Title: How do we manage to "do science" together? – The mutual views on the nature of science influencing the student-scientist interaction in the Imagine School Competition

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1. ABSTRACT

The nature of science refers to the values and assumptions inherent to the development of scientific knowledge, and can be divided in several scientific aspects. The aim of this study was to outline how different views on the nature of science can influence the relations between students and scientists in a student-scientist inquiry partnership. For this study, interviews were conducted with four scientists and four students that were assigned to them in a partnership. The interactions between scientists and students described how they were influenced by the participants' views on the nature of science and how this can result in an either productive or non-productive collaboration. During the cases where the students and scientists perceived a common understanding of the nature of science both couples also reviewed the pleasantness of the interaction. However, during the inquiry partnerships where the student or the scientist did not perceive a common understanding of the nature of science both the scientist and student did not experience a pleasant interaction. Different phases of the inquiry were shown to be influenced by different views. Other factors possibly influencing student-scientist interactions, such as the given freedom for the students to develop their own research and the amount of structure given by the scientist, are described as well. This research could be used to improve student-scientist inquiry partnerships and could be transferable to other student-scientist inquiry partnerships, like school competitions focussed on life science and technology and socio-scientific issues.

2. INTRODUCTION

2.1 Definition of the nature of science

In secondary science education the understanding of the nature of science and particularly of scientific inquiry becomes more important (American Association for the Advancement of Science (AAAS), 1993; Bell, Blair, Crawford, & Lederman, 2003; National Research Council (Ed.), 1996). Scientific inquiry within science education is a process of doing science that facilitates ways of thinking about it and understanding of how scientific knowledge is generated (Houseal, Abd-El-Khalick, & Destefano, 2013), while nature of science refers to the values and assumptions inherent to the development of scientific knowledge which can be divided in several different scientific aspects (Lederman, 1992; Schwartz & Lederman, 2008).

The precise definition of the nature of science is debated among different researchers (Alters, 1997; Lederman, 1992; McComas & Almazroa, 1998; Zeidler, Walker, Ackett, & Simmons, 2002). Despite the lack of agreement on the definition of the nature of science, most of the time researchers agree upon the different categories, they only define them differently (Alters, 1997). In this paper Lederman's (1992) definition of the nature of science is used because various researchers have agreed that this definition is suitable for primary and secondary education (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002; Smith, Lederman, Bell, Mccomas, & Clough, 1997; Smith & Scharmann, 1998).

According to Lederman (1992), the nature of science can be divided into six categories: (a) the tentative nature of scientific knowledge, (b) the empirical nature of scientific knowledge, (c) the subjective and theory-laden nature of scientific knowledge, (d) the creative and imaginative nature of scientific knowledge, (e) the social and cultural embeddedness of scientific knowledge and (f) the difference between scientific theories and scientific laws. Students often do not obtain a proper view on the nature of science, while scientists generally develop different views on nature of science as well. Perhaps the nature of science is as tentative and subjective as scientific knowledge itself, so it will differ between individuals and generations (Popper, 1959; Schwartz & Lederman, 2008).

Scientific inquiry within science education is a process of doing science and in the meantime evaluating and thinking how scientific knowledge is generated. Because scientists investigate different phenomena, they also differ in the method of how the scientific knowledge is generated. There is simply no fixed set of steps that scientists follow to gain scientific knowledge, there is not one universal method to do inquiry. Scientists however use the different categories of the nature of science in the process of doing science. Scientific inquiry is often classified within the nature of science, because scientists use the different categories of the nature of science during inquiry. In addition, scientific inquiry is one of the values used to develop scientific knowledge (American Association for the Advancement of Science (AAAS), 1993).

2.2 Factors influencing teaching and learning of the nature of science

The understanding of the nature of science should develop due to the secondary school science curriculum. Unfortunately, most studies show that the understanding of the nature of science will often not develop when high school students only participate in science instructions (Deng, Tsai, & Chai, 2011; Lederman, 1992). This could lead to misconceptions about scientific practice, such as students thinking that scientific knowledge, like numbers and concepts only arise out of textbooks (Hammer, 1994). Or students might think that scientists believe in an objective or absolute truth (Chai, Deng, & Wong, 2010). Students often are unable to differentiate a scientific law from a scientific theory (Parker, Krockover, Eichinger, & Lasher-Trapp, 2008).

An addition to the secondary science curriculum could be the opportunity to import inquiry-based education to the classroom. Various studies have shown contrasting results, one study claimed that the students' understanding of the nature of science is improved because of inquiry-based education in the classroom (Weaver, 1997). In contrast, other studies claimed that the students' understanding of the nature of science will not develop during in-class inquiry-based education (Deng et al., 2011; Lederman, 1992; Morrison, Raab, & Ingram, 2008). Problems with in-class inquiry-based education are the difficulties in understanding the nature of science by teachers (Abd-El-Khalick & Lederman, 2000) and the lack of teacher's experience with authentic scientific inquiry practices (Justi & Gilbert, 2002). Teachers find it difficult to create an inquiry-based environment that supports students in the development of creating an informed view on the nature of science. One of the suggestions to improve the understanding of the students' nature of science is to let students cooperate with scientists.

In various in-class science projects or extracurricular projects, scientists cooperate with students in the process of doing research. These projects are named student-scientist partnerships and they are project-based instructions, wherein students are active participants in a scientific research collaboration with scientists (Gibson & Chase, 2002; Wormstead, Becker, & Congalton, 2002). Examples of these projects are, Global Rivers Environmental Education Network (GREEN) (Donahue, Lewis, Price, & Schmidt, 1998), the Forest Watch (FW) program (Evans, Abrams, Rock, & Spencer, 2001) and the GLOBE Program (Global Learning and Observations to Benefit the Environment) (Finarelli, 1998). These scientific projects have contributed to the conservation of wildlife and the students' awareness of the conservation message (Jacobson, Mcduff, & Monroe, 1998).

When students are experiencing the ‘messiness’ of doing science and connect the classroom research to the scientific inquiry, they will presumably understand more about the nature of science (Bell et al., 2003).

In addition, inquiry-based learning could also change students’ attitude towards science (Gibson & Chase, 2002; Wormstead et al., 2002). Benefits for scientists are opportunities to collect a great amount of data with help of students (Lawless & Rock, 1998; Moss, Abrams, & Kull, 1998) and development of skills about the epistemological aspects of inquiry based learning (Finarelli, 1998). Scientists can use these educational skills when they elaborate on their scientific findings during a public debate (The Welcome Trust, 2000). The challenges for student-scientist partnerships often mirror the benefits. When students did not appreciate the inquiry, students showed little or no change in the understanding of the nature of science and did not aspire a scientific career (Bell et al., 2003; Donahue et al., 1998; Gibson & Chase, 2002; Khishfe & Abd-El-Khalick, 2002; Moss et al., 1998; Schwartz, Lederman, & Crawford, 2004). The level of appreciation of the student-scientist partnership by the students could be influenced by the interaction with the scientists.

2.3 Interaction between students and scientists

According to Masson and colleagues (2013) an important success factor of student-scientist partnerships is the interaction between students and scientists. If there is a good mutual interaction between students and scientists, the entire project is appreciated (Masson, Klop, & Osseweijer, expected in 2015). When students feel disappointed by this interaction, it could cast a shadow on the students' whole experience, which could lead to negative effects on the students view of research and life sciences (Masson, Klop, & Osseweijer, 2013).

Students and scientists can both be influential for a failing interaction (Masson et al., 2013). For example, some scientists seem to hold misconceptions about science education. In those case, the scientists had little or no training in science education and were unaware how they could develop a proper scientific inquiry lesson (Masson et al., 2013). On the other hand, students can have unrealistic expectations towards the inquiry. Some students tended to believe they can solve global problems during the inquiry, which of course is a unrealistic approach (Masson et al., 2013).

Another aspect that could influence the mutual interaction is the imbalanced expectations the student and scientists obtain. Students look up against the scientists and have acquired a rather stereo type image of the work and appearance of a scientist (Barman, 1999; Finson, 2002; Huber & Burton, 1995). In these studies students were asked to draw a picture of a scientist. In general, seven specific attributes or elements generally appeared. Scientists wore a lab coat, eyeglasses and facial hair, while they were surrounded in an environment containing symbols of research, symbols of knowledge, products of technology and relevant captions such as formulas. On the other hand, the scientists often underestimate the students' general knowledge and capacities. The imbalanced expectations could as well influence the students' and scientists' mutual interaction.

2.4 Research question

The past decades educational researchers have been doing research on the perception of the nature of science of students and scientists in general (Lederman, 1992; Schwartz et al., 2004; Schwartz & Lederman, 2008). Also a lot of research was done on the different elements of creating a successful student-scientist inquiry partnership (Clough, 2006; Colburn & Clough, 1997; Donahue et al., 1998; Gibson & Chase, 2002; Khishfe & Abd-El-Khalick, 2002; Moss et al., 1998; Schwartz & Lederman, 2008), as well as the impact of student-scientist inquiry partnership on the understanding of the nature science (Bell et al., 2003; Moss et al., 1998). It was shown that the interaction between students and scientists was one of the most important success factors of a student-scientist partnership (Masson et al., 2013).

The importance of the interaction during a student-scientist partnership is clear. However, how a good interaction between students and scientists is established remains poorly studied. Different views on the nature of science during a student-scientist partnership could result in different expectations during the inquiry which could influence the mutual interaction between the student and the scientist. So far, no research studied the interaction between students and scientists in combination with the mutual perception on the nature of science. Since a lot of information is lacking, this study will be presented as an exploratory study. In this research it was investigated if the students and scientists have comparable views on the nature of science during a student-scientist inquiry partnership. Secondly the perception of both the student and the scientist towards their mutual interaction was studied and it was analysed whether this perception relates to the mutual understanding of the nature of science. Thus, this study informs on how the interaction in a student-scientist inquiry partnership is influenced by the participants' views on the nature of science.

3. METHOD

3.1 Research context

The Foundation Imagine Life Sciences is an organisation that organises student-scientist inquiry partnerships. Every year the Foundation Imagine Life Sciences organises the Imagine School Competition for high school students and leading scientists. Students and scientists are challenged to translate research from the life sciences and technology field into a sustainable and innovative application. This includes writing a business plan describing the implementation of this idea in a developing country (Schuurbiers & Blomjous, 2007).

One of the aims of Imagine is to help pupils learn more about the practice of science and to get young people interested in science and technology (Masson et al., 2013). Imagine School Competition gives scientists the opportunity to be active in public communication and contribute to secondary education. The benefits for students are an increase in the understanding of scientific research, a positive change in the attitude towards science and an increase in understanding of specific content.

Students and scientists voluntarily sign up to participate in the Imagine School Competition. Some of the student-scientist inquiry partnerships are directly implementable in a developing country, while in other partnerships students are challenged to search for a way to implement the research in a developing country. Students have the opportunity to enrol for their preferred research. The scientists are given the freedom to design the inquiry on their own.

3.2 Sampling techniques

Semi-structured interviews were conducted with four individual students as well as their corresponding supervising scientists. The students and scientists were interviewed separately to avoid interaction during the interviews. The interview was structured using two sections: (a) their general perspective on the nature of science and (b) their opinion on the interaction during the inquiry.

Purposive sampling was used to select varying cases of good and inferior student-scientist interactions. The student or scientist perceived the interaction inferior when the basis of equal cooperation was disrupted. The different case studies were selected by one of the supervisors, Lotte van den Berg, who is working for Imagine as project leader. It was tested if the different case studies matched with the intended cases, by focussing on how the participants perceived the interaction. The sample consisted of four selected pairs as samples (n=4), with one student for each corresponding scientist.

In sampling, four different kinds of interaction cases were chosen. First, a case where the student and scientist both perceived a good interaction. Second, a case where the student perceived a good interaction while the scientist perceived an inferior interaction. Third, a case where the scientist perceived a good interaction while the student perceived an inferior interaction. Fourth, a case where the student and scientist both perceived an inferior interaction. However it was impossible to find a case in which both student and scientist perceived the interaction as inferior because the identified individuals were not willing to participate in the study.

3.3 Data collection techniques

For the development of the questions about the general perspective of the nature of science (Appendix A), questions from the Views of Nature of Science Questionnaire Form-B (VNOS Form-B) (Lederman et al., 2002) were used. According to Lederman and colleagues (2002), VNOS Form-B is a valid tool to test the understanding of the nature of science.

Questions about the interaction within student-scientist inquiry partnerships (Appendix B) were straight-forward questions, in which the students and scientists were asked if the interaction was influenced by the mutual perception of the nature of science. Also, there were straight-forward questions about the interaction. For example, the students were asked if they could operate independently, how they experienced the communication and if there were any problems in the interaction during the inquiry.

The interviews were audiotaped and transcribed. The understanding of the nature of science was divided into six different categories, as subscribed by Lederman and colleagues (2002). In this research the focus was on five categories, because they were used often or appear a lot in the Imagine school competition. These different categories studied were: (a) the creative and imaginative nature of scientific knowledge, (b) the social and cultural embeddedness of scientific knowledge, (c) the subjective and theory-laden nature of scientific knowledge, (d) the tentative nature of scientific knowledge and (e) the empirical nature of scientific knowledge. Creativity and imagination were important for the formulation of research questions and hypotheses during the inquiry (Barrow, 2010). All of the Imagine projects are socially and culturally embedded. The tentative, subjective and empirical nature of scientific knowledge and the difference between scientific theories and scientifically laws were intertwined with scientific inquiry and therefore students were supposed to have different thoughts on those categories.

3.4 Data analysis and interpretation

The different answers given by the participants in the different categories were labelled, according to the labels given by Schwartz and Lederman (2008). For example, within the category 'tentative nature of scientific knowledge', the respondents' answers could be classified under the following types: (a) scientific knowledge is inherently tentative, (b) scientific knowledge is approaching certainty or (c) scientific knowledge is the absolute truth. The different categories with corresponding labels are given in table 1. By doing so, the individual views on the nature of science became clear. Furthermore, the understanding of the nature of science of the students and scientists was easy to compare when the answers were labelled. This way, it was investigated whether the students and scientists had comparable views on the nature of science.

Table 1: The different categories of the nature of science and their corresponding labels according to Schwartz and Lederman (2008).

Categories of the nature of science	Labelling of the categories
The creative and imaginative nature of scientific knowledge	To connect theories
	Research in other perspective
	No creativity in data
The social and cultural embeddedness of scientific knowledge	Both
	Culture influences science
	Science influences culture
	None
The subjective and theory-laden nature of scientific knowledge	Personal subjectivity
	Theory-laden subjectivity
	Ideally no subjectivity
	Absolute truth
The tentative nature of scientific knowledge	Inherent tentativeness
	Approaching certainty
	Absolute truth
The empirical nature of scientific knowledge	Observations filtered through perceptual apparatus
	Observations are absolute

Finally, the interaction between the students and scientists was examined. The individual views of the students and scientists on the interaction was compared per student-scientist pair. It was examined if the students and scientists perceived their interaction in a positive or negative way, whether they perceived this differently or the same and if possible, why they perceived it this way. Moreover, it was examined whether the interaction was influenced by the understanding of the nature of science or scientific inquiry. For example, if there had been a negatively perceived interaction between the student and scientist about the formulation of the research questions and hypotheses, it was asked whether this had anything to do with a disagreement about the creative nature of scientific knowledge. So, it was investigated if the interaction in a student-scientist inquiry partnership is influenced by the participants' views on the nature of science.

3.5 Issues of reliability and validity

The interviews were conducted at a date and location favourable for the interviewee, to comfort the interviewee and to acknowledge the willingness of the interviewee for the participation. The interview scheme had been tested by performing a pilot interview with one the researcher's fellow students, to improve the researcher's interview techniques and the interview scheme. The interviewees' anonymity was guaranteed and is not been mentioned by name in the report. The interviewees' answers have only been used for this research and not for any other purpose or research.

The interviewees were informed that the interviews lasted between 40 and 45 minutes. They were also informed that there were no "right" or "wrong" answers to the questions; it was rather their perception. Finally, the interviewees were told that the goal of the research was to study successes and failures of the Imagine School Competition and not the mutual understanding of the nature of science and their mutual interaction, so they could not be biased.

The interviewees were able to submit their email addresses to receive the final version of the research paper or the final version of a future rapport about the applicability of the results for the Foundation Imagine Life Sciences. Moreover, the interviewees were informed that results will be used to improve the Imagine school competition, as well to improve student-scientist inquiry partnerships in general.

This study could be biased because of socially desirable answers. Students could find it hard to be critical on their supervising scientists even without their presence in the interviews. To try to prevent socially desirable biasing, the students were informed that they cannot give any "right" or "wrong" answers to questions. The interview scheme was tested by performing a draft interview with one the researcher's fellow students, to improve the researcher's interview techniques and the interview scheme.

In order to test the reliability of the data analysis, interrater reliability was checked by asking a second researcher to analyse the understanding of the nature of science according to the analysis scheme. A substantial degree of interrater agreement (75%) was found.

4. RESULTS

The results are presented in three sections. The first section focuses on description of the inquiry of the different cases, the second section focuses on the interaction between students and scientists and the third section focuses on the views on the nature of science by the students and scientists. Every single case will be elucidated in this given order.

Codes were used to identify individual participants' responses. Each code consists of a first part and a second part. The first part corresponds with the case the participants were involved with: DNA analysis (DA), magnetic colloids (MC), meat substitute (MS) or water treatment (WT). The second part corresponds with the role of the participant during the inquiry: student (std) or scientist (sci).

In the first section a description is given about the inquiry executed in the different cases. Different elements of inquiry according to PRIMAS were used to describe the different inquiry cases (Maaß & Reitz-Koncebovski, 2013). The different categories are: (a) introduction / ask questions, (b) formulate hypothesis / explore research, (c) plan the experiment, (d) conduct the experiment, (e) interpret the data and (f) present the findings. In each description the role of the scientist and student during the inquiry is drawn on the basis of these different categories.

In every next section the mutual interaction between the student and scientist is presented. Results are shown about the working environment, if the students could operate independently, how the communication was experienced and if there were any problems in the interaction during the inquiry. Additionally, the goal the scientists had with the interaction is mentioned.

Finally the mutual views on the nature of science per case will be presented. The different categories are: (a) the tentative nature of scientific knowledge, (b) the empirical nature of scientific knowledge, (c) the subjective and theory-laden nature of scientific knowledge, (d) the creative and imaginative nature of scientific knowledge and (e) the social and cultural embeddedness of scientific knowledge.

4.1 DNA analysis:

4.1.1 Description of the inquiry

For the student the inquiry project started with an introducing lecture about DNA given by the scientist. The scientist explained about the techniques used for DNA analysis and the various applications of the techniques. The student was given the assignment to gain more knowledge about the techniques and possibilities of DNA analysis during the exploration phase.

Initially the student came with the idea to do research on the detection of the diseases HIV, tuberculosis or sickle cell disease. This idea was rejected by the scientist, because much research had been done already on HIV and tuberculosis, while research on sickle cell disease would have been too complex for the student. In the end the student and scientist decided to do research on the detection of leprosy by analyzing the DNA of the leprosy-bacteria. Because of the rejection of the previous proposals, it took two months before the student could start conducting the experiment.

In the end the student formulated the research question, the hypothesis and the research design together with the scientist. The student and scientist investigated if it was possible to diagnose an early stage of leprosy by using PCR. The student compared the genome of the leprosy-bacteria known from literature, with the PCR analysis of mucous membrane of a leprosy-patient. During the data analysis, the student compared both DNA sequences. The student concluded that it was possible to detect the leprosy-bacteria in an early stage. The entire research was executed in a single afternoon. The student presented the findings on her own high school, where the scientist was absent.

4.1.2 The interaction

The student was challenged to develop a research question which has something to do with DNA. The scientist had the ultimate goal to give the student an idea on how to solve scientific problems. The student was given a lot of freedom to develop a good research question. Unfortunately, the student was not given a lot of guidance during the inquiry. The interaction within the DNA analysis inquiry partnership did not went flawless. The student had to wait some time before she received answers to her questions. Also different suggestions for research questions and working plan were denied multiple times by the scientist. DA-std was not satisfied about the collaboration with the scientist.

> DA-std: It took some time before I received any answers, mainly during the phase when I was searching for new subjects. I lost a lot of time during this process and maybe I should have received more guidance. The competition started in September. However this subject was approved in December. I nearly lost 3 months only searching for a new subject.

DA-sci was disappointed as well about the interaction with the student. He struggled with motivating the student and was unable to create a lively debate. Although there was enough room to ask questions and to develop research questions, the interaction did not match the expectations.

> DA-sci: I am very disappointed in the interaction with the student. I would like to know why this was so difficult? Was she afraid to ask questions, what was the problem?
> Researcher: Perhaps there was too much freedom for the student?
> DA-sci: Yes, but she asked for this freedom, right? We designed the inquiry to structure it as free as possible. She was able to ask questions, but there was not a debate or any following questions.

4.1.3 Mutual views on the nature of science

The student and scientist differed in their understanding of the nature of science in the DNA analysis case. Only in two out of five categories the student and scientist had comparable views and they were both unable to answer the questions asked about the empirical nature of scientific knowledge. They had comparable views towards the social and cultural embeddedness of scientific knowledge and the tentative nature of scientific knowledge. They both replied that culture is influencing science and science is influencing culture and they also agreed that scientific knowledge is inherently tentative.

The student and scientist of the DNA analysis case disagreed upon the creativity and imaginative nature of scientific knowledge. According to the student, no creativity is needed to interpret data.

> DA-std: Actually, I am not certain. I do not think there is a lot of creativity needed to interpret data.

This is quiet noteworthy because the scientist uses a lot of creativity during the interpretation of his data. DNA sampling generates a lot of raw data and it is a difficult and time-consuming task to structure the results.

> DA-sci: When I am reading a human genome, I am comparing 4,2 million base pairs with a base pair reference. For each variant, I should determine if this is important information for the patient. It is a hell of job to determine what information is necessary and what information is not. It is also important to translate the raw data to understandable information for the doctors and patients.

Also within the category of the subjective and theory-laden nature of scientific nature the student and scientist disagree. The student believed that the personal subjectivity of scientists can result in disagreement among scientists, while DA-sci believed that education or theory-laden differences can influence scientific knowledge. Personal subjectivity and theory-laden supposed to be different labels according to Schwartz and Lederman (2008).

> DA-std: I think it depends on the scientists' background and on the way the scientist received his education. I also think that human beings always have different perspective on things and this is mainly influenced by their environment.

The scientist mainly focuses on differences in disciplines of the scientists that can result in the disagreement among scientists.

> DA-sci: I am an engineer and I think that doctors are applying technology too late for different reasons. In the first place the costs, technology is expensive. In the second place, doctors often desire to much certainty for the application.

4.2 Magnetic colloids

4.2.1 Description of the inquiry

During this inquiry project the student was challenged to perform research on magnetic colloids; nanoparticles that are being used to change the characteristics of other substances. The inquiry project started for the student with a two-day masterclass. On the first day of this masterclass the student obtained an introductory lecture about magnetic colloids. After the lecture the student was challenged to solve math problems on magnetic colloids.

On the second day the student was challenged to create her own magnetic colloids from iron oxide. According to the scientist this is quite an easy inquiry task. After this exploratory stage the student composed the research question together with the scientist. The student decided to focus on the separation of heavy metals from drinking water, the student was challenged to design the best test setup for water purification. The student planned the experiment together with the scientist.

During the conduction of the experiment there was a lot of guidance by the scientist. The student had a few meetings to discuss the fine-tuning of the test setup with the scientist. Together with the scientist, the student had the opportunity to interpret the outcomes of the test setup. In the end, the student decided to investigate if the test setup could be used in Brazil for water purification. The student presented the results on her high school in the presence of the scientist.

4.2.2 The interaction

The main goal of the scientist was to give the student a more nuanced representation of beta education given at universities. The scientist tried to reach this goal, by giving the student a research question, although the student should figure out herself how to tackle this problem. During the inquiry, the interaction went well. The student and scientist did not experience any problems. MC-std even mentioned that she felt very blessed to be linked to MC-sci. The scientist was also very fond on the contact with the student.

> MC-std: The collaborations went well, as a student I had my own division of labor. I was very motivated and the communication with the scientist went well. Yes, I was very lucky with my supervising scientist.

> MC-sci: I think she have found it interesting to peek into a real laboratory, to discuss different subjects, to be around other scientists and to do some experiments. I generally enjoyed the contact with the student.

MC-sci was also present during the end presentation given by the MC-std on her high school. The student really appreciated his presence and appreciated the critique given by the scientist.

> MC-std: He was present during my final presentation on high school. He was very enthusiastic, but had some critical questions as well. He commented that I could have dig in more closely to the subject, which was true.

4.2.3 Mutual views on the nature of science

The student and scientist of the magnetic colloids case had comparable views on the nature of science. They had comparable views in four out of five categories and they both were unable to answer on the questions asked about the empirical nature of scientific knowledge.

For example when questions were being asked about the tentative nature of scientific knowledge, they both elaborated that the nature of scientific knowledge is inherently tentative.

> MC-std: A theory is accepted, until the contrary is proven. You can believe in a theory, but this theory can always change.

> MC-sci: It is the famous philosophical discussion, when a unrefuted theory is being formulated, this is up to no good. You should be able to refute a theory, the theory should be surprising and it should give interesting predictions.

If we take a glance at the creative and imaginative nature of scientific knowledge, the student and scientist had comparable views. When asked whether creativity is needed for the design of experiments, they both appointed that creativity and imagination is needed to put research in other perspectives.

> MC-std: A scientist needs a lot of creativity for the experimental design and also if the scientist want to further investigate a subject, he needs to think creatively.

The scientist not only mentioned that creativity and imagination is needed to put research in another perspective, but also that creativity is required to connect different theories together.

> MC-sci: I think creativity is expressed by finding unexpected insights or solutions, by connecting unexpected relations, by connecting unexpected analogies, by asking questions and think about interesting thought experiments.

They both mentioned that science is socially and culturally embedded in both directions, culture is influencing science and science is influencing culture. They also had comparable views on the subjective and theory-laden nature of scientific knowledge and they both mentioned that the theoretical background of a scientist is subjective and can influence scientific knowledge.

4.3 Meat substitute

4.3.1 Description of the inquiry

For the student the inquiry project started with an introducing conversation with the scientist. The scientist gave the student an inside look in his own research. According to the scientist it is difficult to design a research proposal for the student, which is easily applied to third world countries. The student only had the opportunity to experiment with the growth of *Schizophyllum commune* on different grain soils.

The research question was mainly formulated by the scientist. In this research the student was challenged to investigate the optimum growth of the fungus during different circumstances. The student had the opportunity to carry out the experiment without the surveillance of the scientist and was able to choose the variables he would like to test. The student and scientist planned the experiment together.

The student chose to focus on growing various fungi at different temperatures and media. The data that the student received was the biomass of the fungus and the density of the mycelium. The student was able to interpret the data on his own. According to the student, the best fungi were grown on Sorghum, which grows best in an African climate and has good amino acid composition to be a meat substitute. The results were presented during the final day of the Imagine competition, where the scientist was present for feedback.

4.3.2 The interaction

The scientist participated to the Imagine competition to improve the student's interest in beta education. Although the scientist formulated the research question and research design beforehand, he gave the student the opportunity to choose the variables on his own. Furthermore, the student had the freedom to execute the research on his own, the scientist was available for questions if needed. This freedom gave the student a lot of confidence. MS-std and MS-sci both appreciated the common interaction. There was an atmosphere during the inquiry where the student was able to ask a lot of questions.

> MS-std: He (the scientist) gave me a lot of knowhow about his research because he believed that his research should be passed through to the future generation, because that is what he called me. During the research I received a lot of freedom to execute my own experiments and I received all of his confidence.

MS-sci was only disappointed about the student's motivation. According to the scientist the student was only interested in finishing his junior thesis, he did not have the desire to answer any scientific questions. According to the scientist this could be because of the age and interests of a high school student.

> MS-sci: Maybe the Imagine school competition takes place too early for a high school student. High school students have a strong sense of purpose, but the incentive is not science.

Nevertheless, in the end the student was very pleased about the Imagine school competition and the interaction with the scientist. The student felt like he was working as a real scientist, which was affirmed by the scientist.

> MS-std: I felt as if I was a scientist, working on professional research which was all possible because of the Imagine school competition

> MS-sci: I do believe that the student had the feeling as if he was working as a real scientist, although this research could be executed at home. He worked in a different working environment.

4.3.3 Mutual views on the nature of science

The scientist and the student had a mutual understanding of the nature of science in the meat substitute case. In four out of five categories they had comparable views, they were both only unable to answer the questions about the empirical nature of scientific knowledge.

They both had comparable views on the social and cultural embeddedness of scientific knowledge and they both mentioned that science and culture are influencing each other. They only had different opinions on how science and culture should influence each other.

> Researcher: Is a scientist influenced by societal impacts of society?
> MS-std: Society has something to do with people. I think it is important as a scientist to think about how to explain theories to the public and to think about a target group or different cultures you want to clarify your theories to.
> Researcher: Do you think that society is influenced by scientists?

> MS-std: Yes, because society is learning from scientists, society should use inventions of scientists, or at least learn from them.

The scientist elaborated even more on this subject. He supposed as well that science and culture are both influencing each other but he mentioned the practical use of this connection. According to MS-sci, society is more interested in applied research, while science progresses with fundamental research, so they should be combined together in one researchable question.

> MS-sci: Usually we try to link a fundamental question to applied research. Sometimes they are very closely related, so we use applied research as an excuse to answer fundamental questions and you try to combine both in one researchable question.

In contrast, the student was mainly interested in applied research. The ultimate goal for the student was to help the African population with their food problem. The inquiry was a possibility to reach this goal. So although the scientist and student seem to had comparable views on the social and cultural embeddedness of scientific knowledge, the interpretation is different.

> MS-std: So, we have investigated which mushroom grew best under which circumstances, so it could grow best in Africa. The ultimate goal could be to start up a meat substitute company in Ethiopia, to give the population the chance to get a protein-rich food source besides meat.

On the subjective and theory-laden nature of scientific knowledge they both had the same opinion. According to both, scientists can have different interpretations on the same subject, because there is subjectivity available in research. Subjectivity could commence because of personal differences or theory-laden differences.

> MS-std: As a scientist you can have different interpretations and different opinions on which theory you prefer, or what you think is more interesting. But I think it is good to have different perspectives on one subject, it comes in handy if you want to continue your research, to use different opinions and different views.

> MS-sci: I think that you have quite often an idea about how something works, and you stick with this idea. I think this is even inevitable. Then you're trying to prove or disprove this idea and during this process there could be another scientist who investigates the same phenomenon but this scientist could lead another track and tries to prove his ideas. This is inherent to science.

The student and scientist both agreed on the creative and imaginative nature of science, which places research in another perspective and they also agreed on the tentative nature of scientific knowledge, which is inherently tentative according to them.

4.4 Water treatment

4.4.1 Description of the inquiry

For the water treatment inquiry project the student started with an introducing lecture about the different possibilities of water treatment. During the introducing lecture, the scientist suggested three different techniques to filter the water: solar disinfection, sand filtration and filtration with clothing.

During the exploration of the research, the student decided to visit a water treatment plant for inspirational reasons. Before the student could start with her research, she was challenged to write a research proposal. The student had to include the research question, hypothesis and planning of the experiment. The student decided to focus on water treatment with solar disinfection and filtration with clothing.

During the conduction of the experiment, the student carried out a comparative research. The student and scientist compared different variables, such as presence of solar disinfection, the pore size of the clothing and the structure of the clothing. The student was able to test the water quality by investigating the amount of bacteria and the amount of turbidity in the water. According to the scientist it was easy to interpret the data. The student came to the conclusion that the best way to filter the water is to use solar disinfection first to reduce the amount of bacteria. Then the female garment sari should be used to reduce the turbidity of the water.

After the research was done, the student had to write a business plan about the use of clothing and solar disinfection for water treatment. During the writing of the business plan, the student still had some questions about the techniques she used. She emailed the scientist several times, but the scientist did not reply. The scientist was also absent during the presentation of the student during the finals of the competition and was unable to evaluate the project together with the student.

4.4.2 The interaction

The main goal of the scientist was to transfer his knowledge to the students. The student had to execute a comparative study, in which different variables came up to test different methods of water treatment. The student of the water treatment inquiry partnership appreciated the interaction and communication in the beginning. The first experiments were executed under the guidance of WT-sci. The student only wished to investigate more variables and decided to execute this on school without the supervision of the scientist. When the student had some follow-up questions she could hardly get in contact with the scientist.

> WT-std: In the beginning, the interaction and communication went well. He helped and supported me really good, I think because I had developed my own research questions. But towards the end of the project the communicated diluted a bit and that was a pity.

WT-sci gave the responsibility for contact after the inquiry to the student. The scientist was unaware of the disappointed reaction of the student toward the end of the competition.

> WT-sci: The communication mainly went by email. The question remains, how often would you like to stay in contact. I have given the responsibility for contact to the student. I have regularly mentioned that she could send me her findings, but maybe the hurdle was too big for her.

4.4.3 Mutual views on the nature of science

The student and scientist differed in their understanding of the nature of science in the water treatment case. In three out of five categories the student and scientist had comparable views on the nature of science. Although the student and scientist had different views on two categories of the nature of science, WT-std and WT-sci were the only ones who were able to elaborate on the questions about the empirical nature of scientific knowledge. According to Schwartz and Lederman (2008), the empirical nature of scientific knowledge includes the assumption that scientists do not always have direct access to most natural phenomena. According to the labelling, some say observations of nature are filtered through our perceptual apparatus while other say observations are absolute. According to both WT-std and WT-sci, scientists need to filter our observations through the perceptual apparatus.

> WT-std: Human capacity has its limits. Science has its limits, as in fixed values, you can therefore not measure infinity. I think the mental limit of humans is that we often forget that there is no limit. I think people are addicted to certainty of knowing.

> WT-sci: In my research I often try to demonstrate acute toxicities, but sometimes the effects are not directly traceable. You cannot prove acute toxicities, but it could be available. In other studies they mix drugs together and this influences the mixture. New combinations give unexpected effects, which are not directly traceable by the human apparatus.

The scientist and student disagreed on the social and cultural embeddedness of scientific knowledge. When it came to social and cultural embeddedness in science for example, WT-std mentioned that science and culture are influencing each other. The scientist however experienced in his working environment, that fundamental science is an entity on its own. Within applied science the answers are in favor of the big companies, not in favor of society.

> WT-std: I believe that social values are also influencing the scientists. Social aspects change ´the box´, with thinking in the box and thinking outside the box. A lot of scientists are limited because of ´the box´ created by society.

> WT-sci: Within fundamental science I can examine whatever I want, the outside world is not able to understand, so basically you are on your own. I have also worked for big companies which only

> had one question they wanted to be solved. My job was to answer the question and don't give answers to side question which are not too important to be answered.

And when WT-std elaborated on the subjectivity in science, she phrased that in an ideal world there should be no subjectivity. It is even impossible to be constantly objective in science. WT-sci commenced that subjectivity in science arises from theory-laden differences. The student and scientist elaborated on different aspects of subjectivity.

> WT-std: So a really good scientist would be very objective, but I actually believe that in real life objectivity is nearly impossible. Some things in life can never be proven or unproven.
>
> WT-sci: Within fundamental sciences I have checked data of other scientists. I have found a few revelations that other scientists had not found before, perhaps because I looked to data with another perspective then the other scientists.

5. DISCUSSION

5.1.1 DNA analysis

Within the case of DNA analysis, the student and scientist had some different views on the nature of science. When it came to the social and cultural embeddedness and the tentative nature of scientific knowledge they had comparable views, but when it came to creative/imaginative and subjective and theory-laden nature of scientific knowledge they had contradicting views. According to the student there was no creativity needed in science while the scientist is contradicting this statement. Furthermore, the scientist stated that the subjectivity in science mainly arises from theory-laden differences, while the student believed that it arises from personal and theory-laden differences.

Creativity is an important feature within the origination of scientific knowledge. Creativity is important for the development of the research questions, the planning of the experiment and the interpretation of the data (Barrow, 2010). Subjectivity is another important part of science, but is especially important in regard to interpreting the data (Lederman et al., 2002). It is unfortunate that the scientist and student had contradicting views on the creative and subjective nature of scientific knowledge. The scientist used a lot of creativity during the interpretation of his data, because he needed to distinguish which variation in DNA data is important.

The student was challenged to develop research questions and methods concerning DNA analysis in third world countries. It was striking to notice that the interaction was failing during the exploration and planning of the experiment. Especially during this phase of inquiry, creativity was needed. The scientist thought this would be an easy task, however the student experienced this differently. DA-std struggled with the lack of guidelines. The scientist thought it was an advantage that the student could develop any possible research. However, the student lost a lot of time during the process of developing research questions and methods.

The scientist on the other hand was disappointed about the student's input. DA-sci hoped for a lively debate with the student. However, the student did not ask questions and did not suggest proper research questions. According to the scientist, this could be because the student was too unfamiliar with the subject. DA-std would have appreciated if she would have received more guidance during the initial phase.

5.1.2 Magnetic colloids

The student and scientist had a mutual understanding of the nature of science in four out of five categories. They had comparable views on tentative nature, the creative and imaginative nature, the socially and cultural embeddedness and the subjective and theory-laden nature of scientific knowledge. They both were unable to answer the question about the empirical nature of scientific knowledge.

The student and scientist did not experience any problems within the mutual interaction. The magnetic colloids inquiry project had the intended design to challenge students to develop their own testing setup in order to separate toxic substances out of a mixture. During the inquiry there was no prescription available on how to execute the experiment and the student was able to create a useful testing setup with the feedback of the scientist. The student appreciated the guidance.

The testing setup was the starting point of the inquiry and the student was able to elaborate on this design within their own high school. The student and scientist had an appointment once a month to discuss the progress. MC-std and MC-sci really appreciated the interaction. The collaboration and communication with the scientist went well and the student felt lucky that she was linked with the scientist.

It seems like the clear structure was beneficial for the mutual interaction. The research question and research design were well prepared by the scientist, before the inquiry even started. During the inquiry the scientist gave a lot of guidance, which was appreciated by MS-std. The mutual understanding of the nature of science could have been beneficial for the interaction between the student and the scientist. However it is probable that the clear structure and the amount of guidance were the key factors for the proper interaction.

5.1.3 Meat substitute

The scientist and the student had a mutual understanding of the nature of science in the meat substitute case. They had comparable views on the tentative nature, the creative and imaginative nature, the subjective and theory-laden nature and the socially and cultural embedded nature of scientific knowledge, although they both were unable to answer the question about the empirical nature of scientific knowledge.

The student and scientist agreed that science and society influence each other, although they had different opinions on how science and society should influence each other. According to the scientist, science will progress with fundamental research while society is more interested in applied science. In contrast, the student was mainly interested in applied research with the ultimate goal to help people in developing countries.

The different views on how science and society should influenced each other, could have been influential for the interaction between the student and scientist. The scientist was disappointed with the student's intrinsic motivation. According to the scientist, the student was not motivated to answer any scientific questions, the student was only occupied in getting a good grade for his junior thesis. MS-sci suggested that maybe an intrinsic motivation to answer scientific questions is too much to ask for high school students. It is more likely that the student was just motivated in the social aspect of the Imagine school competition. This does not correspond with the scientist's intrinsic motivation to be active in the scientific community, the urge to find answers to fundamental research questions.

The student did not have any problems with the motivational differences. In fact the student enjoyed it when the scientist was elaborating on his research.

> MS-std: He often gave me a peek into his own research. He can be very enthusiastic about his own research, he showed me even things which had actually nothing to do with my own research. But still, this was quite fun and we gained a lot of extra knowledge.

Moreover, the student experienced the interaction as pleasant. The student appreciated the freedom given by the scientist; the student was able to develop his own research questions and research methods. This was also one of the scientist priorities; MS-sci gave the students a lot of freedom during the inquiry and tried to inspire the student to develop a research on their own.

5.1.4 Water treatment

The student and scientist did not have an entire mutual understanding of the nature of science. They had comparable views when it came to the tentative nature, the empirical nature and the creative nature of scientific knowledge. The student and scientist did not have comparable views when it came to the social and cultural embeddedness and the subjective nature of scientific knowledge. According to the student science and culture are influencing each other, while the scientist believed that science is an entity on its own and is not influenced by society. When it came to the subjective nature of scientific knowledge, the student opined that in an ideal world there should be no subjectivity at all. On the other hand, the scientist believed that subjectivity arises from theory-laden differences.

The student and scientist clearly had different views on the social aspect of science. WT-sci stated that in his work as a scientist, society is not involved. Within fundamental science, society is not able to understand his findings. While within applied science, big companies raise questions which have to be solved, in which society is not interested. WT-std on the other hand, stated that society and science often influence each other. The student was also very interested in the social appliance of science, and decided to develop a workshop to inform the local community on water treatment.

During the inquiry the student was challenged to use different research techniques for the treatment of clean drinking water. During the initial inquiry the student received proper comments and experienced a positive interaction. After the initial inquiry the student continued with the social part of the research, in which the guidance of the scientist was redundant. Subsequently, the student decided to investigate more variables but she was unable to get in contact with the scientist and the interaction was declining.

It could be possible that the failing interaction during the end of the competition was caused because of different views on the social and cultural nature of scientific knowledge. The social feature of the Imagine school competition was an important addition for the student, while the scientist was more interested in the scientific issues. On the other hand, the scientist was unaware of the failing communication when asked about it. It seems like the different interests resulted in bad communication during the end of the competition. The reduction of communication towards the end of the competition is already reported by Masson and colleagues (2013), in which the lack of communication between students and scientists is the cause of a failing interaction.

5.2 Other factors influencing the interaction

In this research it was investigated if the mutual views on the nature of science influence the interaction during a student-scientist inquiry partnership. In this research other factors became apparent that could influence the interaction between students and scientists.

The lack of communication was a factor mentioned in previous studies. Students often indicated that they were disappointed in the scientists' level of engagement. They felt like their questions were long left unanswered and they did not feel encouraged (Masson et al., 2013). According to Masson and colleagues (2013) this problem will often arise with scientists, because it is not seen as a priority of scientists' daily work to answer emails from students.

Another factor that could influence the interaction is the difference in intrinsic motivation. Students felt highly motivated by the opportunity to actually help people in developing countries, the students were less interested in the inquiry. For the scientist, the social features were often a side issue of inquiry. Moreover, for the students the project was also important, because their report would be assessed as a part of their final exam result. For scientists there was less at stake, it was not a part of their professional career (Masson et al., expected in 2015).

The amount of structure that was given by the scientist during the inquiry was another important success factor for the interaction. If students clearly follow the steps of inquiry based learning by PRIMAS (Maaß & Reitz-Koncebovski, 2013), they will be aware of what is expected of them. Students will have the opportunity to ask questions directly, they will be able to discuss different elements of the inquiry with the scientist and they can work independently.

Another important factor was the amount of guidance by the scientist during the inquiry. The amount of guidance was also cohesive with the amount of structure. When the scientist was available for questions and gave advice during the inquiry, this was much appreciated by the students. Although the students liked to receive enough freedom to develop their own research questions and methods, guidance during this process is really important. When the students did not receive any guidance during this process, they were unable to continue and the interaction declined.

The amount of freedom and guidance given by the scientist also depended on the initial goal of the scientist. For example, in two cases the scientists had the main goal to give the students a more nuanced representation of beta education and make students more interested in beta education. In both cases the scientists had formulated the research question and research design beforehand. During the inquiry, the scientists gave the students only freedom in choosing the variables. The scientists tried to guide students as much as possible. In another case where the main goal of the scientist was to transfer his knowledge, the research question was designed beforehand by the scientist as well. The scientist gave the student a lot of guidance during the experiment.

In the case of DNA analysis, the ultimate goal of the scientist was to solve scientific problems. The scientist decided to choose a different approach. He gave the student a lot of freedom in developing the research question. During this process the student did not receive a lot of guidance, which caused the student to be unable to develop a proper research question. Unfortunately, the scientist gave the student too much freedom and in the meantime too little guidance. The ultimate goal to teach the student to solve scientific problems failed as well.

6. CONCLUSION

This research explored the question whether the interaction in a student-scientist inquiry partnership is influenced by the participants' views on the nature of science. The results indicated that comparable views on the nature of science go together with a positive interaction between students and scientists in an inquiry partnership. During two cases where the students and scientists had perceived a high common understanding of the nature of science (four out of five categories), both couples reviewed a productive interaction. During the inquiry partnerships where the student and scientist perceived a less common understanding of the nature of science (two out of five categories and three out of five categories) they did not experienced a pleasant interaction. So is the interaction in the various student-scientist inquiry partnerships influenced by the participants' views on the nature of science?

When the individual cases are examined further, the interaction seemed to be influenced by participants' views on the nature of science. For example within the two cases where there was a poor common understanding of the nature of science. In the DNA-analysis case the student and scientist disagreed upon the creative/imaginative and subjective/theory-laden nature of scientific knowledge. The interaction was failing during the initial phase of the inquiry, where both creativity and subjectivity was needed.

In the water treatment case the student and scientist disagreed upon the social and cultural embeddedness and the subjective nature of scientific knowledge. The scientist stated that science is not influenced by society, while the student stated the opposite, science and society are continuously influencing each other. In this case the interaction was failing during the time the student had to write a business plan, concerning the health care of a developing country. The social component was important for the student while it was unimportant for the scientist. This could be the reason for the failing interaction, although the scientist was unaware of this failing interaction. Perhaps the scientist was not interested in the practical use of the inquiry, and that is why the communication as well as the interaction degraded.

Within the meat substitute case the student and scientist had different opinions on how science and society should influence each other. The student was mainly interested in applied science for developing countries, while the scientist was more interested in fundamental research. Because the student was mainly motivated for the social aspect of science, which does not correspond with the scientist's intrinsic motivation to be involved in science, the scientist had the feeling the student was not motivated at all.

Although the scientist was disappointed about this part of the interaction, the student was very enthusiastic about the interaction with the scientist.

Within the magnetic colloids case the student and scientist developed a mutual understanding of the nature of science. The scientist and student also did not experience any problems during the interaction. This could indicate a positive relationship between the mutual understanding of the nature of science and the mutual interaction. But it also seemed that the clear structure of the inquiry and the proper amount of guidance by the scientist were beneficial for the interaction between the student and scientist.

In conclusion, it would be wise to focus on the nature of science during a student-scientist inquiry partnership to increase the interaction. Furthermore, it would be wise to focus on the given freedom of students during the inquiry. The students should be given enough freedom to develop their own research questions and research methods. Although the students should receive enough freedom, they should also receive enough guidance during the process of devolving these research questions and research methods. This study showed that if the students do not receive enough guidance, the interaction between students and scientists could fail. Meanwhile scientists should still focus on their communication with the students. If the communication between the students and scientists is failing, the interaction is perceived inferior as well.

7. FUTURE RECOMMENDATIONS

The results of this study are relevant for different student-scientist inquiry partnerships with the same features. Imagine school competition focusses on life science and technology and on socio-scientific issues. One of the aims of Imagine is to help pupils learn more about the practice of science and to get young people interested in science and technology. By implementing the results of this study student-scientist interaction can be improved, leading to a more productive outcome of student-scientist inquiry partnerships.

One of the limitations of the research was that it was only possible to interview the students and scientists after the competition. Therefore it was only possible to investigate the view of the nature of science after the competition. It would be interesting to compare the student's views of the nature of science before and after the competition, by taking the VNOS questionnaire before and after. Probably no differences in views of the scientists will be seen, although maybe the students will change their views during the partnership. Scientists have been able to develop the nature of science during their entire scientific career, while for the students it was probably one of the first times they came into contact with inquiry.

It would also be interesting to examine the interaction during the partnership. It could be possible that the interaction is changing over time. Moreover it would be interesting to observe and assess the students and scientists during the interaction. In this case the credibility and validity of the results will be increased, due to triangulation.

Future studies should also change the labels of the categories of the understanding of the nature of science. According to Schwartz and Lederman (2008), the creative and imaginative nature of scientific knowledge mostly occurs during the collection and analysing of the data. This view is recurrent in the questions from the VNOS as well as the labelling of the categories of the VNOS. In my opinion however, the creative and imaginative nature of scientific knowledge mostly occurs during the formulation of the research question and hypothesis and the planning of the experiment. During this phase researchers have the highest degree of freedom because they are not able to follow a strict plan for data collection or analysis.

I also disagree with the labelling and questions about the empirical nature of scientific knowledge. According to Schwartz and Lederman (2008), the empirical nature of scientific knowledge has something to do with the perceptual possibilities of humans. Although this is a part of the empirical nature of scientific knowledge, I believe the empirical nature of scientific knowledge has more to do with providing evidence with the use of measurements. The question used to acquire the view on the empirical nature of scientific knowledge, does not relate to the labelling of the category as well.

8. APPENDIX A

Questions from the Views of Nature of Science Questionnaire Form-B (VNOS Form-B):

1. Scientists perform experiments when trying to solve problems. Other than the planning and design of these experiments, do scientists use their creativity and imagination during and after data collection? Please explain your answer and provide examples if appropriate.

2. Are cultural and social viewpoints influencing the theories of scientists? And vice versa?

3. Some astronomers believe that the universe is expanding while others believe that it is shrinking; still others believe that the universe is in a static state without any expansion or shrinkage. How are these different conclusions possible if all of these scientists are looking at the same experiments and data?

4. After scientists have developed a theory (e.g. atomic theory), does the theory ever change? If you believe that theories do change, explain why we bother to teach scientific theories. Defend your answer with examples.

5. Is there a difference between a scientific theory and a scientific law? Give an example to illustrate your answer.

6. How are science and art similar? How are they different?

9. APPENDIX B

Questions about the interaction within student-scientist inquiry partnerships for the students (Dutch):

1. Zou je willen beschrijven hoe het onderzoek van de Imagine Scholierencompetitie eruit heeft gezien?

2. Welke nieuwe kennis heb je door het onderzoek opgedaan? Hoe heb je deze nieuwe kennis verkregen?

3. Hoe was de begeleiding van de wetenschapper gedurende het onderzoek?

4. Was er verschil in de begeleiding aan het begin en aan het einde van het onderzoek?

5. Heb je het gevoel dat je deze kennis ook nog voor ander onderzoek kunt gebruiken?

6. Welke verschillende vakgebieden waren in het onderzoek betrokken? Zo ja, hoe werden deze dan gecombineerd?

7. Werd er in het onderzoek nog impliciet of expliciet vergelijking getrokken met andere voorbeelden uit de wetenschap? Zoals?

8. Welke kwaliteiten heb je nodig om een goede wetenschapper te zijn, denk je? Zou jij een goede wetenschapper kunnen zijn? Had jij ook daadwerkelijk het gevoel alsof je aan het werk was als een wetenschapper?

9. Hoe is de samenwerking met de wetenschapper verlopen gedurende het onderzoek? Licht het toe.

10. Heb je enige problemen ondervonden gedurende het onderzoek dat je hebt uitgevoerd?

11. Hoeveel ruimte kreeg je voor het ontwikkelen van je eigen onderzoeksvragen, hypotheses, data analyses en conclusies?

12. Was het mogelijk om je eigen ideeën in het project te stoppen? Hoe werd er naar je geluisterd als je met eigen ideeën voor het project kwam?

13. Was er de mogelijkheid om genoeg vragen te stellen aan de wetenschapper? Zo ja, hoe creëerde de wetenschapper deze atmosfeer? Zo nee, waarom was dit niet mogelijk?

14. Hoe verliep het contact gedurende het onderzoek dat je met de wetenschapper hebt uitgevoerd?

15. Hoe was de communicatie met wetenschapper verschillend ten op zichtte van bijvoorbeeld je begeleidend docent van je profielwerkstuk?

16. Is het project uiteindelijk geëvalueerd en hoe ging dat dan in zijn werk?

17. Hoe heb je de Imagine scholierencompetitie in zijn geheel ervaren?

10. APPENDIX C

Questions about the interaction within student-scientist inquiry partnerships for the scientists (Dutch):

1. Zou u willen beschrijven hoe het onderzoek van de Imagine Scholierencompetitie eruit heeft gezien?

2. Met welke intentie heeft u deelgenomen aan Imagine.

3. Hoe heeft u de leerlingen begeleid gedurende het onderzoek? Hoe had u het onderzoek voorbereid?

4. Heeft u rekening gehouden met de aanwezige basiskennis van de leerlingen voor u het onderzoek had opgezet? Viel dit mee viel dit tegen?

5. Zat er verschil in de begeleiding van de leerlingen gedurende het begin ten opzichte van de begeleiding aan het einde?

6. Heeft u de leerlingen expliciet iets geleerd over de wetenschappelijke methode en de manier hoe wetenschap in zijn werk gaat? En impliciet?

7. Heeft u de leerlingen daadwerkelijk het gevoel gegeven alsof ze aan het werk waren als een wetenschapper?

8. Denkt u dat de leerlingen genoeg bagage hebben om als wetenschapper te werken?

9. Hebben de leerlingen een duidelijk beeld gekregen van wat wetenschap eigenlijk is (eventueel refereren naar eigen ideeën nature of science)

10. Wat hebben de leerlingen geleerd van de wetenschappelijke methode en het uitvoeren van wetenschap?

11. Vind u het belangrijk dat de leerlingen meer begrijpen van de wetenschappelijke methode en het uitvoeren van wetenschap?

12. Hoe is de samenwerking met de leerling verlopen gedurende het onderzoek? Licht het toe. (-> verbindt met het onderzoek)

13. Heeft u enige problemen met de leerlingen ondervonden gedurende het onderzoek dat u hebt uitgevoerd?

14. Hoeveel ruimte kreeg je voor het ontwikkelen van je eigen onderzoeksvragen, hypotheses, data analyses en conclusies?

15. Kwamen de leerlingen met goede inzichten of ideeën gedurende het onderzoek? Was er voor de leerlingen ruimte om met nieuwe inzichten of ideeën te komen?

16. Hebben de leerlingen veel vragen gesteld? Zo nee, waarom denkt u dat de leerlingen hier niet de ruimte toe vonden?

17. Heeft u het project uiteindelijk met de leerlingen geëvalueerd? Zo ja, hoe ging dat dan in zijn werk?

18. Reflecterend. Hoe heeft u het onderzoek ervaren?

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