outside Western Europe and North America students seem to be more interested in their science classes and in those countries there is no debate concerning a lack of interest in science. The Netherlands is often designated as a 'typical case' in research on interest in science as its students score well on achievement in math and science in studies such as PISA (the Programme for International Student Assessment, a well-known large scale international survey) but come out at the bottom in surveys in which interest in science is measured. Although there are signs that during the last couple of years interest in science has increased in the Netherlands, as for instance can be seen in the higher number of students who enter universities of technology such as Eindhoven University of Technology, levels of interest still appear to remain well below those of other countries. It is not yet clear why these differences exist, but some publications suggest the state of development of a country and the quality of education play a role.

This dissertation was part of the Science Education for Diversity project, which was set up to investigate international differences in interest in science among students and the teaching practice in science education in six different countries around the world, the United Kingdom, the Netherlands, Turkey, Lebanon, India and Malaysia. The research was done with the help of partners in these countries and was funded by the European Union. One of the main ideas behind the project was to find the reasons behind the higher interest in science in countries outside Western Europe and to find out which features of their educational practice could be adopted in order to increase interest in science in countries such as the Netherlands and the United

Kingdom. The countries were chosen because of their very different locations in the world and their different populations. The research project investigated interest in science among 10 to 14 year old students and the role science education played in shaping this interest. Both students and teachers were investigated with questionnaires and interviews. The age group of 10 to 14 year olds was chosen because previous studies had found that in this period in a students' life, students often lose their interest in science.

The studies in this dissertation focused specifically on the relationships between interest in science, views on science and teaching practice. Interest is a complex and multifaceted construct. Therefore, in this study not only interest in science as it is presented in science classes in school (interest in school science) was included, but also interest in extracurricular activities and interest in having a job related to science. Regarding views on science, nature of science (NOS) was an important construct in the studies. Nature of science refers to beliefs concerning the way science functions and how scientists do their work. Over the years, nature of science has received increasing interest in research as it has been found that students often have naïve or even wrong ideas about science. Students, for instance, often fail to understand what a scientific theory is, that scientific theories can change over time and are never completely certain and that scientific work often involves collaboration and creativity. These ideas are often not explicitly taught in class. As far as teaching practice is concerned, this dissertation investigated whether nature of science was taught in class and what kind of science activities were offered to the students.

The following research questions were investigated in this dissertation:

1) What differences in student interest in science exist among students in the six countries involved, what differences exist in students' views of science, of what science is and of how scientists work, and what

relationships exist between interest in science and views on science? (chapter 2)

2) What differences exist in teachers' views about the nature of science in the six countries involved, how do teachers in the six countries differ in their perceptions of their own teaching practice, and what relationship exists between teachers' views of the nature of science and their perceptions of their teaching practice? (chapter 3)
3) How can Dutch students be divided into different groups according to their interest in science and do these groups view science differently? (chapter 4) And,
4) Do Dutch teachers perceive differences in interest in science among their students and do they adjust their teaching to account for these differences? And what goals do teachers have when teaching science? (chapter 5)

The study reported in chapter 2 investigated the question what international differences in student interest in science exist, what differences in views on the nature of science and how these views related to interest in science students have. For this purpose, a questionnaire study on interest in science was conducted in the six countries. In total, over 9000 students completed this questionnaire. Different forms of interest in science were measured in this questionnaire: interest in science classes as given in school, interest in extracurricular activities that are related to science or technology and interest in having a job related to science. Factor analyses on the questionnaire data indicated that these different interests could be distinguished similarly in all six countries. On all of these factors, Dutch and British students scored statistically significantly lower than their Turkish, Lebanese, Indian and Malaysian counterparts. However, it should be noted that differences in interest between the six countries were relatively small compared to differences between students within countries. Gender and age appeared to be related to interest in science. Girls were found to have a lower interest in science than boys. This gender difference was most pronounced for the interest in having a job related to science. Older students tended to be less interested in science than younger students. The only exception to this rule was the interest in having a science job which was similar for students with different ages. This first study also investigated how students viewed science. There were international differences in how students viewed science and the work of a scientist. Most notably, students in the countries outside Western Europe had a far more optimistic view of science and believed in great numbers that science can solve most societal problems. Across all countries, students who had a greater interest in science also had more optimistic views about science.

The study described in chapter 3 of this dissertation investigated the views and teaching practices of the teachers in the six different countries that took part in the research project (research question 2). In total, 331 teachers completed a questionnaire in which they were questioned about their views on what science is, on science teaching and about their perceptions of their own practice of teaching science. This study revealed that teachers had similar views on science as their students did in the previous chapter. Teachers in countries outside Western Europe saw science as more secure and unchanging than teachers in the Netherlands and the United Kingdom. This was however not reflected in their teaching. Teachers outside Western Europe indicated to pay more attention to nature of science in their classes and to include more varied activities for their students.

In chapter 4, the types of interest and views of Dutch students on science were investigated more in-depth via interviews (research question 3). In total, 40 Dutch students were interviewed and their answers were recorded and transcribed. Students were grouped into four different groups on the basis of the answers they gave in the interviews. The first group was the group of students that were interested in science primarily because of the content of the science. Content was a running thread in the answers that these students gave. Not only were they interested in the content of their science classes, but when they went to visit science museums they reported to be primarily interested in learning new things. Many of these students said that they were interested in having a job related to science later in life, and again mostly because this would mean they could occupy themselves with learning about science. This is different compared to the second group of students that was identified, the group of students that was primarily interested in the activities related to science. This groups most of all enjoyed doing experiments in class and in science museums and said that they would enjoy working as a scientist because it would allow them to work in a lab. The third group of students was not interested in science at all or even strongly disliked science. The fourth group of students that was identified in the study was a group of students that had no yet made up its mind about science and that did not yet have a clear idea about what science is. The students in this group did have an interest in science but this was generally limited to specific topics, such as the human body or animals. This group was the largest of the four identified groups and whereas the first two groups were mainly made up of boys and the third group of girls, this group was evenly mixed between boys and girls.

The last study presented in chapter 5 investigated more in-depth the views of teachers on the interest of their students and the way science is taught in class via interviews. A total of 14 Dutch teachers were interviewed for this study. These interviews made clear that most of the interviewed teachers did not make any distinctions between different groups of students, regardless of their gender, background, ethnicity or interest. Teachers said that they perceived few differences between boys and girls concerning their interest in science and that if they differentiated between boys and girls this was mainly in the form of giving boys more guidance because they were considered to be less independent than girls. Teachers neither perceived any different types of interest within their classes such as those that were identified in chapter 4 of this dissertation. Nonetheless, teachers employed several of the strategies that are often advocated for making science interesting to students such as the inclusion of experiments and discussions that relate science to the everyday life of the students. However, teachers paid little attention to nature of science and to history and ethics of science in their classes.

This study thus confirmed that there are international differences in interest in science and that Dutch students score relatively low as compared to students from other countries. However, the study also showed these international differences to be relatively small compared to the much larger variation between students in interest in science within countries. It was found that within this variation, girls tend to be less interested in science than boys and younger students tend to be more interested in science than older students. These age and gender differences were also in alignment with findings of previous studies.

The interview study found that Dutch students could be divided into four different groups, those who were interested in the content of science, those interested in the activities related to science, those had no interest in science whatsoever and those who had an interest in only specific areas of science. Interestingly, the last group – with mixed interest in science – was the largest group and compared to the questionnaire study, the interview study suggested that interest in science in the Netherlands was actually larger than expected and not as 'black and white' as the questionnaire study seemed to suggest. Thus, the answer to the question if students are interested in science may also be related to the type of instrument used to measure it and it seemed that the qualitative component of interest is as important to include in research as its quantitative component.

It was also found that science interest was correlated with views on science. In the international questionnaire study, it was found interest in science correlated strongly with believing that science can solve societal problems, a view that was more prevalent outside Western Europe. In the Dutch interview study, it was found that those students who had only a partial interest in science were less knowledgeable about what science is and what scientists do than the students who held a strong interest in science. A few years before they must make the choice whether or not to continue with studying science, many students still appear to be unfamiliar with science and this unfamiliarity seems to be linked to disinterest.

Teachers around the world also differed in their views on science, with the teachers outside Western Europe believing in greater numbers that science was unchangeable and secure. This was however not reflected in their teaching. It is thus not yet clear why student views on science differ around the world but it does not seem to be a straightforward consequence of the education students receive. This leaves open an alternative explanation that individual differences related to students, their backgrounds and culture also may play a role in how students perceive science. Copying features of the educational systems of countries outside Western Europe will thus not likely lead to an increase in interest in science.

Interviews with the Dutch teachers revealed that they did not discern different groups of students within their classrooms, but that they did employ many strategies that should in principle make science more attractive for students. These and other results suggest there are still ways in which education could be improved. Teachers should for example be more aware of different interests in science among their students. Whereas it would be difficult to understand the interests of every individual student in a classroom, knowledge of the existence of different interest groups will be of great use for offering more differentiated education. In particular the large group of students with a mixed interest currently seems to be badly served by the instruction it receives. In this respect, greater attention should also be paid to the nature of science, as it appeared that few students had a good understanding of it.

Of course, as with any dissertation, there are limitations to be mentioned. First of all, although the number of 9000 students who completed the student questionnaire was very large, they came from a relatively small number of schools. The interview studies also relied on a relatively small numbers of students and teachers. Furthermore, questionnaires and interviews in this research project were made to investigate a great number of different possible explanatory factors behind interest in science. Views on science were one of the explanatory factors but were not the sole factor under investigation in the larger SED project. A more specific questionnaire or interview study would be needed to understand in greater detail the precise relationship between interest in science and views on science.

The first two studies in this dissertation were primarily conducted to find out why students in different parts of the world are or are not interested in science. These studies add to the discussion on why international differences in interest in science exist and how they can be explained. It shows that views on science are an important explanatory factor for understanding the current differences in interest in the world, possibly a more important factor than the status or pay of a career in a science related field. The last two studies which investigated Dutch students and teachers through interviews, have more practical implications for teaching. Above all, they show the necessity for understanding what drives different groups of students towards or away from science. Currently there still seems to be a mismatch between the interests of many students, which are not properly met and the offered instruction which serves those students already interested in science best. Without knowledge of what students actually want to learn or of what they do not yet have a clear (or naïve) image about, any attempts to increase interest will be ad-hoc and may not reach the intended students.

Samenvatting

Interesse in wetenschap en techniek bij leerlingen is een onderwerp dat veel aandacht trekt in Nederland en in veel andere landen in Europa. Regelmatig verschijnen er artikelen in de media waarin geklaagd wordt over een gebrek aan interesse in natuurwetenschap bij jonge leerlingen of een geringe aanwas van nieuwe studenten in de bètastudies bij universiteiten. Buiten West Europa en Noord Amerika lijken leerlingen meer geïnteresseerd in de bètavakken en in het bèta domein. Nederland neemt een uitzonderlijke positie in het onderzoek naar interesse in natuurwetenschap en techniek omdat Nederlandse leerlingen goed scoren op prestatietesten in onderzoeken zoals PISA (het bekende onderzoek van het Programme for International Student Assessment), maar onder aan de ranglijst blijken te staan bij internationale onderzoeken waarbij interesse in bètavakken gemeten wordt. Ondanks enkele aanwijzingen dat interesse in natuurwetenschap bij leerlingen is toegenomen de afgelopen paar jaar, zoals bijvoorbeeld zichtbaar in een toename in het aantal studenten bij technische universiteiten zoals de Technische Universiteit Eindhoven, blijft het algemene niveau van interesse lager dan in andere landen. Het is nog niet duidelijk waarom er internationale verschillen zijn in interesse in natuurwetenschap en techniek, maar verschillende publicaties wijzen naar mogelijke verbanden met het niveau van ontwikkeling van een land en de kwaliteit van het onderwijs.

Dit proefschrift is onderdeel van het Science Education for Diversity (SED) project dat was opgezet om internationale verschillen in interesse in het bèta domein bij leerlingen en de praktijk van lesgeven te bestuderen in zes verschillende landen, het Verenigd Koninkrijk, Nederland, Turkije, Libanon, India en Maleisië. Het onderzoek werd uitgevoerd met partners in deze landen en werd betaald door de Europese Unie. Een van de voornaamste ideeën achter het project was om uit te vinden waarom er in landen buiten West Europa een grotere interesse in wetenschap en om uit te vinden welke aspecten van het onderwijs overgenomen kunnen worden om een grotere interesse in wetenschap te kweken in landen als Nederland en het Verenigd Koninkrijk. De landen die meededen aan het onderzoek waren uitgekozen vanwege hun sterk van elkaar verschillende populaties en plaats in de wereld. Het onderzoeksproject onderzocht interesse in wetenschap bij 10 tot 14 jarigen en de rol die het wetenschapsonderwijs dat zij genoten speelde in het vormen van hun interesse. Zowel leerlingen als docenten werden onderzocht met behulp van vragenlijsten en interviews. De leeftijdsgroep van 10 tot 14 jarigen was gekozen omdat eerdere studies hadden aangetoond dat in deze periode van het leven een leerling, veel leerlingen hun interesse in de bètavakken verliezen.

De studies in dit proefschrift richten zich specifiek op de relaties tussen interesse in wetenschap, ideeën over wetenschap en de lespraktijk van docenten. Interesse is een ingewikkeld construct met meerdere dimensies. In dit onderzoek werd niet alleen interesse in wetenschap zoals het tijdens lessen op school wordt gegeven (interesse in bètavakken) gemeten, maar ook interesse in buitenschoolse activiteiten en interesse in het hebben van een baan die met wetenschap en techniek te maken heeft. Wat betreft de ideeën over wetenschap was nature of science, of de aard van wetenschap, een belangrijk construct in de studies. De aard van wetenschap refereert naar de manier waarop wetenschap functioneert en waarop wetenschappers wetenschap bedrijven. De aard van wetenschap is door de jaren heen steeds meer een onderwerp van onderzoek binnen het bètaonderwijsonderzoek omdat het is gebleken dat veel leerlingen naïeve of onjuiste ideeën hadden over wetenschap. Veel leerlingen begrijpen bijvoorbeeld niet goed wat een wetenschappelijk theorie is, dat zulke theorieën door de tijd heen kunnen veranderen kunnen veranderen en dus nooit helemaal zeker zijn en dat wetenschappelijk werk vaak samenwerking en creativiteit vergt. Deze ideeën worden vaak niet expliciet onderwezen. De vragen aan de docenten over de praktijk van lesgeven, onderzochten of de aard van wetenschap werd behandeld in de klas en wat voor activiteiten tijdens de vakken die met de natuurwetenschap hebben te maken worden gedaan.

De volgende onderzoeksvragen zijn onderzocht in dit proefschrift:

1) Welke verschillen in interesse in wetenschap en techniek zijn aanwezig tussen de zes deelnemende landen (in het onderzoek), welke verschillen zijn zichtbaar in opvattingen over de aard van wetenschap, en hoe zijn opvattingen over de aard van wetenschap gerelateerd aan de interesse in wetenschap? (hoofdstuk 2)
2) Welke verschillen zijn er tussen docenten uit de zes landen wat betreft hun opvattingen over (de aard van) wetenschap, hun percepties van het lesgeven in wetenschap, en welke relatie is er tussen opvattingen over (de aard van) wetenschap en de perceptie van het lesgeven in wetenschap en techniek? (hoofdstuk 3)
3) Hoe kunnen Nederlandse leerlingen onderverdeeld worden in verschillende groepen naar gelang hun interesse in wetenschap en hoe verschillen die groepen van elkaar in de manier waarop ze tegen wetenschap aankijken? (hoofdstuk 4)
4) In hoeverre percipiëren Nederlandse docenten verschillen in interesse in wetenschap bij hun leerlingen en passen ze hun manier van lesgeven daarop aan? In hoeverre besteden ze aandacht in hun onderwijs aan de aard van natuurwetenschap? (hoofdstuk 5)

Het onderzoek in hoofdstuk twee had als onderzoeksvraag welke verschillen in interesse in wetenschap van leerlingen er tussen verschillende landen waren, welke verschillen er waren in opvattingen over wetenschap en hoe deze beide aspecten aan elkaar gerelateerd waren. Het onderzoek in dit hoofdstuk beschrijft de gegevens verzameld via vragenlijsten, uitgevoerd in alle zes de landen. In totaal vulden meer dan 9000 leerlingen de vragenlijst in. De vragenlijst richtte zich op verschillende vormen van interesse in wetenschap: interesse in wetenschap zoals het op school werd gegeven, interesse in buitenschoolse activiteiten die met wetenschap of techniek te maken hebben en interesse in het hebben van een baan die met wetenschap te maken heeft. Factor analyses toonde aan dat in alle zes de onderzochte landen deze verschillende vormen van interesses onderscheiden konden worden. Op alle factoren scoorden Nederlandse en Britse leerlingen significant lager dan Turkse, Libanese, Indiase en Maleisische leerlingen. Wel bleek dat de verschillen in interesse tussen landen relatief klein waren in vergelijking met de verschillen tussen leerlingen binnen een land. In het bijzonder geslacht en leeftijd bleken een verband te houden met interesse in wetenschap. Meisjes hadden over het algemeen een geringere interesse in wetenschap dan jongens. Het grootste verschil tussen jongens en meisjes werd gevonden bij de factor voor interesse in banen die gerelateerd zijn aan wetenschap. Oudere leerlingen bleken iets minder geïnteresseerd in wetenschap dan jongere leerlingen. De uitzondering hierop was de interesse in het hebben van een baan die gerelateerd is aan wetenschap, deze was vergelijkbaar bij oude en jonge leerlingen. In dit onderzoek werd ook onderzocht hoe leerlingen tegen de aard van wetenschap en het werk van wetenschappers aankeken. Ook hierin waren er internationale verschillen. Leerlingen in landen buiten West Europa hadden een veel optimistischere blik op wetenschap en geloofden in grotere getalen dat wetenschap de meeste maatschappelijke problemen kan oplossen. Ongeacht het land bleek dat leerlingen die een grotere interesse in wetenschap hadden, ook een meer optimistische visie op wetenschap hadden.

Hoofdstuk 3 van dit proefschrift beschreef een studie naar de ideeën en de onderwijspraktijk van docenten uit de zes verschillende landen die meededen aan het onderzoeksproject. In totaal vulden 331 docenten een vragenlijst in met vragen over hun opvattingen over wetenschap en het lesgeven in de bètavakken en hun percepties van hun lespraktijk in de bètavakken. Het onderzoek toonde aan dat docenten vergelijkbare opvattingen over wetenschap hadden als leerlingen in de studie in het tweede hoofdstuk. Docenten in landen buiten West Europa zagen wetenschap als zekerder en onveranderlijker dan docenten in Nederland en het Verenigd Koninkrijk. Dit was echter niet te merken aan de manier van lesgeven. Docenten van buiten West Europa gaven aan meer aandacht te geven aan de aard van wetenschap tijdens hun lessen en stopten meer gevarieerde activiteiten in hun lessen.

In hoofdstuk 4 werden de interesses en opvattingen van de Nederlandse leerlingen in meer detail onderzocht met behulp van interviews. In totaal zijn 40 Nederlandse leerlingen geïnterviewd en hun antwoorden zijn opgenomen op band en uitgeschreven. Op basis van de antwoorden die zijn gegeven in de interviews zijn de leerlingen in vier verschillende groepen ingedeeld. De eerste groep bestaan uit leerlingen die voornamelijk vanwege de inhoud geïnteresseerd zijn in wetenschap. In bijna alle antwoorden die deze leerlingen gaven kwam de inhoud van de wetenschap terug. Ze waren niet alleen geïnteresseerd in de inhoud van de bètavakken die ze op school kregen maar ook bij het bezoeken van een wetenschapsmuseum of centrum waren deze leerlingen voornamelijk geïnteresseerd in het leren van nieuwe dingen. Veel van de leerlingen in deze groep zeiden dat ze geïnteresseerd waren in een baan die met wetenschap te maken heeft, en wederom voornamelijk omdat dit zou beteken dat ze zich zouden kunnen bezig houden met het leren over wetenschap. Dit is anders dan bij de tweede groep, de leerlingen die voornamelijk geïnteresseerd waren in de activiteiten die aan wetenschap gerelateerd zijn. Deze groep vond het voornamelijk leuk om proeven te doen op school en in wetenschapsmusea en de leerlingen in deze groep zeiden dat ze het leuk zouden vinden om als wetenschapper te werken omdat ze dan in een laboratorium zouden kunnen werken. De derde groep leerlingen had geen enkele interesse of had zelfs een grote hekel aan wetenschap. De vierde groep bestond uit leerlingen voor wie het nog niet helemaal duidelijk was of ze wel of niet in wetenschap geïnteresseerd waren en die ook nog niet een duidelijk idee hadden wat wetenschap is. Leerlingen in deze groep waren meestal wel geïnteresseerd in wetenschap, maar dit was over het algemeen beperkt tot specifieke onderwerpen zoals het menselijk lichaam of dieren. Van de vier groepen was deze laatste groep de grootste. De eerste twee groepen bestonden voornamelijk uit jongens en de derde uit meisjes, de laatste groep bestond uit ongeveer evenveel jongens en meisjes.

In het laatste onderzoek dat in hoofdstuk 5 beschreven is, is met behulp van interviews onderzoek gedaan naar hoe Nederlandse docenten dachten over hun leerlingen in relatie tot hun vak en het bèta domein en over de manier waarop de bètavakken worden onderwezen. Er werden 14 Nederlandse docenten geïnterviewd. De interviews maakten duidelijk dat de meeste docenten geen verschil maakten tussen verschillende groepen leerlingen tijdens het lesgeven, ongeacht geslacht, achtergrond, etniciteit of interesse. De docenten zeiden dat zij weinig verschillen zagen tussen jongens en meisjes wat betreft interesse in wetenschap en dat wanneer zij op een andere manier lesgaven aan jongens en meisjes, zij de jongens meer structuur gaven omdat die minder zelfstandig werkten dan meisjes. Docenten zagen in hun klassen ook geen duidelijke groepen met verschillende interesses zoals die waren geïdentificeerd in hoofdstuk vier van dit proefschrift. Desalniettemin gebruikten de geïnterviewde docenten veel strategieën die vaak worden aangeraden om wetenschap aantrekkelijk te maken voor leerlingen zoals het doen van experimenten in de klas en het houden van discussies die wetenschap verbinden aan het dagelijks leven van leerlingen.

Er kan dus worden geconcludeerd dat er internationale verschillen zijn in interesse in wetenschap en dat Nederlandse leerlingen, in vergelijking met leerlingen uit andere landen, relatief laag scoren. Echter, deze conclusie kan sterk genuanceerd worden met de opmerking dat binnen elk land dat aan het onderzoek meedeed een veel grotere variatie is aangetroffen tussen leerlingen wat betreft interesse in wetenschap. Gebleken is dat meisjes gemiddeld wat minder geïnteresseerd zijn dan jongens en jongere leerlingen geïnteresseerder zijn dan oudere leerlingen. Deze bevindingen in relatie tot geslacht en leeftijd komen overeen met de resultaten van eerdere onderzoeken. Het interview onderzoek toonde aan dat Nederlandse leerlingen in vier verschillende groepen ingedeeld konden worden, zij die geïnteresseerd waren in de wetenschappelijke inhoud, zij die geïnteresseerd zijn in activiteiten die met wetenschap te maken hebben, zij die helemaal niet geïnteresseerd zijn in wetenschap en zij die alleen geïnteresseerd zijn in bepaalde aspecten van wetenschap. Deze laatste groep – met een gemengde interesse in wetenschap – was de grootste groep studenten. Als je het interviewonderzoek naast het vragenlijstonderzoek legt, lijkt het onderzoek met interviews te suggereren dat de groep leerlingen die in wetenschap is geïnteresseerd, groter is dan verwacht en dat de situatie niet zo zwart wit is als de vragenlijst studie lijkt aan te tonen. Het antwoord op de vraag of leerlingen wel of niet geïnteresseerd zijn in wetenschap houdt dus ook verband met het instrument waarmee gemeten wordt en het lijkt dus belangrijk om zowel kwalitatieve als kwantitatieve meetmethoden te gebruiken.

Er is ook een verband gevonden tussen interesse in wetenschap bij leerlingen en de ideeën die de leerlingen over wetenschap hebben. Uit het internationale vragenlijst onderzoek bleek dat interesse in wetenschap correleerde met het idee dat wetenschap maatschappelijke problemen kan oplossen, een idee dat buiten West Europa meer gemeengoed was. In het Nederlandse interview onderzoek bleek dat de leerlingen die weinig of geen interesse hadden in wetenschap, veel minder goed wisten wat wetenschap is en wat wetenschappers doen dan geïnteresseerde leerlingen. Veel leerlingen blijken, een paar jaar voordat zij een keuze moeten maken of ze wel of niet door willen gaan met de bètavakken, nog relatief onbekend te zijn met wetenschap en deze onbekendheid lijkt verband te houden met desinteresse.

Er waren ook verschillen in opvattingen over wetenschap bij docenten, waarbij de docenten buiten West Europa in grotere aantallen geloofden dat wetenschap zeker en onveranderlijk was. Dit had echter geen directe consequentie op het aangeboden onderwijs. Het is dus nog niet duidelijk waarom de opvattingen van leerlingen over wetenschap per land verschillen maar het lijkt niet zo te zijn dat dit puur komt door het onderwijs wat deze leerlingen krijgen. Dit laat een alternatieve verklaring open dat individuele verschillen tussen leerlingen, achtergrondkenmerken en cultuur ook een rol spelen in hoe leerlingen tegen wetenschap aankijken. Het overnemen van eigenschappen van onderwijssystem uit landen buiten West Europa zal dus waarschijnlijk niet eenduidig leiden tot een toename van interesse in wetenschap.

Interviews met Nederlandse docenten toonden aan dat zij geen verschillende groepen studenten ontwaarden in hun klassen, maar wel dat zij veel strategieën gebruikten die, in principe, wetenschap aantrekkelijk zouden moeten maken voor leerlingen. De resultaten suggereren dus dat er nog genoeg aspecten zijn waarin het onderwijs in de bètavakken verbeterd kan worden. Docenten zouden zich bijvoorbeeld meer bewust moeten zijn van de verschillende soorten en typen interesses in en opvattingen over wetenschap van hun leerlingen. Het zal moeilijk zijn om bekend te zijn met de interesses van elke leerling in een klas maar kennis van het bestaan van verschillende groepen leerlingen met verschillende interesses zal erg nuttig zijn bij het aanbieden van meer op maat gemaakt onderwijs. In het bijzonder de grote groep leerlingen met een gemengde interesse in wetenschap lijkt op dit moment slecht bediend te worden met het onderwijs dat ze ontvangen. Er moet daarnaast ook meer aandacht worden geschonken aan de aard van wetenschap omdat blijkt dat weinig leerlingen dit goed begrijpen

Uiteraard, zoals bij elk proefschrift, kunnen er beperkingen bij dit onderzoek worden benoemd. Allereerst is het aantal van ruim 9000 geënquêteerde leerlingen weliswaar erg groot, maar al deze leerlingen kwamen wel van een relatief klein aantal scholen. De interview onderzoeken hadden ook een relatief klein aantal respondenten. De vragenlijsten en interviews die voor het SED onderzoeksproject zijn ontwikkeld waren op een zodanig manier ontworpen dat ze groot aantal mogelijke verklarende factoren voor interesse in wetenschap onderzochten. Opvattingen over wetenschap waren één van deze mogelijke factoren maar waren dus niet de enige factor die werd onderzocht. Een meer specifieke vragenlijst of interviewprotocol is nodig om in meer detail de relatie tussen interesse in wetenschap en opvattingen over wetenschap te onderzoeken.

De eerste twee onderzoeken in dit proefschrift zijn met name gedaan om uit te zoeken waarom leerlingen in verschillende delen van de wereld wel of niet geïnteresseerd zijn in wetenschap. Deze onderzoeken voegen wat toe aan de discussie over waarom er internationale verschillen in interesse in wetenschap zijn en hoe deze verklaard kunnen worden. Ze tonen aan dat de opvattingen over wetenschap een belangrijke verklarende factor zijn voor de huidige verschillen in de wereld, misschien wel belangrijker dan de status of het salaris van een aan de wetenschap gerelateerde baan. De laatste twee onderzoeken waarin Nederlandse leerlingen en docenten werden onderzocht met behulp van interviews hebben meer praktische implicaties voor het lesgeven. Deze onderzoeken tonen bovenal de noodzaak aan van het goed begrijpen waarom verschillende groepen leerlingen wel of niet geïnteresseerd raken in wetenschap. Er lijkt nog steeds een scheve verhouding te zijn tussen de interesses van veel leerlingen en het onderwijs dat aan leerlingen wordt aangeboden, dat vooral gericht lijkt te zijn op de groep leerlingen die al sterk geïnteresseerd zijn in wetenschap. Zonder deze kennis zullen pogingen om interesse toe te laten nemen ad hoc zijn en wellicht niet het beoogde effect hebben.

Dankwoord

Februari 2010 begon ik als promovendus bij de Eindhoven School of Education aan een promotietraject wat was verbonden aan een groot Europees project. Veel onderwijskundige kennis had ik op dat moment nog niet maar de vraag waarom de ene leerling geïnteresseerd raakt in wetenschap en techniek en de andere niet intrigeerde me en het internationale verband waarin het onderzoek werd uitgevoerd sprak me erg aan. Nu, inmiddels bijna vijf jaar later heb ik wel die kennis opgedaan. Zoals elk promotietraject had ook mijn onderzoek de gebruikelijke ups en downs en drukke en rustige periodes. Van de moeite die het kost om scholen te vinden die mee willen werken aan je onderzoek en de stress die het kost om de deadline te halen die de Europese Unie had gesteld voor een rapport tot de harde afwijzing die je krijgt van een tijdschrift op een artikel waar je eindeloos aan geschaafd hebt. Maar natuurlijk ook de leuke dingen, de uiteindelijke acceptatie van een artikel, het reizen naar India en Indianapolis om over je onderzoek te vertellen en te discussiëren, het interviewen van leerlingen en het moment waarop SPSS je de resultaten geeft waarvan je denkt die ga ik publiceren. En om de paar maanden kwam een trotse medepromovendus de laatste kamer van de gang binnen om mij een vers gedrukt proefschrift te overhandigen. En elke keer dacht ik hoe lukt het me ook om in de resterende jaren of maanden ook zo'n boekje vol te schrijven. Uiteindelijk is ook dat mij gelukt.

Natuurlijk zijn er een hele hoop mensen die het mogelijk hebben gemaakt dat ik dit proefschrift heb kunnen schrijven en die ik graag wil bedanken. Allereerst mijn dagelijks begeleider en collega in het Science Education for Diversity project Michiel. Helaas kan je dit niet meer lezen omdat je vorig jaar door alvleesklierkanker bent overleden. Jij was degene die het onderzoeksproject had binnengehaald waar mijn promotie op gebaseerd is en we hebben die jaren voordat je ziek werd heel intensief samengewerkt. Je was een hele fijne begeleider en ik kon altijd bij je terecht voor inhoudelijke discussies over wat ik geschreven had en raad over hoe verder te gaan met het onderzoek.

Ik wil ook mijn promotoren bedanken. Koeno voor de begeleiding tijdens de eerste maanden van mijn onderzoek en Perry die na Koeno's pensionering het stokje van hem overnam. Perry met jouw kennis van kwantitatief onderzoek was je een goede aanvulling op Michiels kwalitatieve kennis en daarmee waren jullie het juiste team om mij te begeleiden. Je hebt me goed op weg geholpen met multilevel analyse en met het schrijven van artikelen. Ook leerde je me hoe ik het best om kon gaan met het commentaar van de reviewers en hoe ik mijn artikelen moest herschrijven.

I would like to thank Helen Haste who worked with Michiel and me on the SED project and who developed much of the research materials on which the research in this dissertation is based. Your short visits to Eindhoven were intense and really propelled my analysis of the data and my thinking forward. I would also like to think all of my international colleagues on the SED project from the UK, Turkey, Lebanon, India and Malaysia. I am very grateful that I was able to use the data that you have collected in your home countries. Not every phD student is able to play with a dataset of over 9000 students. I would also like to thank you all for the comments you have given me on my presentations and papers during meeting or via e-mail.

Uiteraard wil ik ook alle scholen, docenten en leerlingen bedanken die hebben meegedaan aan het onderzoek. Zonder jullie was het onderzoek wat ik heb uitgevoerd nooit mogelijk geweest. Jullie zorgden voor wat nu geanonimiseerde quotes en getallen in databestanden zijn waarop dit proefschrift is gebaseerd.

Graag wil ik ook de studenten bedanken die ik begeleid heb tijdens mijn promotie, Roel en Nicole. Roel, jij kwam voor mij op het juiste moment, in een van de drukste periodes van een promotie en verzamelde een heleboel data waar ik je erg dankbaar voor ben.

Ook wil ik graag al mijn collega's en oud-collega's van de Eindhoven School of Education bedanken voor de feedback op posters en presentaties de afgelopen jaren en voor de samenwerking bij het lesgeven. Natuurlijk ook bedankt voor de gezelligheid bij de ESoE en tijdens de bijeenkomsten in München en Hamburg en tijdens de onderwijsresearchdagen. Huub, je was de laatste vier jaar mijn kamergenoot en hoewel je meestal rustig geconcentreerd doorwerkt kon ik ook erg met je lachen en flauwe gesprekken hebben.

Als laatste wil ik mijn familie en vrienden bedanken. Jullie hebben me geholpen met mijn verhuizing naar (en binnen) en Eindhoven en de afgelopen jaren de broodnodige steun en afleiding gegeven van het academische werk. Mama, Nils, Linnea en Fokko, de laatste tijd waren jullie maar een busritje van mij verwijderd en ik was erg blij dat ik deze drukke periode dicht bij mijn familie heb kunnen doorbrengen. Leonard, bedankt voor al je steun en aandacht de afgelopen jaren dat ik hier in Eindhoven promotiewerk heb gedaan.

List of publications

Articles in peer reviewed journals

Van Griethuijsen, R.A.L.F., van Eijck, M.W., den Brok, P.J., Haste, H., Skinner, N., Mansour, N. & Boujaoude, S., (accepted by Research in Science Education) Global Patterns in Students' Views of Science and Interest in Science.

Van Griethuijsen, R.A.L.F., van Eijck, M.W., den Brok, P.J., Haste, H., Hetherington, L. & Savran, A.C. (submitted) Teachers' Views on Nature of Science, Teaching Goals and Practice of Teaching the Nature of Science around the World.

Van Griethuijsen, R.A.L.F., van Eijck, M.W. & den Brok, P.J. (submitted) Interest in Science and Ideas about Science among 10 to 14 year old Dutch students.

Research reports

Van Griethuijsen, R.A.L.F., van Eijck, M.W. (2010) Country Report The Netherlands – Work Package 2, report submitted to the European Union.

Choksi, B., Chunawala, S., Natarajan, C., van Griethuijsen, R.A.L.F., van Eijck, M.W., den Brok, P.J. … Wegerif, R. (2011) Science Education for Diversity: WP2 - Synthesis Report, report submitted to the European Union.

Van Griethuijsen, R.A.L.F., van Eijck, M.W. & den Brok, P.J Science, Choksi, B., Chunawala, S., Natarajan, C. … Wegerif, R. (2011) Education for Diversity: WP3- Synthesis Report, submitted to the European Union.

Conference papers

Van Griethuijsen, R.A.L.F., van Eijck, M.W. & Gravemeijer, K.P.E. (2010) Diversity and attitudes towards science education, poster presentation at the Joint Researcher Winter School, December 2010, Munich, Germany.

Van Griethuijsen, R.A.L.F., van Eijck, M.W. & den Brok, P.J. (2011) Attitudes towards science of Western and non-Western primary and secondary school students, presentation at the Joint Researcher Winter School, November 2011, Hamburg, Germany.

Van Griethuijsen, R.A.L.F., van Eijck, M.W., den Brok, P.J. & Haste, H. (2012) Differences in interest in science and views of science around the World, presentation at the NARST conference, March 2012 Indianapolis, the United States.

Van Griethuijsen, R.A.L.F. (2012) Interest in science courses among Western and non-Western students in primary and secondary education [in Dutch], presentation at the Educational Research Days, June 2012, Wageningen, the Netherlands.

Van Griethuijsen, R.A.L.F., van Eijck, M.W., den Brok, P.J., Haste, H. (2013) Interest in science and views of science around the world, presentation at the ESERA conference 2013, September 2013, Nicosia, Cyprus.

Curriculum vitae

Ralf van Griethuijsen was born on August 21st 1981 in Leende, the Netherlands. After finishing pre-university education (vwo) in 1999 at Sint Joriscollege in Eindhoven, the Netherlands, he enrolled at University College Utrecht. In 2002 he obtained his Bachelor of Science degree (cum laude) with a major in science and a minor in social science. He obtained a Master of Science degree in Biomolecular Sciences from the Chemistry department of Utrecht University in 2005. As part of his studies, he did research on protein folding and lipid transport. In 2009, he obtained a Master of Science degree in Biomedical Sciences with a specialization in science communication from the Vrije Universiteit Amsterdam. During he studies, he interned at the magazine for the Dutch organization for chemists. In 2010 he started a PhD project at Eindhoven School of Education (Eindhoven University of Technology) of which the results are presented in this dissertation.

ESoE dissertation series

Sande, R. A. W. van de (2007). Competentiegerichtheid en scheikunde leren: over metacognitieve opvattingen, leerresultaten en leeractiviteiten.

Hooreman, R. (2008). Synchronous coaching of trainee teachers: an experimental approach.

Rajuan, M. (2008). Student teachers' perceptions of learning to teach as a basis for supervision of the mentoring relationship.

Raessens, B. A. M. (2009). De E-kubus: een analysemodel voor curricula.

Rohaan, E. J. (2009). Testing teacher knowledge for technology teaching in primary schools.

Oemar Said, E. (2009). De Da Vinci Case: een onderzoek naar de relaties tussen vernieuwende leeromgevingen en de motivatie en regulatievoorkeuren van leerlingen in het MBO

Koopman, M. (2010). Students' goal orientations, information processing strategies and knowledge development in competence-based pre-vocational secondary education.

Mittendorff, K. M. (2010). Career conversations in senior secondary vocational education.

Crasborn, F. J. A. J., & Hennissen, P. P. M. (2010). The skilled mentor. Mentor teachers' use and acquisition of supervisory skills.

Bragt, C. A. C. van (2010). Students' educational careers in Higher Education: A search into key factors regarding study outcome.

Bakker, G. de (2010). Allocated only reciprocal peer support via instant messaging as a candidate for decreasing the tutoring load of teachers.

Vos, M. A. J. (2010). Interaction between teachers and teaching materials: on the implementation of context-based chemistry education.

Bruin-Muurling, G. (2010). The development of proficiency in the fraction domain.

Cornelissen, L. J. F. (2011). Knowledge processes in school-university research networks.

Kraemer, J-M. (2011). Oplossingsmethoden voor aftrekken tot 100.

Stiphout, I. M. van (2011). The development of algebraic proficiency.
Saeli, M. (2012). Teaching programming for secondary school: a pedagogical content knowledge based approach.
Putter-Smits, L. G. A. de (2012). Science teachers designing context-based curriculum materials: developing context-based teaching competence.
Ketelaar, E. (2012). Teachers and innovations: on the role of ownership, sense- making and agency.
Dehing, F. (2012). Preparing students for workplace learning in higher engineering education.
Vrijnsen-de Corte, M. C. W. (2012). Researching the teacher-researcher. Practice-based research in Dutch professional development schools.
Doppenberg, J. J. (2012). Collaborative teacher learning: settings, foci and powerful moments.
Linden, P. W. J. van der (2012). A design-based approach to introducing student teachers in conducting and using research.
Diggelen, M. R. van (2013). Effects of a self-assessment procedure on VET teachers' competencies in coaching students' reflection skills.
Gorissen, P. J. B. (2013). Facilitating the use of recorded lectures: Analysing students' interactions to understand their navigational needs.
Keuvelaar - van den Bergh, L. (2013). Teacher feedback during active learning: The development and evaluation of a professional development programme.
Pillen, M. T. (2013). Professional identity tensions of beginning teachers.
Marée, T. J. (2013). Scripted collaborative enriched skeleton concept mapping to foster meaningful learning.
Gómez Puente, S.M. (2014). Design-based learning: exploring and educational approach for engineering education.
Coninx, N.S. (2014). Measuring effectiveness of synchronous coaching using Bug-In-Ear device of pre-service teachers.
Griethuijsen, R.A.L.F. van (2015). Relationships between students' interest in science, views of science and science teaching in upper primary and lower secondary education.