Master Thesis

"A relation at the borders of facts and fiction"

A study on the way Dutch nano-medical scientists construct their relationship with society and how these constructions can affect this relationship

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Date:	13-01-2012

Preface

This report describes the Master thesis project I have conducted for the faculty Applied Communication Sciences of Wageningen University. This project gave me the opportunity to combine my background as molecular biologist with my current specialization in science communication. Originally, my Master thesis was combined with a traineeship of the Rathenau Institute and the Dutch Embassy in Tokyo. The aim of this traineeship was to map the latest nano-technological developments in Japan and its expected societal implications. Due to the very unfortunate happenings in Japan last March, I was not able to conduct the interviews planned for my thesis project. In order to precede the thesis trajectory in The Netherlands, I changed the thesis subject, resulting in a subsequent delay. With regard to the subject, the focus on the nano-medical field remained.

I would like to thank all respondents for their participation in this study. The interesting insights you expressed during the interviews were not only worthwhile for my own personal point of view, but also very useful for the project described in this paper. Without your participation it would not have been possible to come to the valuable data and subsequent conclusions of the study. Moreover, I would like to say thanks to my supervisors Hedwig te Molder and Bart Walhout. Hedwig, thank you for your enthusiasm and stimulating feedback. Thanks to, amongst others, your positive attitude I was able to quickly shift and restart my graduation project after my unexpected return from Japan. Bart, I would like to thank you for your valuable input and your willingness to supervise me, although circumstances changed. Furthermore, I would like to thank Steven, my parents, Suzanne and Maud for all their support, enabling me to proceed the thesis trajectory and Daphne for making working at home more appealing.

Rotterdam, 2011

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Overview

Abstract

It has been acknowledged, that besides technologies shaping society, society can also shape technologies and their outcomes. Through the social construction of technologies, social values are embedded within technological developments. In The Netherlands an increased need for including societal values, offering guidance to the responsible development of technologies, pushes for a further involvement of the public. As public engagement requires involvement of the public in the scientific process, a lot of attention is currently paid to how to involve the public in this process. The successful implementation of engagement activities depends, however, on the actions and thoughts of both the public and the science community as these activities build a relation between them. To better understand this relationship and the way it is constructed, it is relevant to study how the science community approaches this relation. This approach is based on scientists' conscious or unconscious generalizations, known as folk theories. Folk theories of scientists have already been identified, but are often described in very general terms. Moreover, it has been suggested that the cultures of scientific disciplines can be very different. This study specifically focuses on the folk theories of scientists working in the Dutch nano-medical field. This research area is of special interest because, compared to other fields of science, nano-medicine has the potential to directly impact society by influencing the healthcare system and subsequently human health.

Fifteen semi-structured interviews have been conducted with scientists working in the Dutch nano-medical field. Based on these interviews, the folk theories of these scientists have been identified. These folk theories and the connection between them, gave insights in the way respondents constructed their relationship with society. Three main themes in these constructions have been brought forward in this report. The first theme that arose showed that respondents constructed their relation with society differently in applied and fundamental research, viewing the relationship within the fundamental phase as limited. They clearly directed the relation to the application phase, in which potential beneficial applications are generated for society. Secondly, fear for the extinction of the research area due to societal interference, was often put forward in respondents´ talks. Through this construction, respondents distanced themselves from society, therefore limiting their relationship. A last theme recognized within respondents' constructions, was the general description of public engagement as top-down communication, such as transferring knowledge. Constructions of public engagement as a dialogue were generally not brought forward in the interviews. The difficulty of creating a dialogue is according to respondents due to the gap between society and the science they are conducting. This gap derives from a lack of knowledge and interest of the public.

These three themes demonstrate that, although respondents are aware of their relationship with society, they clearly direct society to the borders of the scientific process. Following respondents, involving society within these borders would be difficult due to their lack of knowledge. Furthermore respondents' perspectives, subjective and often unfounded, are often found to be not compatible with the objectivity of scientifically generated knowledge.

Moreover, respondents expressed the fear that engaging the public in this process could stop current technological developments. Directing the relationship with society outside the technological process, could hinder the further implementation of public engagement and especially more upstream activities in technological developments. Based on these findings, several recommendations for improving the implementation of public engagement practices have been made. Firstly, showing scientists that engagement of the public in fundamental stages could possibly improve publics general knowledge level, leading to better understanding of the public on future applications, could increase scientists´ perception of the societal relevance of its research and therefore their willingness to engage society in their research. Secondly, showing scientists that societal interventions do not necessarily hinder developments, but can change the direction of the developments positively could furthermore diminish scientists' fears and improve scientists' views of societal involvement.

Key words: folk theories, nano-medicine, public engagement, scientist-society relationship

1. Introduction

When introducing new technologies, interaction between these technologies and society arises. On the one hand, technological developments have the potential to impact society and, on the other hand, these developments can be shaped by society through their values. The final outcome of technological innovation depends on this interaction (Shelley Egan, 2011). A rising demand for the responsible development of technologies pushes towards an increasing inclusion of societal values through further public involvement. Currently, a lot of attention is paid to how to engage the public. Scientists' involvement in public engagement activities has been addressed to a minor extent. The relationship that is built by engaging the public is however constructed by the actions and thoughts of both the public as the scientific community. In order to improve recent public engagement activities, a better understanding of this relationship should be obtained. Therefore the study described in this report, aims to increase recent understandings of the relationship between society and the science community, by investigating the way scientists construct their relation with society. This study specifically focuses on the constructions of scientists working in the Dutch nano-medical field. This research area is currently seen as one of the most advanced sectors in The Netherlands. As nano-medical technologies are expected to greatly impact society by influencing the health care system and subsequently human health, engagement of society in these developments is of special interest (Lührs et al., 2010)

This chapter will further introduce the study described in this report. The first paragraphs will elaborate on the current developments in the Dutch nano-medical field and the social context in which these developments take place. The subsequent paragraphs will discuss the research questions and aims of the study and describe the setup of the report.

1.1 Dutch nano-medical field

Nano-medicine means the application of nanotechnology, the study of manipulating matters at a scale of 10^{-9} of a meter, in the medical field. As diseases start at this nano-level, the Holy Grail in medicine is an intervention on that scale (NWO, 2005). The nano-scale is becoming increasingly accessible in medical science and technology. Currently, the application of nanotechnology in medicine is worldwide regarded as one of the most advanced sectors (Nanomed, 2011). The FES High Tech Systems and Materials Program and a program of the Dutch Science Organization NWO were established to financially support and promote the Dutch nano-medical field and subsequently to increase the Netherlands´ international competitiveness in this field (Walhout et al., 2010). The main lines of research in the field of nano-medicine can be divided in studies for diagnostics, monitoring and treatment (NWO, 2011). Based on these categories, four main nano-medical research areas can be distinguished in The Netherlands. The first area, known as 'biomarkers', is based on the ability of molecules to detect the one-set and status of possible diseases without the person actually having signs of sickness (Boenink, 2009). Through these biomarkers, earlier diagnosis of certain diseases becomes possible. Research in the second area of nano-drug delivery has led to the development of nano-sized delivery vehicles, consisting of an inner core that encapsulates a drug and a bio-compatible outer core. Through these vehicles the drug can be released locally, overcoming the potential side-effects of existing drug delivery systems (Bhowmik et al., 2009). The third main nano-medical area, known as Regenerative Medicine, RM, combines tissue engineering and stem cell research on a nano-level. By using various RM techniques, it is possible to grow cell sheets from cultured cells (van den Besselaar and Gurney, 2009). RM can be useful for better acceptation of biomaterials when repairing body tissue, but can also help to restore functions by regenerating whole organs (Walhout et al., 2010). The last research area of interest within the Dutch nano-medical field arose when the miniaturization in both the electronics as well as the life sciences made the integration of these fields possible. The application of the semiconductor technology in the life sciences resulted in the development of nano bio devices for more sensitive, rapid, non-invasive, cheaper and portable diagnostics (Pautler and Brenner, 2010).

1.2 Social context

Various industrial parties, academic and national research institutes in The Netherlands are currently working on the nano-medical research areas, biomarkers, DDS, RM and nano-bio devices, that have been mentioned in the previous paragraph. High expectations on evolving nano-medical applications within these four research fields for healthcare have been raised (van Geest, 2011). On the side of the potential beneficial impact on society, considerations about the importance of nano-medicine must be placed in context of the health problems they address. At present, the Dutch medical sector is challenged by the growth of chronic diseases, such as cancer and heart and vascular diseases (Nanopodium, 2011). Nano-medical research can contribute to the current knowledge about diagnosing and treating these diseases at a nano level (Walhout, 2010). Through this knowledge, physical and chemical processes can be better controlled and new nano-medical therapies can be developed, offering chances to tackle chronic diseases (Riehemann et al., 2009).

Besides having great opportunities, nano-medical applications can, once developed, pose big challenges for society. At present, the attention on the possible societal implications of these developments is mainly limited to studying the risks of the nano-materials used in nano-medical applications. Preliminary evidence suggests that engineered nano-particles may have undesirable toxicological properties, presenting potential risks to human and environmental health and safety (Bowman and Fitzharris, 2007). The risk of applying nano-particles or nano-manipulated substances in disease treatments is nevertheless, still unknown.

Recent developments in nano-medicine are not only expected to influence human health, but have the potential to revolutionary impact all aspects of public health care, hence transforming the medical system (Pautler and Brenner, 2010). Regeneration of tissues and early diagnosis through nano-bio devices is expected to stimulate the development of temporal treatments of currently chronic diseases. Continual handlings by patients and their general practitioners can therefore be substituted by one single treatment in the hospital, possibly leading to changes in work strain and evolving activities of the hospital and general practitioners. Besides earlier diagnosis, the application of nano bio devices will result in easier diagnostic handlings. Physicians will be able to test diseases by portable devices in several minutes, leading to less invasive diagnostic activities and more rapid medical decision making (CMSI, 2009). Through these devices, certain medical procedures could increasingly be moderated outside the hospital or practice location. This is also referred to as decentralization of medical care. The easy use of nano-bio devices can lead to home application in the future as well (Melchior, 2009). Self-prognosis and monitoring by home tests increases the need of patients' understanding about the underlying technology and the proper handling of these devices. Controlling the own personal health and playing a more active role in the health care trajectory is, however, not always easy (Walhout et al., 2010). Incorrect use could lead to improper treatment and raises certain safety issues (NOST, 2011). Home-applications could also lead to a change of patients' and physicians' daily routines and different doctor-patient relationships (Ferrari et al., 2009 and Harden, 2009). The ability to self-manage personal health could, for example, increase the threshold of patients´ tendency to visit their general practitioner. A reduced involvement of the physician in a patients´ treatment plan makes it more difficult for the general practitioner to get a good view of patients' health. This can lead to a shift of physician's tasks to more controlling and informing activities, needed to help patients to properly guide these self-diagnostic handlings (Walhout et al., 2010). Advanced nano-medical technologies will furthermore result in longer life spends and an increasing population age, which can consequently result to changes in health insurance. The use of robots for medical handlings might be required to born additional costs (Garcés and Cornell, 2001).

1.3 Social construction of technologies

The possible societal implications, illustrated in the previous paragraph, demonstrate the potential of nano-medical research to affect society in different ways. Growing cultural awareness on the potential outcomes of technological change, such as in the nano-medical field, addressed the need for assessing technological developments (van Est, 2011). By paying close attention to societal implications of technologies, a responsible development of these technologies has been thought to occur (Mills and Fleddermann, 2005). Technology Assessment, TA, has shown to be useful for analyzing and mapping the societal impacts of scientific and technological developments (Staman, 2010). The evaluation of the acceptability of these impacts is inherently social rather than scientific. In order to for technologies to be accepted, technological developments have to be adapted to current social developments (Kyle and Dodds, 2009). By including societal values in the scientific process, possible unwanted outcomes for society can be prevented (Grunwald and Hocke, 2010). The adequate timing of social inquiry within scientific and technological progress has been in discussion since the very beginning of reflection on science and technology. It has often been observed that as the technology and its social consequences are already implemented in society, societal reflections are too late to steer these consequences (Grunwald and Hocke, 2010). The legitimacy of today´s technologies greatly depends on the involvement of society in the technological process (Felt et al., 2009). In order to keep in track with social developments, involving society at an early stage has been recognized (Decker and Ladikas, 2004). By early engagement of society, current nano-medical developments could be better adapted to existing societal values, offering guidance to the responsible development of the nano-medical area (Katz et al., 2005). Hence, the interaction between nano-medical technologies and society can be improved (Nordman and MacNaghten, 2010). Engaging the publics during an early phase has furthermore increasingly been recognized to be essential to build trust and to anticipate on objections (Nordman and Rip, 2009). Subsequently, backlash can be prevented and wide public acceptance of the technology can be achieved (Petersen et al., 2009).

1.4 Problem statement

Calls from society for engaging the public in technological developments, are recently growing. A lot of attention is therefore paid on how the public could be involved in the scientific process (Petersen et al., 2009). Initiatives are increasingly undertaken to engage the public and to investigate whether these initiatives have been effective. In The Netherlands, the Committee Societal Dialogue Nanotechnology has been concerned with engaging the public in nano-technological developments. Through for instance the project Nanopodium, the Committee stimulated conversations and exchange of thoughts, ideas and suggestions on nano-developments (Nanopodium, 2011). In the UK, the Nanotechnologies Engagement Group was established in 2005 to consider and subsequently learn from previously undertaken activities for engaging the public within nano-technological developments (Doubleday, 2007). These two examples demonstrate the attention that is currently paid on how to engage the public. The successful implementation of public participation activities depends not only on the actions and thoughts of the public, but those of the scientists as well. The possible involvement of scientists within these public participation activities is, however, addressed to a minor extent. Also scientists' understandings and experiences of public engagement have received only limited attention until now (Burchell, 2009). Van Est underlines the importance of experts visions and actions in public engagement activities by stating that it is not only a matter of involving stakeholders and citizens upstream, but that experts need to move upstream as well (van Est, 2010).

The relation between scientists and society, which is established by engagement activities, is constructed by the actions and thoughts of both the publics and the scientists. To better understand this relationship, it is relevant to look how the science community approaches this relation. The way scientists construct their relationship with society is expected to differ, depending on the research area or discipline in which the scientist is active. Compared to other technological areas, nano-technological developments go along with a high level of ethical and social related aspects (Nordman and Rip, 2009). The relation with society is therefore specifically interesting in this research area. Particularly the nano-medical field has the potential to greatly impact society by affecting human heath through various new medical treatments and devices. It is especially interesting to study the folk theories of scientists working in the nano-medical field, due to the potential societal impacts of this research area. The way scientists construct their relationship with society is possibly different in the nano-medical area compared to the other nano-areas due to the direct impact of nano-medical technologies on public health. Moreover, the folk theories scientists hold on different aspects of society and their relation to this society could differ due to a different societal attitude towards this research field than other nano-fields. Because of its potential to improve medical treatments, a more positive public attitude towards nano-medicine, compared to other nano-fields, is expected. Berube stated that it is likely that the medical applications of nanotechnology will foster a renewed interest and trust in the field through the prolonged escape from death (Berube, 2008). On the other hand, the higher impact of nano-medicine on society could also result in fear for risks among the public.

1.5 Research questions and aims

The constructions nano-medical scientists will apply with regard to their relationship with society are expected to have possible communicative implications. These constructions give an incentive for scientists´ actual behavior, shaping the future interaction between the science community and society. How scientists construct their relationship with society, enable them to describe, approach and handle this relation in a certain way. The actual implementation of public engagement activities depends on the constructions and subsequent actions of both the public and science community. In order to obtain more knowledge on the constructions of nano-medical scientists, the study described in this report aimed to investigate and answer the following research question:

"How do Dutch nano-medical scientists construct their relationship with society and how could these constructions influence this relationship?"

Scientists' constructions are thought to be based on their conscious or unconscious generalizations, known as folk theories. Folk theories emerge when actors attempt to capture patterns in what is happening in their world and subsequently color their views (Rip, 2006). Folk theories of nano-scientists have already been identified, but are currently described in very general terms. Moreover, research suggests that the cultures of scientific disciplines can be very different. Hence, it is of interest to specifically study the folk theories constructed in a particular nano-field (Davies, 2008). The folk theories that scientists hold on their relation with society are of interest for obtaining insights in the way scientists approach and potentially handle this relationship. Insights in the way nano-medical scientists construct their relationship with society can therefore be obtained by studying the existing folk theories of these scientists on different aspects concerning this relationship. Based on various known folk theories of scientists and specifically nano-scientists on multiple aspects relating to scientists' relationship with society, which will be discussed in the following chapter, the following sub-research questions were formulated:

"What folk theories do nano-medical scientists have with regard to:

- *technology development and assessment in relation to society*
- *the roles of the public in scientific and technological developments*
- *public engagement in the research process*
- *their own roles in public engagement*

These sub-research questions were used as a basis for the interviews conducted in this study. Fifteen nano-medical scientists active in different sectors and research areas of the Dutch nano-medical field have been interviewed. This study aims to identify the folk theories of nano-medical scientists through these interviews, enabling to answer the sub research questions. Knowledge on scientists´ folk theories and the connection between these theories has subsequently been used for obtaining a better understanding about how scientists construct their relationship with society and subsequently answering the main research question. Insights in the way Dutch nano-medical scientists construct their relationship with society are interesting and valuable to obtain more knowledge on how they will potentially approach this relationship. Using specific constructions enables Dutch nano-medical scientists to position themselves in a certain way within their relationship with the public. As a result, scientists´ constructions can give an indication of the possible future interaction between nano-medical scientists and society and to what extent societal values will be embedded in the scientific process. When designing or implementing public engagement practices, insights in the nano-medical scientists' constructions could be helpful for successfully implementing these activities. Finally, these insights could lead to recommendations on how the action orientations could be influenced in order to successfully implement public engagement activities. By increasing public engagement, nano-medical developments could be adapted to the current societal developments. Also the interaction between nano-medical technologies and society could be improved, stimulating a responsible development of the nano-medical area.

1.6 Overview report

The following chapter gives an overview of the different science-society relationships and known folk theories of nano-scientists and scientists in general that have been discussed in previous literature. Based on this existing knowledge, hypotheses on the folk theories of nano-medical scientists and how nano-medical scientists construct their relationship with society have been formulated. The various methodologies that have been applied in this study are discussed in the fourth chapter. Subsequently, the research results that have been obtained via analyzing the interviews are presented in chapter 5. The results will be further discussed in chapter 6. This chapter will also consider possible limitations of this study and will give some recommendations for future research.

2. Theoretical Background

This chapter will discuss various relevant theoretical concepts. In the first section existing knowledge on scientist-society relations and the mutual roles and tasks of both society and the science community will be described for getting more insights in these relationships and how these are formed. In the second part, attention is paid to known folk theories of scientists described in existing literature. Specifically, the folk theories that scientists hold in relation to their relationship with society are brought forward.

2.1 Scientist-society relations

Like other relationships, scientist-society relationships consist of a connection which is established directly, via communications and cause and effect relations, or indirectly, via other concepts or activities of other people. Within this relationship both parties have certain roles and functions, based on certain underlying reasons and conditions of what both parties should do (Hessels et al., 2009). These underlying reasons and conditions can change and therefore the relationship. This paragraph describes different scientist-society relations and the accompanying mutual roles of both society and the science community, found in existing literature. In order to indicate a representation or a part of society, especially in the context of communication, the concept ´public´ has been regularly applied. This specific concept has been chosen, because of its use in both existing literature as by the respondents of this study.

2.1.1. Changing relations

The relation between scientists and society has been conceptualized in different ways in existing literature depending on the interface between society and technologies. Originally, people take comfort in the dominance of technical expertise (Kerr et al., 2011). Within this approach, scientific developments are based on internal factors, such as the logical structure of theories or the relationship between hypothesis and evidential support, and not on external factors such as societal characteristics (Elzinga, 2011). As a result, knowledge production by the scientific community is seen as outside society (Hessels et al., 2009). This relation between scientists and society is restricted to science influencing society through the possible outcomes of scientific developments in a deterministic way (Grunwald and Hocke, 2010). Not only scientists, but also the public has found to highly value the dominance of expertise, consequently maintaining this limited relation (Felt et al., 2009). This authoritative position of science, also makes her controversial as well. Although the presumptions underlying scientific claims indicate that the discussion is closed, scientific claims are still challenged in science-society debates (te Molder, 2011).

This singular view on scientist-society relations has been more and more replaced by a broader perspective. A two-way relationship between scientists and society is increasingly acknowledged. Within this relationship, society delegates research to science via financial incentives, enabling the science community to produce its knowledge (Elzinga, 2011). As scientists are dependent on their societal environment for their existence, they cannot easily break the relation with society. To take societal wants seriously and meet societal needs, scientists have to shift their activities or create an image which corresponds well with these societal demands (Hessels et al., 2009). Whether these societal demands are indeed met has been increasingly questioned due to skepticism of Western societies about the contribution of technological advancements to the public good (Rejeski, 2008). A far-reaching assumption about the malleability of technology has more and more shown to be recognized by society (Grunwald and Hocke, 2010). Society therefore increasingly inquires to be informed about the potential safety, environmental and other effects of nano-medical developments that could have an impact on society. In order to meet the rising demands of an inquiring public, scientists cannot simply drop their wisdom in society and expect others to deconstruct them. Bawa and Johnson indicated that more attention should be paid to emerging public concerns with regard to nano-medical developments to increase societal trust in this field and to prevent any future public backlash (Bawa and Johnson, 2008). Engaging the public in the technological process seems to be inevitable (Marris and Rose, 2010 and Oppenheimer, 2011).

Within a once-skeptical scientific community there is a growing recognition that societal relevance of emerging technologies should be incorporated in its development (Nowotny, 2000). Davies demonstrated that scientific communities thought that by communicating the expected relevant societal outcomes and promises of research through one-way communication, public understanding and evaluation of technologies could be improved (Davies, 2008). Following this course, public engagement had been constructed as top down communication for improving public understanding of science (Burchell, 2009). By implementing such public engagement activities, greater public support for science and subsequently successful innovation was pursued (Levitt, 2003 and Kyle and Dodds, 2009).

Failures of appropriate top down communication, like the introduction of genetically modified organisms, GMOs, resulted in a critical public perception on the unidentified risks of GMO’s and subsequently commercial failure in Europe. Expertise is as a result, more and more contested by the public (Kerr et al., 2007). Through widespread concerns about the legitimacy of science and growing skepticism towards the objectivity of science, scientists have become less and less autonomous (Davies, 2008). Consequently, scientists are more and more part of an unavoidable and contentious public discussion about science and technology (Kerr et al., 2011 and Oppenheimer, 2011). Earlier public involvement was put forward as a way to handle this increasing skepticism and the consequent limited success of technologies (Stone, 2010). It was thought that the moment the public is engaged in the debate, impacts publics´ attitudes towards the acceptance of technologies and their applications. Involving the public too late can result in mistrust, which in turn can lead to opposition to products shaped by that technology (Kyle and Dodds, 2009). In an article of Petersen, scientists also recognize this necessity to engage publics during the early phase of technology development in order to achieve public acceptance (Petersen et al., 2009).

Moreover, a new course arose, which argued that the cause of the public mistrust problem is the continuing failure of scientific institutions to create a dialogue. In order to restore public trust in science, a two-way dialogue was put forward (Wynne, 2006). As a result, the top down discourse is more and more replaced by a two way engagement model based upon dialogue and deliberation in Western countries (Burchell, 2009).This model is based on a learning cycle, involving scientists as well as the public (Grunwald and Hocke, 2010). By a mutual learning approach both parties can learn from each other through sharing knowledge, expertise and skills (Ison et al., 2007). Learning can be reached by clarifying the relations between what scientists can offer and promise, and what demands and values prevail in society. Through this learning cycle an ideal shaping of a technology can be reached. In this sense, the relation between technology and society could be seen as a co-evolution (Grunwald and Hocke, 2010). Within this relation, the public is involved prior to significant research activities take place and before attitudes towards the technology are established. This discourse based on the notion of ''upstream public engagement,'' is a way to consciously include societal values in scientific and technological developments by an earlier public involvement in the research and development process (Petersen et al., 2009 and Barnett, 2000). In this way, public perspectives can make substantive and highly valuable contributions in identifying scientific priorities and improving scientific projects. It has been argued that through this upstream engagement, research is better informed and more aligned with public needs, and negative preconceptions and cultural barriers between scientists and the community can be overcome (Kyle and Dodds, 2009). Done well, it is thought to build trust, understanding and collaboration, bringing scientists and the public closer together.

Western scientists are under growing pressure to respond to societal expectations and perspectives. Therefore, more institutional support and funding for participating activities and programs have become available (Burningham et al., 2007 and Petersen et al., 2009). Although a wave of funding for public communication has been initiated and language and practice may have changed, the impetus toward public engagement with science continues today (Davies, 2008). In many European countries there is still little call for upstream engagement. Even in The Netherlands and The United Kingdom, trendsetting on these activities, upstream public activities have led to mixed experiences and results (van Est, 2010). The Dutch Study Center for Technology Trends, which started up a public discussion on nanotechnology in 1996, for example showed the challenge of incorporating an upstream public perspective. This discussion the Center aimed for was never materialized, demonstrating that moving public engagement upstream is by no means self-evident (van Est, 2010). Van Est states that in order to engage the public upstream, experts need to move upstream as well (van Est, 2010). Barnett also puts forward the challenge of designing a relevant dialogue. He states that it is not clear how a successful public debate can be conducted or how public engagement will contribute to the assessment and regulation of the possible implications of nanotechnologies (Barnett, 2000). These complex and timely public engagement activities include more than research into the ethical, legal and social dimensions of science. Furthermore, the way public engagement activities are actually conducted is often far from being directly involved in determining research priorities or influencing product development. Yet, these activities mostly results in political discussions (Kerr et al., 2011).The relationship between science and society is thus positioned at the borders of the scientific process, attributing societal involvement in science solely at these borders. In order for science communication to be really interactive, thorough mutual interest in each other's' motives is necessary (Hedwig, 2011).

2.1.2 Mutual roles and tasks

Different, evolving scientist-society relationships have been described in existing literature. With regard to their relationship, different roles and tasks could be attributed to both scientists and society. Which roles and tasks are attributed to the public also depends on how the public and the relation with the public are characterized. The public could be seen as the whole society, locally involved populations, consumers or individuals, which all have their own perspectives and expectations (Stone, 2010). The more directly this public is involved, the more roles generally are attributed to them. When technical expertise is approached as dominant within technological developments, publics' role has been found to be limited. With regard to this approach, the public is solely involved in experiencing the possible outcomes of the technology (Grunwald and Hocke, 2010). Less singular views on scientist-society relations describe a more extensive role for the public. Societies' task to finance science by financial incentives has for instance been recognized (Hessels et al., 2009). For improving public knowledge and subsequently public support, a top down relationship was increasingly recognized by science and technology associations (Davies, 2008). Within this relationship, based on top-down communication, the public has the task to listen to scientists and therefore to enable scientists to transfer information to them. In relationships where the public is more upstream engaged, more roles and tasks are expected from the public. The public has the task to share knowledge, expertise and skills. Besides an informing role, the public has the task to learn from scientists´ knowledge and expertise (Ison et al., 2007). Through upstream engagement, the public can help to define and reframe problems and to identify and implement solutions (Barnett, 2000). Sometimes different and opposing roles are expected of the public. When introducing medical innovations, such as vaccines, consumers are expected to make their own choice about joining or not joining the program. At the same time, in contrast with this role as legitimate stakeholders, the public should accept these vaccine programs (Hobson-West, 2007). Due to these opposing expectations, it is unclear for society which role it should fulfill. Confusion about their mutual tasks and roles makes a proper interaction between society and the science community difficult.

Originally, scientists' roles and responsibilities are characterized as producing knowledge outside society (Hessels et al, 2009). Following this repertoire, associating science and scientists with universality, scientists claim the truth based on the technical knowledge they produce (Nerlich, 2009 and Jasanoff and Martello, 2004). Based on this competence, the task to give universal scientific advice to regulatory bodies has been attributed to scientists (Shelley-Egan, 2011). As regulatory bodies are increasingly dependent on technical and scientific information, scientist's role as advisor, influencing public policy, has been expanding (Jasanoff, 1994). Scientists' advice contains however, besides objective knowledge, often an ethical judgment. These ethical considerations can, in addition to professional tasks, add a moral task to a scientists´ job description. Besides, science based knowledge is often context-based, emphasizing the borders of scientists´ universality (Jasanoff, 1994). Due to this societal context of research, researchers should pay attention to societal wants and needs during their research activities. Scientists have the role to be socially accountable and to contribute to the responsible governance of science (Kjølberg and Strand, 2011). A more upstream engagement of the public, formulates the task for scientists to share knowledge and skills. Furthermore, upstream engagement activities demand from scientists to take publics perspectives seriously and to listen and learn from the public.

2.2 Folk theories of scientists

Scientists and society both have their own interests and perceptions with regard to their relationship. When trying to understand what is happing with regard to this relationship, both parties capture patterns based on experiences in the past and are reflexive about them. Based on these past experiences, parties build general assumptions. These conscious or unconscious generalizations are called folk theories. A folk theory is often defined as a conceptual framework that relates different mental states to each other (Malle, 2003). Folk theories operate prior to any particular conscious or unconscious cognition and provide the interpretation of that cognition. Subsequently, folk theories color the views and interpretations of actors and connect them to behavior (Malle, 2003). With folk theories is not meant theories of the folk, but generally accepted theories that form part of a repertoire of a group. Folk theories of mainly European and North-American nanotechnologists have already been identified and described in general terms (Rip, 2006). In the following sub-paragraphs folk theories of nano-scientists and scientists in general that have been found in existing literature will be described. These theories are specifically related to different aspects that relate to scientists relationship with society. Highly important constructions have been printed in bold.

2.2.1 Folk theories of scientists on technology development and assessment

The theories scientists hold on technology development and assessment, are thought to influence the position they impute to society and themselves with regard to the development and assessment of technologies. Deuten et al. shows that scientists find it important to finish their research aims and that they, as a result, become concerned about everything that indicates concern or resistance to this mission. Following this folk theory, technologies are developed anyhow and therefore attention should be paid to how to get them accepted (Deuten et al., 1997). A majority of the nano-scientists are of the opinion that **it would not be possible to stop the current nano-technological developments** (Rip, 2006). It is even thought to be unethical to halt this technological progress due to its economic and social potential. Trying to realize a new technology by overcoming these roadblocks, and not understanding the phenomena underlying these roadblocks, was seen by scientists as their main aim (Rip, 2006). These constructions demonstrate a very black and white view on technology: the technology will or will not develop, with society potentially stopping the developments. Scientists' constructions do not illustrate the possibility of technologies to develop in various different ways.

This folk theory of society as endangering technological developments was also clearly demonstrated by the way scientists talked about public risk perception as forming and enlarging the possible roadblock of nanotechnology innovation (Rip, 2006). Nano-scientists that participated in a study of Nordman and Rip indicated that worries about futuristic visions and imagined risks of nanotechnology can hinder all ongoing work in nano-science and technology (Nordmann and Rip, 2009). A paper of the Nanologue project indicated that some scientists didn't see any risks directly associated with nano-technological components, while others viewed the nanotechnology feature as the component enabling all risks bound to it. These scientists indicated that more work had to be done mitigating potential risks than promoting benefits (Nanologue, 2006). No attention should be paid, however, to imagined risks brought forward by society (Nordmann and Rip, 2009). A **division between futuristic risks and realistic risks**, which should be investigated and handled, was made. Not only risk identification by the public, but also the **rising need to be socially relevant is increasingly mentioned by science community as endangering the existence of fundamental research**. Pursuing the direct application of science could diminish creativity needed in fundamental research activities and therefore be at expense of revolutionary findings (Sol, 2011).

2.2.2 Folk theories of scientists on the public

Previous studies have shown that nano-scientists have many folk theories about the public (Mody, 2008). An example of such a notion is viewing the public as a singular and homogenous group. Nano-scientists that participated in a study of Burchell showed a more heterogenic view, categorizing the public according to the extent to which their science is criticized or supported (Burchell, 2009). This binary division views people as critical or as supportive towards a technology. People who are both critical towards a technology as support it, are not taken into account.

Following Helen Haste, **nano-scientists distance themselves with regard to their beliefs and actions from non-experts** by attributing other characteristics to these outsiders (Kerr et al., 2011). Unlike themselves, the public does not have expertise and cannot speak for everything regarding nanotechnology (Bawa and Johnson, 2008). When scientists are talking about their own beliefs and actions, they depict these beliefs as legitimate and objectively derived from the natural world. The beliefs and actions of non-scientists by contrast, are seen as subjective and derived from personal shortcomings (Burchell, 2007). The wordings scientists use for describing public perspectives, indicates that these perspectives are seen as not theoretically grounded nor based on systematic observation, **but deriving from emotional arguments and self-interest** (Levitt, 2003). In line with this notion, nano-scientists view the public as emotionally driven and **susceptible to fearful interpretations**. Differences in public understandings of risks are, as a result, explained by publics´ individualization or personalization of risks. Expressions of concern were indicated as evidence of individualism and selfishness. In this way, scientists diminish the legitimacy of public views, enabling them to pay limited attention to these views.

Another folk theory about the public is about the wow-yuck pattern. This theory constructs the public as being easily impressed but just as easily disappointed, depending on the information that they pick up. By constructing society as easily disappointed, nanotechnologists see public concerns everywhere, even when there is little or no concern. They interpret these concerns as fear and phobia which can hinder technological advancements (Rip, 2006). As a consequence, **society is constructed as a potential roadblock to further development** (Bawa and Johnson, 2008). Based on this theory, scientists indicated that greater attention should be paid to public concerns in order to prevent any public backlash (Bawa and Johnson, 2008).

Almost all the nano-scientists participating in a study of the sociologist Stone were of the opinion that the **public is badly informed** about nanotechnologies (Stone, 2010). Also scientists working in the genetics field described the public as ignorant about their research (Kerr et al., 2011). In general, scientists evaluate public knowledge as very limited (Burchell, 2007). Levitt showed that scientists assumed that society lags behind technological change and has to catch up (Levitt, 2003). Folk theories of nano-scientists have been found in which publics are seen as empty vessels that have to be filled by explanations of what nanotechnology is really about (Rip, 2006). These models of a lacking public are increasingly replaced by views of the **public as intelligent, supportive and scientific capable** (Burchell, 2009). Burchell for example illustrated that English scientists in general, describe the public as knowledgeable, capable and as active knowledge-seekers. This public has an opinion and plays an indispensable role in generating politically relevant knowledge and increasingly emerges as a more legitimate stakeholder in scientific innovations (Burchell, 2009). Particularly in relation to biology and medicine, improved perceptions of the capabilities of non-scientists to understand and discuss scientific matters are reported. Due to an increasing public interest and support in medical developments, public views are more and more perceived as serious statements and therefore taken into account (Kyle and Dodds, 2009).

2.2.3 Folk theories of scientists on public engagement

The folk theories scientists have on the public are thought to coincide with the theories they hold on engaging the public within the scientific process. Scientists that participated in a study of Kerr et al. **constructed public engagement as unnecessary** (Kerr et al., 2011). With regard to this theory, public visions are seen as irrelevant within the objectivity of science. This objectivity justifies the dominance of technical expertise, the existence of scientific developments and therefore a lack of societal interference. Yet, Western scientists increasingly do acknowledge the importance of engaging the public within the scientific process. They are aware of an increasing societal pressure to respond to the expectations and perspectives of society (Burningham et al., 2007). As a result, scientists find it **increasingly important to involve people outside the scientific community in the nano-medical field** (Petersen et al., 2009).

Young and Matthews showed that in general experts' views on public participation were found to swing from strongly positive to strongly negative, coinciding with issues of control over knowledge (Young and Matthews, 2007). The more control the scientific community would have, the more positive public participation activities were regarded. The less control the scientific community would have and the more their authority is restricted, the more endangering and therefore negative, public participation activities were perceived. Nano-scientists that participated in a study of Petersen hold a general positive attitude towards public engagement. These scientists mentioned publics´ right to know about scientific and technological advancements as a reason to engage the public. Due to the **importance of public engagement for democratic reasons**, it is seen as ´the right thing to do' (Petersen et al., 2009). Scientists indicated the publication of reports as a way to meet the democratic demand for transparency about their activities and in general about the process for deciding on funds allocation (Grunwald and Hocke, 2010). In this way, the authoritarian position of scientists is still warranted, explaining the open attitude towards engaging the public.

Another reason scientists´ indicated for the importance and usefulness of public engagement, is the fact that it gives researchers a change to talk about their work and why it is important (Davies, 2008). Within this theory, public engagement is constructed as a way to improve **public understanding of technological developments**. Consulting the public was put forward as a helpful way for identifying publics' knowledge gaps and devising public communication programs to remedy these deficits (Levitt, 2003). With regard to these ideas, public engagement was constructed as a way to educate people. In some studies, this public educational communication is directly associated by scientists as a way to interest society into science. Scientists that participated in a study of Rip were of the opinion that they not only have to interest society, but even have to impress the public (Rip, 2006). They state that impressing society is needed for stimulating a positive public opinion. When a technology is strongly supported by the public it is easier to mobilize external resources. As these resources are an essential perquisite for continuing their research, obtaining these resources is seen by scientists as a justification for allowing them to exaggerate the benefits of a technology in their external communication (Rip, 2006). Another reason for scientists to mainly address the positive aspects of technologies is to balance current public debates which mainly focus on the risks of new technologies and are dominated by societal critiques (te Molder, 2011). Davies states that although constructions of scientists vary, ranging from simply making people understand to convincing people of their role, these constructions share the basic concept of an one-way education process in which scientific information is given to a deficient public (Davies, 2008).

Most of the studies agree that scientists still predominantly engage in one-way communication with the public (Mogendorff et al., 2011). By engaging the public in a one-way manner, enables scientists to keep the control over knowledge and therefore their authoritarian position. Nevertheless, scientists often construct this one-way public engagement as a difficult process (Davies, 2008). Scientists acknowledged that these difficulties of top-down communication are due to a lack of adequate scientific understanding of the public (Petersen et al., 2009). Constructions of this public communication as dangerous were even used by scientists. They mentioned that one requires extreme caution when communicating with the public to prevent audiences from misunderstanding or misusing scientific information (Davies, 2008).

A minority group of scientists that participated in a study of Davies did, however, not view public engagement as difficult one-way communication but as a context-dependent two-way dialogue (Davies, 2008). This theory of public engagement was hold by scientists who found it of importance to have a sense of what the public thinks. In addition to being useful to scientists in helping them to understand public opinion, a two-way dialogue was constructed by scientists as having a possible positive impact on science. Public participants in such a debate might "come up with a view" that is useful to science (Davies, 2008). Scientists working in controversial areas such as stem cell research, often acknowledged the **incorporation of public perspectives in assessment activities as a reason for engaging the public** (Barnett, 2000). Due to the controversies in these fields, scientists are pushed towards ensuring the social conditions within their research. Although engaging the public in this way could endanger scientists control over knowledge, scientists recognize the importance of a two-way dialogue. This is probably due to the fact that if scientists do not participate in engagement practices, they will lose accountability and therefore their authoritarian position.

With regard to this public dialogue, scientists reported a general feeling that these discussions had no structure and were not very advanced (Nanologue, 2006). Besides lacking profound arguments, scientists indicated that irrational statements dominated the discussion. Scientists felt that in order to obtain rational public discussions, a realistic projection of the potential impacts of nanotechnology must be communicated to the public (Rip, 2006). In general, scientists were of the opinion that the public was negatively influenced by mediating social actors, mostly the media, but also activist groups, corporations and religious opponents. Consequently, the media was portrayed by experts in negative terms (Burchell, 2007). McDaid, on the other hand, showed that academics experienced the media as very positive and as a key partner in engaging the public (McDaid, 2008). The way the media was constructed was found to be dependent on which messages the media communicated and how these were interpreted by the public. The more positive the messages and public reactions were, the more positive the media was regarded.

2.2.4 Folk theories on scientists from scientists themselves

Scientists have certain ideas about what their job as a scientist entails and what tasks include their job description. In this sub-paragraph, scientists' theories on their own roles in the context of public engagement, which have been found in existing literature, will be described. With regard to the folk theories of scientists on their own roles, two interpretative repertoires can in general be distinguished. The first repertoire depicts scientists' actions and beliefs as heavily dependent on speculative insights, personal characteristics, social ties and group membership (Shelley-Egan, 2011). This repertoire constructs scientists as being one of the various stakeholders, with their own subjective ideas, within scientific processes. The other repertoire depicts scientists' actions and beliefs as deriving from empirical characteristics of an impersonal natural world. Studies on scientists´ folk theories mostly confirm this last repertoire. Shelley-Egan showed that nano-medical scientists perceived their own **responsibility in producing objective, disinterested knowledge** to contribute to the advancement of science. This generation of objective knowledge was thought by scientists to take place within a protected space, largely independent of actors outside their community (Shelley-Egan, 2011). Scientists that participated in a study of Elzinga maintained the ideal of purity and disengagement from the business of society (Elzinga, 2011). In line with this notion, nano-scientists often insulated themselves from taking up broader social and ethical aspects of their research (Shelley-Egan, 2011). These nano-scientists were of the opinion that science and social and ethical issues are clearly separated and that they therefore **cannot be responsible for dealing with broader social and ethical considerations**.

The Dutch nanotechnology initiative NanoNed on the other hand, did recognize the need of nano-scientists to socially embed their scientific activities to improve the science-society interaction. In order to do this, NanoNed suggested that scientists **should collaborate with social scientists, ethicists and humanists** rather than hire these experts to do the work for them (Shelley-Egan, 2011). In this way, scientifically approaching this societal relation, society will be indirectly involved in the scientific process. Yet, scientists indicated that, although they were willing to include potential social issues in their research, **they did often not know how to approach these issues**. Scientists' concern about the challenges of undertaking professional scientific work outside recognizably scientific spaces and their reluctance to venture into the range of nonscientific spaces that are associated with public engagement, has been repeatedly brought forward. In scientists´ talks, such spaces emerge as potentially unfamiliar, unpredictable and difficult to control, and scientist interviewees often described feelings of discomfort, exposure and vulnerability. Scientists found great difficulty in distinguishing its boundaries and separating expert knowledge from value laden subjective judgments (Oppenheimer, 2011). As a result, they expressed concerns about whether academics were really the best placed people for engaging the public (Burchell, 2009). **A lack of time for core activities was mentioned by scientists to be a major drawback of public engagement.** Researchers encountered the difficulty of accommodating public engagement activities within their already-overstretched job descriptions. As public engagement was not seen as important as other activities like teaching, research and even administration it was often constructed as possible endangering the core business of doing science, such as conducting scientific experiments due to time constraints (McDaid, 2008). Scientists felt that public engagement was not always positive for the academic progress (McDaid, 2008). Moreover, including societal values was often found to be under-incentivized and under-rewarded. They even revealed that participation in public engagement could hamper core scientific activities by exposing them to unfamiliar and challenging social situations and causing professional stigma. Nevertheless, when it was put to them directly, a number of interviews rejected the notion that scientists' participation in public engagement brings with it the risk of professional stigma (Burchell, 2009).

Highlights previous research

Various folk theories of nano-scientists and scientists in general, have been described in existing literature. Previous research showed, for instance, that scientists depicted technology development in a black and white manner: the technology will or will not develop. In general, scientists constructed technology development as an unstoppable process, in which the technology will develop anyways. These scientists stated that stopping the development of their technologies would be unethical and impossible due to their great potential. Although technology development was often constructed as unstoppable, scientists expressed worries about the possible resistance of technology developments through the futuristic risk perception of society. Scientists' constructions about technological developments as possibly developing in various ways have not been found in existing literature.

Two contrasting scientists´ folk theories on the public have been found in previous studies. Firstly, a folk theory describing the public as distant from themselves has been mentioned. With regard to this theory the public was described, in contrast to themselves, as unknowledgeable and their views as subjective, fearful and derived from personal shortcomings, emotional arguments and self-interest. Constructions of the public as a possible roadblock, due to these fearful perceptions, have been formulated by nano-scientists. On the other hand, constructions have been shown which describe the public as intelligent, supportive and capable. This folk theory on the public was specifically expressed by scientists working in more biological and medical areas, which had an improved perception about the capabilities of the public due to more public interest and support in these areas.

Based on these two public models, different constructions of public engagement have been recognized. Studies in general indicated, that public engagement has been increasingly constructed by scientists as important. In line with a model of a lacking public, theories on public engagement have been found as improving public understanding to remedy knowledge deficits. Engaging the public was seen furthermore seen as valuable for increasing public interest and acceptance of technologies. Although seen as worthwhile, this public communication has often been constructed as difficult and complex due to limited public interest. Folk theories on public engagement, which are based on more improved models of the public, have been found as well. These theories, especially hold by medical scientists, construct public engagement as including public perceptions and exchanging knowledge within a dialogue. With regard to their own role within public engagement, scientists see themselves only in the role of delivering objective disinterested knowledge. Due to the perceived incompatibility of objective knowledge and societal aspects, scientists indicated that they cannot be responsible for dealing with broader social and ethical considerations. Others constructed their involvement in public engagement as necessary, but these activities not as important and sometimes even hindering core activities. Engagement activities are thus seen as difficult compatible with existing academic tasks.

Through these identified folk theories, scientists construct their relationship with society in different ways. Constructing technology development as unstoppable and hindrance of these developments through society as unnecessary indicates, for instance, a limited relation to society. On the other hand, existing research shows that scientists increasingly acknowledge the value of public engagement. Constructions of mainly medical scientists of public engagement as exchanging knowledge within a dialogue, demands an extended relationship with society with extensive direct communications.

2.3 Hypotheses

Based on the folk theories of nano-scientists and scientists in general that have been identified in existing literature, illustrated in paragraph 2.2, certain expectations on the folk theories of the respondents of this study can be formulated. This paragraph describes the various hypotheses that have been formulated based on these expectations.

Hypothesis: Nano-medical scientists will construct nano-medical technologies as unstoppable

In previous studies a folk theory of nano-scientists and scientists in general, in which technology developments were constructed as unstoppable, was shown. This unstoppable character was linked to the great potential of technologies, constructing the hindrance of technology developments as unethical. Due to the possible beneficial implications of nano-medical technologies, it is expected that nano-medical scientists will evaluate publics´ view on nano-medical technologies as mainly positive. Due to the possible improvement of medical treatments through nano-medical developments, it is hypothesized that nano-medical scientists will also construct stopping of the developments in their fields as unlikely and impossible.

Hypothesis: Futuristic risk perception will be perceived by nano-medical scientists to a minor extent

Scientists' constructions, described in existing literature, show that scientists view public risk identification as enlarging the possible roadblock of nanotechnology innovation. These futuristic visions of the public are positioned in contrast to realistic risks, which should be handled. Because risk assessment is differently evaluated in medical fields than in other, more consumer fields, scientists´ constructions on the assessment of risks could differ between these research areas. In medical fields, risks are generally more accepted. It is therefore hypothesized that a futuristic risk perception of the public will be mentioned in nano-medical scientists´ talks to a minor extent.

Hypothesis: Nano-medical scientists will, in general, depict the public as a legitimate and capable stakeholder

Different, sometimes contrasting, folk theories on the public have been found in existing literature. With regard to nano-medical scientists, models describing the public as knowledgeable and capable are expected to be found. Firstly, because such models increasingly replace models of a lacking public in Western countries. And secondly, because in particular in relation to biology and medicine, improved perceptions of the capabilities of non-scientists to understand and discuss scientific matters have been reported. Moreover, the growing autonomy of patients and their increasing demand to be involved are expected to put pressure on current public models.

Hypothesis: Both one as two way constructions of nano-medical scientists on public engagement are expected

It is hypothesized that nano-medical scientists will apply both one as two-way constructions of public engagement. Most of the studies agree that scientists still predominantly engage in one-way communication with the public (Mogendorff et al., 2011). Therefore, one-way public engagement activities are also thought to be constructed by the respondents of this study. Previous studies demonstrated that scientists working in more controversial fields describe public engagement in general as two-way activities. As medical technologies could give rise to quite controversial issues, constructions of engaging the public in a two-way manner, are expected to be found as well.

Hypothesis: Nano-medical scientists will construct involvement in public engagement limited to rational aspects

Based on previously identified folk theories of nano-scientists, it is expected that nano-medical scientists will construct their own role in public engagement as limited. In her thesis Shelley-Egan showed that, although nano-scientists found it important to include social and ethical aspects, they clearly distanced themselves from these issues. These scientists constructed objective science and social issues as clearly separated. Because nano-medical scientists' scientific background is comparable to that of other scientists, the folk theories they will hold on their own role within public engagement are expected to be similar.

Hypothesis: Nano-medical scientists will construct their relationship with society as increasingly mutual

On the one hand, it is expected that nano-medical scientists will view the development of nano-medical technologies as highly beneficial and unstoppable and therefore societal involvement as unnecessary. On the other hand, societal engagement is thought to be found worthwhile due to the high societal relevance of this research area. Also previous studies demonstrate that in Western societies societal involvement is increasingly valued. Existing literature also indicates that specifically in medical research areas this public engagement is described in a two-way manner. Moreover, nano-medical scientists are expected to regard the public as capable stakeholder and therefore willing to engage them in a mutual way. Based on these contemplations, it is hypothesized that nano-medical scientists will increasingly describe their relation to society as a mutual relationship

3. Methods

In this third chapter an overview of the methods that have been applied in this study, is presented. Through these methods, which are qualitative in nature, folk theories of Dutch nano-medical scientists on the different themes put forward in the sub research questions, were identified. Based on these folk theories and the relatedness between the theories, insights about how these scientists construct their relation with society, have been obtained. As quantitative research methods could only be useful for describing nano-medical scientists' views in very general terms, a qualitative and not a quantitative methodology was applied in this study. Qualitative research methods are valuable for exploring more extended insights in underlying attitudes and were therefore more suitable for this study (Silverman, 2010).

3.1 Selection respondents

In this study 15 scientists working in the Dutch nano-medical field, were interviewed. These interviews took place between August and October 2011. In order to identify relevant participants, an overview of the Dutch nano-medical innovation system was created through web-based information and publications of The Dutch Nanotechnology Initiative NanoNed. This innovation system can be described as existing of four research areas, namely biomarkers, drug delivery systems, regenerative medicine and nano-bio devices. Table 1 shows the main industrial players and academic and national research institutes in The Netherlands, per research area.

Table 1: Overview the main nano-medical research areas and the accompanying academic and national research institutes and industrial players.

Research Field	Academic Institutes	National Research Institutes	Companies
Biomarkers	TU Delft	Kavli Institute	ACS Biomarker
	Erasmus MC		Modiquest
	Nijmegen University		Skyline Diagnostics
			Future Diagnostics
			Eurodiagnostica
			Medtronic
			NanoSens
			Immunicon
Drug Delivery Systems	Leiden University	LACDR	DSM
	Utrecht University		BioMaDe
	Groningen University		Philips
			Syntharga
			ISA Pharmaceuticals
			Cytocentrics
			Nanomi
			BioNT
			OctoPlus
Regenerative Medicine	Erasmus MC	MIRA	Hep-art Medical Devices
	Groningen University	NIRM	River Diagnostics
			Philips
			Medtronic
			Pharmacell
Nano-bio devices	TU Twente	TNO Holst Center	Philips
	Delft University	AMOLF	MagnoTech
	TU Eindhoven	MIRA	

In order to improve collaboration between the different actors within these research areas, various public private programs have been created by the Dutch government (NanoNed, 2011). Examples of these programs are Center for Translational Molecular Medicine, CTMM, Bio Medical Materials program, BMM, and TI-Pharma. These interconnected programs, working together and jointly investing in projects, focus on diagnosis, drugs and devices (Walhout et al., 2010). Furthermore, the open innovation called Holst Center was established by amongst others the government of the Netherlands and Belgium, to stimulate industry and academia collaboration on, amongst others, nano-bio devices (Holst Centre, 2011). Information on these Dutch public-private programs and the overview depicted in table 1, were used to identify potentially relevant respondents. Respondents were selected via the purposive sampling approach. Purposive sampling is a form of non-probability sampling, which means that potential respondents are “hand-picked” for the research based on existing knowledge on the nano-medical innovation system (Polit and Hunglar, 1999). People who were relevant for the research and together form a representative group for the field, could therefore be selected (Dane, 1990). As a result it is not necessary to safeguard the validity of the study through including a sufficiently large number of examples in the study. This is advantageous as the qualitative methodologies used are quite time-consuming and therefore not many participants could participate.

Possible interesting and relevant nano-medical scientists were found via existing contacts of the researcher, recent publications and web- investigations based on the information from the abovementioned overview of the Dutch nano-medical innovation system. The selected scientists are employed at different national or academic research institutes or companies in The Netherlands. A clear distinction has been made between private and public research institutes, as perspectives and experiences can differ between these two types of institutes. The scientists vary with regard to the sub-research field they are working in, the institutes or companies they are working for and the programs they are involved in. Some of the scientists are more familiar with societal discussions and public engagement practices than others. A great variation between the participants was aimed for when selecting the participants, in order to optimally reflect the real Dutch nano-medial field. With regard to the division males/females within the group of interviewees, the researcher tried to obtain a reasonable reflection of the actual situation within the nano-medical research community in The Netherlands. A proportion of around 1:4, 1 female on 4 men, was pursued.

An introductory email about the research, shown in appendix 1, was send to all relevant potential participants of the study. This email was followed up with a telephone call or another email to pre-book an interview. Interview locations and times were also agreed on via telephone or by email. An overview of all the respondents that participated in this study is depicted in appendix 2. For privacy reasons the different respondents are characterized with a specific notation, consisting of the letter R and a number.

3.2 Semi-structured interviews

De data for this study has been collected via interviews. Around 15 verbal interviews were conducted face-to-face with Dutch nano-medical researchers working in national, academic research institutes or companies. The scientists were interviewed individually in order to obtain information on the specific and individual perspectives. Semi-structured interviews with a structured set of open questions were used, in order to be open for new unexpected information and to create enough leeway to facilitate modification and elaboration (Silverman, 2010). In this way, more profound insights in the folk theories that respondents brought forward, could be obtained. A list of open questions, shown in appendix 3, was previously formulated and used as a guideline for the interview. The interview questions have been structured by the themes which are put forward in the sub research questions. The following themes were employed as a framework for the interviews: technology development and technology assessment, the public, public engagement and scientists' roles within public engagement. During the interviews the predetermined questions were combined with spontaneous issues that emerged in the interview. Eliciting responses from the scientists in the semi-structured interviews was a joint articulation process with the interviewer (Silverman, 2010). Thus, the order and manner in which research themes are addressed, and the attention that each theme received, were determined by both the interviewee and the interviewer. In addition, interviewees were able to raise issues for discussion that are outside or complementary to the research themes conceived by the researchers.

The interviews took place at a familiar place for the interviewees, their office or their working environment. In this way, an effort was made to create a naturalistic and comfortable environment for participants. The interviews, which took approximately 1 hour per interview, were digitally recorded for professional transcription.

3.3 Data analysis

The interviews were analyzed via qualitative analysis techniques. First the data was organized via a lengthy and iterative process of reading the interview transcripts, listening to the interview voice files, identifying predetermined and emergent themes in the data, writing short commentaries on individual interviews or segments across the interviews, reorganizing the data around themes and further close reading of the thematically organized data. The themes brought forward in the sub-research questions were used as a guideline for selecting the themes. The interpretive coding technique was subsequently used to systematically analyze the collected fragments and themes. This theory involves the 'open coding' of qualitative texts in contrast to the closed coding of survey answers into categories performed by the researcher. Codes, usually a word or a short phase that suggests how the associated data segments inform the research objects, were attached to text fragments in the data and categorized per theme (Silverman, 2004). An example of such a code is `unknowledgeable`, which was frequently mentioned in relation to the public. This code was categorized under the theme 'public'. The coding was not supported by a computer program. An overview of the different codes, categorized per theme, was made. Subsequently, the similarities and differences between codes, the context in which the codes were used and the relationship between one or more codes within one interview or among interviews, were investigated.

Based on these reflections, the main or most interesting theories of respondents were selected. In the presentation of the data, personal identifying information was removed in order to protect respondents´ anonymity.

3.4 Limitations methods

The methodologies applied in this study, described in the previous paragraphs, have certain advantages and disadvantages. This paragraph illustrates the limitations and therefore the potential backsides of the research methods that have been applied.

For selecting the respondents, a biased sampling method has been used. As respondents are therefore not randomly picked from the total group of relevant actors within the nano-medicine community, the representativeness of the respondents could be at issue. In small groups, on the other hand, hand picking can for that very reason increase the representativeness of respondents (Polit and Hunglar, 1999). The amount of participants used in qualitative studies, is always rather small (Silverman, 2010). In this study the respondent group consists of 15 nano-medical scientists. As this is just a selection of the total group of scientists working in the nano-medical field, it is disputable to what extent it is possible to generalize these findings. A limited amount of respondents is, nevertheless, valuable for obtaining more in depth knowledge on respondents' folk theories.

In this study, information was collected via semi-structured interviews. This type of interviewing could be seen as a rather subjective method. The question posed by the interviewer is interpreted by the respondent, which could be interpreted differently than the interviewer has meant. The same applies for the answer of the respondent which will be interpreted by the interviewer. Due to mutual influence of both the interviewer as respondent on the interview, the course of the interviews varied. This flexibility of the semi-structured interviews resulted in differences in the way questions were posed and the content of the questions per interview (Lindlof and Taylor, 2002).

Key themes were identified via a lengthy and iterative process of reading and notation of the interview transcripts. The analysis has been performed by no one other than the author. It could be possible that other key themes would have been identified or somewhat differently notated by someone different than the author. In this qualitative analysis the possibility of the researcher taking a 'neutral' or transcendental position is seen as more problematic (Silverman, 2010). In order to systematically analyze the data, coding of the qualitative texts was performed by the author. A frequent criticism of coding method is that it seeks to transform qualitative data into quantitative data, thereby draining the data of its variety, richness, and individual character. Nevertheless, these codes are soundly linked to the underlying data throughwich some of the richness has been brought back (Lindlof and Taylor, 2002).

4. Results

The interviews conducted for this study, have been analyzed via the qualitative data analysis techniques mentioned in chapter 3. This fourth chapter gives an overview of the results that have been obtained through this analysis. The aim of the interviews was to identify specific folk theories that respondents hold on different elements concerning respondents' relationship with society. These elements are incorporated in the sub-research questions:

"What folk theories do nano-medical scientists have with regard to:

- *technology development and assessment in relation to society*
- *the roles of the public in scientific and technological developments*
- *public engagement in the research process*
- *their own roles in public engagement*

Thus, the folk theories of respondents on technology development and assessment, the roles of the public, public engagement and their own roles in public engagement, have been explored during the interviews. Very diverse folk theories expressed by respondents, have been identified. The context of these theories has subsequently been investigated to determine the way respondents construct their relationship with society through these theories. The following paragraphs discuss the main theories that were brought forward in the interviews and their context, per sub-research question. A number of fragments from the interviews are quoted in order to illustrate and comment on the results. All the fragments have been analyzed and subsequently translated from Dutch to English by the interviewer and author of this report. The translations are as literal as possible for analytical purposes. For privacy reasons, the quotes are used anonymously. To clarify the background of the respondents of the specific quotes, a code has been used. The letter "R" in combination with the number 1 to 15 indicates the specific respondent. In appendix 2, the corresponding information per respondent code has been given. In the fragments, the letter I represents the interviewer. The letter codes have been placed before the quotes to illustrate the source of the quote. Sometimes, sections within the quotes are cut. These omitted sentences are indicated with a "S″ in combination with the corresponding line numbers and depicted within brackets.

4.1 Folk theories on technology development and assessment in relation to society

This paragraph focuses on the first sub research question, *"What folk theories do nano-medical scientists have with regard to technology development and assessment in relation to society and how does that influence nano-medical scientists' constructions of their relationship with society?".* With regard to technology development and assessment, four major theories were brought forward by a majority or a considerate number of the respondents. These theories and the way these theories influence respondents' constructions of their relationship with society, are discussed in the following sub-paragraphs.

4.1.1 Technological developments cannot be stopped by societal interventions

Analysis of the interviews demonstrates that 7 out of 15 respondents constructed technological developments as unstoppable processes. This unstoppable character has been indicated by statements as: "If things are possible, they will happen". Respondents mentioned that societal measures, such as restricting regulations, have a minor influence, because the technology will develop anyway. This claim has been associated in the interviews to constructions of society as possibly wanting to stop the development of technologies. This folk theory enables respondents to explain the little attention paid by the science community to society and consciously including societal values when developing technologies. As the technology will proceed, there is no need in taking societal wishes into account. Through these constructions, respondents depict a black and white view of technology development: the technology will or will not develop. That a technology has the possibility to develop in different ways has not been mentioned by respondents.

(1)	*I:*	*"To what extent are the values or wishes from society taken into account?"*
	R14:	*[S230-236] "Thus, you can forbid it, but when you forbid it here, then it will go on in Zimbabwe or Azerbaijan. It can happen everywhere.* ***Society does not stop it****."*

Four of these seven respondents specifically mentioned economic values as a push for the unstoppable technological developments. These respondents depicted financial drivers as a justification for the existence of the technology. Financial aspects were described as being more dominant than other societal aspects in influencing developments. Within nano-medical developments, the health care costs were explicitly mentioned as a financial driver. Through nano-medical applications, the current high health care costs could be tackled. Attributing the unstoppable character of nano-medical technologies to external factor, such as economic factors, enables respondents to justify the impossibility of societal influence within the process.

(2)	*I:*	*"To what extent is it possible to stop developments that society would rather not see?"*
	R15:	*"****Oh it is not possible to stop it, I think.*** *I mean the idea is that you can* ***tackle the medical costs*** *to a certain extent. If everyone continues visiting the doctor, it is already unaffordable."*

(3)	*I:*	*"To what extent is it possible to stop these technological developments when society indicates they do not want them?"*
	R13:	*"Yes I think with everything, I mean, that there are certain aspects, such as* ***financial aspects, that are so dominant that you will finally be driven to.*** *I mean, and of course in health care, costs are expanding enormously. Thus you have to look how to control it."*

Following respondent 4, the inability to stop further developments makes fear about potential technological outcomes unnecessary. This claim enabled the respondent to state that, as fear feelings have no use, scientists should diminish or take away these public fears by education about the win-wins. What exactly should be explained to the public is not mentioned by respondent 4. By stating that "it" has to be explained, the respondent creates the idea that it is obvious that fear feelings are unsupported in this case. As a result, respondents indirectly state that society should accept the technology in order for scientists to continue their research. By constructing public fears as illegitimate, attention for public concerns is put forward as unnecessary.

(4) *I:* *"Did you encounter, during these sessions, any perspectives that surprised you?"*

R4: *[S292-295] "I think it would be sensible to take away the fear feelings of people when using new technologies.* ***You cannot stop technology.*** *Therefore you should try to explain it well and especially where the win-wins are."*

Two respondents indicated that they find the uncontrollability of technologies by society problematic and even alarming. They perceived, in contrast with the other 5 respondents, a less limited role of society within the technological process. Nonetheless, these respondents also described society as possibly wanting to stop the developments within technologies.

(5) *I:* *"Thus the scientist has as aim to steer society. What role does society have?"*

R12: *[S609-615] "The problem with science and technology development is sometimes that as things are possible, they will happen. There is always one idiot in the world that thinks he or she can do something and that is difficult to control."*

4.1.2 Unpredictability of technological developments makes assessment of technologies difficult

The previous paragraph showed that 7 respondents described technological developments as unstoppable. The other 8 respondents of this study constructed technological developments as difficult to predict by stating for instance, that you could not foresee these developments. Respondents claimed that the progress and direction and, as a result, the future impacts of the developments, are hard to determine. Monitoring the long term effects was therefore constructed as being not very useful.

(1) *I:* *"And do you also monitor these long term effects in your academic work?"*

R6: *"That is a very good question. Look, the aims in that research are sometimes hard to pose as it is* ***often research that is not very good to predict****." […]*

Respondent 8 described monitoring of long term outcomes during the research phase, due to its' numerous potential outcomes, as difficult. As it is not possible to incorporate everything during these monitoring activities, respondent 8 stated that it is time-wise not very useful to perform these activities.

(2) I: *"What is your vision on the fact that the ethical aspects are not viewed before the end of this chain?"*

R8: *[S225-227] "And then, in retrospect, you could have thought about it earlier but the problem is that you do not know halfway through which paths will result in real applications.* ***And then incorporating everything immediately seems to me a waste of energy.*** *It seems to me a difficult one."*

By constructing TA activities as difficult due to the unpredictability of technological developments, respondents created a distance between their own research activities and the assessment of these activities and their potential outcomes. Respondent 5 even directly distanced himself from viewing potential impacts, by claiming to be unknowledgeable on these aspects. The fact that they do try to study the impacts could indicate that they have the idea that this is, nevertheless, expected from them. These constructions enable respondents to safeguard the possible limited activities they perform to assess the impacts.

(3) I: *"And to what extent are the impacts viewed beforehand?"*

R5: *"Yes we try to do that.* ***Nevertheless, this is a way of looking at coffee grounds[1].*** *That is partly due to the fact that I do not understand that."*

Respondent 3 claimed that a lack of knowledge on the expected outcomes of nano-medical developments, due to the unpredictability of these developments, makes it difficult to discuss the future evolvement of the nano-medical area. This difficulty is directly associated with the inability to incorporate public perspectives, enabling respondents to continue their work without seriously studying or even ignoring these perspectives. Respondent sketched a view in which incorporating these perspectives could lead to imaginary discussions on technologies.

(4) I: *"And to what extent could the perspectives of non-scientists be relevant?"*

R3: *[S26-39] "I mean it is good to have the discussion, but also to realize that* ***you could not foresee to a great extent.*** *I mean, in these discussions I feel like going back in time and inventing the transistor and then having to predict that this will fifty years later result in internet through which people will communicate differently. That is just impossible. I mean in the sixties there were also all kinds of fantasies about flying cars, jets and so on that have not come true. And internet did arise.* ***So thus it is enormously difficult to project what technologies will do in the future.****"*

4.1.3 Societal relevance results in minor attention for fundamental research

In the interviews, technology innovation is repeatedly described as a pipeline, starting with fundamental research and leading to societal use of the technology through applications. The research activities during the fundamental phase are often depicted as not socially relevant. A majority of the respondents, 9 out of 15, claimed that the need for being societal relevant in research, demanded by the government and society as a whole, could hamper the possibility of conducting fundamental research. Societal importance of research is constructed as a way to be successful and the other way around. As respondent 10 stated it, "If you cannot predict how it can be relevant for

[1] "Looking at coffee grounds" is a literally translated Dutch expression, meaning that it is not possible to predict the future.

society, you have now difficult times." Respondents described doing societal relevant research as a way of paying attention to the societal context of their research. These 9 respondents are mainly involved in more fundamental research activities, whose daily work is often quite distant from the development of eventual applications. Through its´ talk, respondent 10, created the idea that studying and explaining the societal importance of their research is not part of researchers job description by stating: "As a basic researcher, I still have to make clear how societal important this is."

(1) *I:* *"In what way do you find it important to pay attention to the ethical and societal context of research?"*

R10: *[S137-162] "And I am just a basic researcher, but still I have to make clear how societal important this is because that is how you score. Well, for my research it is not a problem as I am very translational. But if you are working on a very fundamental level with something you, if you are honest, cannot predict how it* ***can ever be relevant for society, you have now difficult times****."*

The danger of losing fundamental research through the augmented requirement of societal relevance is constructed by respondents as a pity or even as immoral. Respondents indicated that this fundamental phase is crucial for high quality research, creativity in science and therefore future innovation. Respondent 7 for example, claimed that no new ideas will arise from applied studies and therefore no new technologies will arise when fundamental research will disappear. Respondent 12 expressed that in order to obtain subsidies research, scientists will go along with societal relevant themes, resulting in poor research. Through this reasoning, the importance of creative, non-relevant research that is not bound to the restrictions of societal relevance is underlined.

(2) *I:* *"And what is your view on the division of the subsidies into certain core areas?"*

R7: *[S509-514] "If a torrent of discoveries from pure sciences is not continued, then you will become intellectually bankrupt in several years.* ***Then you only know how you make things better, but there is no new technology arising.***

(3) *I:* *"What will be the position of fundamental research?"*

R12: *[S86-107] "But it should not be that on a certain moment NWO puts all his money into these kind of public-private collaborations because then it could go wrong. Because people should nonetheless, adapt to the field. I mean, if you do not adapt than you do not have research. Thus you do have to focus. And what you would then get is that people go along with certain hypes where they do not have a lot of knowledge on.* ***As a result you get poor research and no one is waiting for that.*** *Thus you do have to try to maintain strengths because in these new ideas arise, which are of importance for the future society."*

Monitoring the potential societal outcomes of research has been illustrated by respondents as a way to view whether research is societally relevant. As a result, looking at the long term effects was viewed as hampering the creation of revolutionary ideas.

(4) I: *"And do you monitor the long term effects?"*

R6: *[S354-362] "You do see that there is more and more focus, but as a result you withdraw a piece of creativity I think.* ***I am of the opinion that a part of fundamental research has to be kept. Yes it is very easy to say that it has no added value.*** *[…] It does not have to be just studies that bring us to the moon of a new class of I don't know what. It don't have to be only revolutionary ideas, because when ideas are revolutionary you know that you will never reach them within the time span of a project of about two or five years."*

Respondents described a clear division between societal relevant work and non-societal relevant work. With regard to this division, a contrast was created between applied, societal relevant, research and fundamental, non-societal relevant, research. Applied research has been described as deriving from past discoveries. Fundamental research, on the other hand, has been depicted as working pure scientifically not based on societal questions.

(5) I: *"And what is your view on the division of the subsidies into certain core areas?"*

R7: *[S509-511] "But you always try to have an element within this area of education and research of* ***pure fundamental work****. For the simple reason that this, the* ***societal relevant work*** *we are currently conducting, is based on discoveries of the past. Technology is not born from a societal question. That societal question is built on technology and not the other way around. […] Thus you just always want researchers that are working pure scientifically. And that maybe have to scratch one's head for a while to say what the societal relevance of their work is."*

The other respondents, who did not mention this construction, of societal relevance as hindering fundamental research activities, in their talks are in general more directly involved in application development. Their research is consequently more easily relevant for society. Respondent 14 for instance, regarded societal relevance as important and expressed positive feelings with regard to the increased necessity of research to be of significance for society. Respondent 14 explained other scientists' inclination to look at the fundamental side and consequently avoiding societal aspects of their research, by mentioning the evaluation mechanisms of science visitation committees which are mainly focused on fundamental aspects.

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(6) I: *"How do you see the relation between your research and society?"*

R14: *"What we still have in The Netherlands, but what is changing, is that* ***people are inclined to look at the more fundamental side****. Because when we had a science visitation in the past, and that is still the case, then the fundamental aspect, of how many papers you have and in which papers, comes first. Although you see that this is changing and I find that, in my own specialism* ***very important to develop technologies that can be used by patients****.*

4.1.4 Social relevance of technologies as an opportunity

During the interviews, the relation between nano-medical technologies and society has been repeatedly described as taking place on the applied level. A majority of the respondents claimed that at this level, societal need and technologies find themselves through health care applications.

(1) I: "What way does your research play a role within society?"

*R5: "Thus, when we are developing a new technology than it is our intention that it will be applied in healthcare. […] They are sitting together in big teams to make sure **that technology and societal needs will find each other**."*

These applications are subsequently constructed as being socially relevant by having a valuable impact on society. Respondents claimed that their research is important for society through the development of cheap and sufficient medical applications, such as medicines. Respondent 4 talked about generating personalized medical treatments as a way in which nano-medical research can contribute to society.

(2) I: "How do you see the relationship between your research and society?"

*R5: [S40-43] "To make sure that it will become better, cheaper and with less people, within a shorter term. By realizing these kinds of things you **can really create a big societal impact.**"*

(3) I: "How do you see the relationship between your research and society?"

*R4: "What is the **importance for society?** That is prescribing medicines that are most sufficient. We view a development of personalized medicine, which is focused more and more on the individual patient."*

Respondents concretely stated that these possibilities for society were formed in the applied level, which has a clear relationship with society through its applications, and not in the fundamental level which is aimed at understanding things. This first research stage arises from societal questions as the fundamental stages are driven by curiosity, explaining their different roles with regard to their relevance for society.

(4) I: "How do you view the relation between your research and society?"

*R13: [S4-8] "And knowledge that we develop, in first instance often curiosity driven research, through which we try to understand things. But finally we see that our research can be easily translated to applications, in the **form of possibilities for society**."*

A specific group of respondents, whose work is more strongly related to the creation of industrial applications or medical treatments, were found to construct the societal relevance of their work as an opportunity. These respondents constructed society and societal values as generating opportunities through this societal relevance. These respondents viewed employing these opportunities as important and valuable for science and technology development. A distinction between industrial and scientific opportunities was made by respondents. Respondents 11 and 15 for instance, described society as a source of market opportunities for their business.

(1) *I:* *"To what extent does this gamma group take the values of society into account?"*

R11: *[S3-10] "But I find it as important to adapt to the opportunities that exist, which we now probably overlook. That is at last what we do. That is* ***identifying opportunities and the market*** *and looking whether we, from our technology, generate an answer and put up a business around it."*

Other respondents described these opportunities arising from society and societal values, as a drive or motivation for doing research. The relationship with society and conducting societal relevant research is, as a result, constructed as important. The following fragments of respondent 6 and 12 for example, demonstrate this scientific opportunity.

(2) *I:* *"To what extent is it important for you to do societal relevant research?"*

R6: *[S17-25] "That you know that there are patients getting better and having less side-effects,* ***is a motive to develop something****."*

(3) *I:* *"How do you view the relation of your research in relation to society?"*

R12: *"So actually, although we are working quite fundamentally, I view this relation with society as very important, because what we are doing has to have always something applicable in order for what we are doing to be interesting.* ***Having an application in our eyes, even though it is far away, motivates me and my employees a lot****."*

Looking at opportunities that arise from society has been constructed by respondents as a way for looking at the ideas that exist within society. Respondents indirectly indicate that they take into account societal values by studying the economic and scientific opportunities that arise in society in relation to scientific and technological developments. They themselves, however, determine whether these values are actually adopted within the developments.

(4) *I:* *"How is determined what ideas exist in society?"*

R15: *"Where we look at first is what currently exists in society but also in the market. What are the opportunities and then viewing whether these fit our strengths".*

4.2 Folk theories on the public

This paragraph discusses the results that were found when studying the following sub-research question: "*What folk theories do nano-medical scientists have with regard to the possible roles of the public in technological developments and how does that influence nano-medical scientists' constructions of their relationship with society?"* With respect to this research question, three main theories came up in the interviews.

4.2.1 Incorrect risk perception of the public could hinder developments

With regard to the assessment of nano-medical technologies, the evaluation of potential risks has been repeatedly mentioned by respondents. A main theme that has been brought forward in a majority of the interviews, addresses public's risk perception. Respondents regularly expressed complaints about publics´ existing ideas about risks. Respondents claimed that people generalize and wrongly characterize the risks. Publics´ description of the risks was constructed as incorrect and various examples of these incorrect ideas were mentioned. One of these examples is demonstrated in the following fragment.

(1) I: "How do you react on such perspectives?"

R5: [S25-31] "People are saying that when you are inhaling these things than it is bad and when you are inhaling nano-particles of say a few nano-meter than these will stay in your lungs. ***But that is not true.*** *Those particles are too small. These particles immediately leave the lungs again."*

Some of the respondents, like respondent 3 and 11, spoke about imaginary risks. These respondents posed societies description of imaginary risks in contrast to their own evaluation of real risks. These real risks should be, according to respondents, studied and controlled. Respondents claimed that as imaginary risks are not real, no attention should be paid to these risks or to its´ proper handling. As the real risks are already assessed, it has been stated in the interviews that no new approach for risk assessment is needed.

(1) I: "Which perspectives stroke you during these discussions?"

R3: [S104-113] "Thus we have to stop this and make rules and that's it. Yes, but let's start to understand first what it is, what the possibilities are and what eventually ***the real risks*** *are and if there are risks than we have to control these. But this is nothing new on the horizon; we are doing this for years. I don't understand why this demands a new approach or something."*

These imaginary or wrongly characterized risks were constructed by respondents as potentially resulting in the unnecessary hindering of the developments in the nano-medical field. The beneath fragment shows that respondent 11 illustrated paying attention to imagined risks and controlling of these risks as potentially resulting in putting a moratorium on all nano-developments. Through these constructions, respondents created the idea that risk assessment belongs to the responsibility of authorized parties, such as companies and the government and not to society as society cannot well evaluate these risks.

(2) I: "Do you have the idea that all visions are well heard?"

*R11: [S148-158] "****But not by putting a moratorium on all nano-developments.*** *That is ridiculous. These kinds of things have no sense. You have to talk about it clearly and try to explain what it is really about. And what the real risks are; and not only the imagined risks. With all new technology developments there are risks that have to be controlled and companies will do that and the government will create regulations, but have to take care that regulations will* ***not be so limited that the developments will be stopped.****"*

4.2.2 Lack of public knowledge makes communication difficult

A majority of the respondents, 10 out of 15, depicted the public as unknowledgeable and having a lack of technological understanding. Respondent 9 even stated that the Dutch society is techno and beta-phobe. Following respondents, the public has no idea what is going on in their research field. This low knowledge level and the lack of capabilities to understand messages were constructed as resulting in illegitimate and extrapolating public statements. Respondent 6 indicated that these insufficiently covered messages can be quite frustrating for experts in the field, thereby distancing society and the science community.

(1) *I:* *"And do you have the idea that the knowledge is currently sufficient?"*

R9: *"As a country we are rather* ***technophobe****, as you look at how nanotechnology is embraced in the United States or Japan and how we are doing that, that is an enormous difference. Secondly, we are rather* ***beta-phobe****. Put everything with a = sign in between and people think ieee, that is probably very difficult. That is also very characteristic for, I would almost say, the whole Western society at the moment."*

(2) *I:* *"To what extent do you think there is public awareness about your research field?"*

R6: *"People* ***do not have a good technological understanding.*** *Of course not everyone has to be the expert, but as a result* ***they say things that are not sufficiently covered.*** *And I think that is only frustrating for people who are specialized."*

Most of the respondents explained publics' limited knowledge by mentioning the complexity of the research area. The scientific and technological developments are depicted by respondents as difficult to understand.

(3) *I:* *"Do you have the idea that society has a lot of trust in the developments with regard to nano-medicine?"*

R11: *[S74-79] "Those developments are so difficult to communicate, translate and describe, that* ***most people do not understand what it is about.****"*

Of this group of respondents, five of them related this knowledge gap to publics' disinterest in science and technology in general. These respondents argued that the public is not interested and does not want to know what the scientific findings or technologies are about. Respondents depicted that as a result, the public has been responsible for their own limited understanding. Through this claim respondents constructed publics' limited understanding as being their own fault.

(4) *I:* *"Do you have the idea that society has a lot of trust in the developments with regard to nano-medicine?"*

R11: *[S74-80] "When they see the word nano, they already get a fright reaction as waaah that is very dangerous.* ***They don´t want to know what it is about or what it means.****"*

Respondents furthermore claimed that as the public is unknowledgeable, it is not easy to communicate with them. Describing the public as uninterested and having little knowledge, enabled respondents to explain why it is currently difficult or even impossible to communicate their message to the public.

(5) *I:* *"And do you have the idea that the knowledge is currently sufficient?"*

R9: *"[S216-220] Thus, the knowledge level is therefore decreasing.* ***That is very critical because as a result it is often difficult to communicate your message.****"*

(6) *I:* *"Is it difficult to explain the research to others?"*

R2: *[S355-358] "You stand there with your scientific poster and you are not so happy and start to speak with people and then they look at you and* ***you realize that even the word molecule stays there.****"*

The importance of communicating their message was mainly related to safeguarding public trust in the nano-medical developments. By communicating to the public what the developments actually mean, can improve their understandings and prevent fright reactions as mentioned in the previously shown fragment of respondent 11.

(7) I: *"Do you have the idea that society has a lot of trust in the developments with regard to nano-medicine?"*

R11: *[S74-83] "And you can try to explain that nano is just a prefix that means 10 to the -9 or something, but it is not useful for them.* ***That you can really explain what nano-medicine actually means, and why it is now so important, is very difficult****."*

4.2.3 Role public in creating borders

7 out of the 15 respondents constructed a pro-active role for the public within technological developments. These respondents, mainly involved in industry or application development, claimed that the public, specifically the end user, is involved in the scientific process by letting the scientific community know what they want with regard to the final technological applications.

(1) *I:* *"How do you see the relation with society?"*

R13: *"That relation is very important, because they are the end users and* ***you have to know what this user wants.*** *[…] Yeah so, involved in how long a test should take, how fast, with what do I have to use it."*

Moreover, respondents described a role for the public in reacting on research and indicating their limits in relation to this research. According to these respondents, the public should let them know what they want and what they don´t want with regard to the current scientific and technological developments. As a result, the borders within scientists can operate could be defined. Respondents´ talks showed that the initiative in communicating these limits was constructed as publics´ own responsibility.

(2) *I:* *"Thus the scientist has as goal to steer society. Which role does society have?"*

R12: *"Well I think that society has to indicate to what extent they want changes. I mean society is of course, look if they don´t want something it will not happen. There is now a discussion in Germany on nuclear energy. And as society on a certain moment says: Yes sorry, but we don´t want nuclear energy anymore, than it is a fact that you cannot implement nuclear energy. I think* ***society has to clearly indicate the borders within they want to operate****."*

(3) *I:* *"Should society have a role in these aspects?"*

R14: *"Then the role of society to science is to make sure scientists do not go into that direction because it is unethical or inhuman. Well, I think there is a role for society to explain or trying to* ***explain to scientists what they do and do not want****."*

By constructing this pro-active role of the public, the respondents clearly put the responsibility of ethical judgment on the side of the public, therefore designating themselves from these aspects.

4.3 Folk theories on public engagement

This paragraph describes the main folk theories that respondents brought forward in the interviews when discussing public engagement and possible methods for engaging the public. Two main folk theories were identified. Public engagement was firstly constructed by respondents as a valuable PR tool and secondly as a way to transfer knowledge for obtaining public acceptation.

4.3.1 Public engagement as valuable PR tool

An important reason for engaging the public, put forward by almost all respondents of this study, is to make advertisement for their profession. Respondents described this advertisement in different ways. Engaging the public was for instance expressed as a way to make the public enthusiastic about the research field by showing how beautiful and wonderful these scientific topics are, but also by demonstrating what potential it may have. In this way, a good impression of the field was generated by the public.

(1) *I:* *"And does it help to break through the closed attitude of the public?"*

R7: *[S56-81] "So that they can disseminate this information to the big public, but most of all because we as scientists or as scientific organization* ***have the assignment from the government to inform society and to give a good impression to society.****"*

A reason that was mentioned by respondents for constructing public engagement as a PR tool was the future survival of the field. By convincing the public of the worth and potential of their research field, people of the next generation could become enthusiastic about the field and will continue research activities in the future.

(2) *I:* *"Do you find it important that there will be more societal awareness about your research?"*

R8: *[S133-136] "More than awareness, it is more some sort of* ***enthusiasm, fascination*** *also by students. That I find important. That the* ***next generation will continue this research*** *and something like that. And has ambitions in these directions, how do you call that, a drive which you need to have to do this kind of research.*

Another reason that has been mentioned for showing the enormous potential of the research field is for improving the current public debate. Respondents created the suggestion that problems in communicating and debating with the public is due to the lack of knowledge of the public on the positive aspects of the research and technology development.

(3) *I:* *"How could this debate improve?"*

R3: *"I think it would be sensible to inform people about the worth of science and nature and the beauty and its enormous potential."*

4.3.2 Knowledge transfer for diminishing public fears and increasing public acceptance

In all the interviews, knowledge transfer has been mentioned as a way for engaging the public. Public engagement by educating the public has indirectly been constructed as a way for increasing public acceptation in two ways. One group of 6 respondents indicated that transparent explanations could decrease or even take away currently postulated fearful perceptions of the public. Constructing publics' fear feelings as unjust, because the situation has not changed, and as creating obstacles for technological development, enabled scientists to explain why these feelings should be taken away.

(1) *I:* *"In these sessions you mentioned, were there any perspectives or questions that surprised you?"*

R4: *[S292-293] "Thus, good listening to the questions they pose, indicates where people may see bears on the road*[2]*. That is the way I always simply say it.* ***I find it important to explain things transparent. I think it would be sensible to take away fear feelings in people when using new technologies.****"*

(2) *I:* *"So the distrust lies mainly in the risks of the particles and not in the whole product?"*

R15: *"Here we do not view nano differently than five years ago. We are working with it in an equal manner. It is as safe or unsafe as it was then. You see that only the way people view it changes.* ***That is for a great extent possible to explain, I think.****"*

Another group of respondents constructed public education as a way to make public attitude towards the technology more positive. They claimed that good and open communication about the technology and its usefulness can prevent negative perspectives and consequently public resistance towards technologies. Public communication was thus constructed as a way to stimulate public acceptation.

[2] "Bears on the road" is a literally translated Dutch expression, meaning worrying beforehand.

(3) I: "And do you think that society is very aware about the developments in this research?"

R2: [S223-225] "But you have a lot of topics ***where the society reacted very badly*** *and they have no awareness of what is going on. They can't analyze that. And they just believe a guy that suddenly says this is not good you know. And you have a lot of people following that but there is no rational about I accept that or I confuse that. [...]* ***And I think this is a problem with communication,*** *because in Germany the government was really open and was communicating with people about this is what we have done, this is what it says, this is what is finished, this is why it useful for you."*

(4) I: "And how do you react on such expressions?"

R7: [S25-31] "But then you hope by discussing it, to show why it is not that bad or dangerous. […] So again, making clear that there is a distinction between different things to ***prevent that people will react harsh against the development of nanotechnology, as they did with biotechnology and gene technology."***

Three respondents indicated that due to their transparent and clear explanations, they created more public understanding and positive reactions from society. Respondent 4 for instance claimed that fearful reactions could be well handled by transparently explaining what you are doing. During the interview, respondent 5 mentioned that there was much public acceptance recognized with respect to their technology, because they told their story to the outer world.

(5) I: "Are there also more fearful reactions?"

R4: No, because when you ***transparently explain*** *why you are doing something, these reactions will be well managed."*

(6) I: "And what do you think is the reason that in RM there are little problems with societal acceptation?"

*R14: [S51-65] "****Well I think that there is only one way through which you can decrease these fears and that is by explaining it.****"*

(7) I: "And do you think that within society there is sufficient attention for your research area?"

R5: [S224-262] "When you tell such a story to the outer world, it is taken like sweet cookies[3] because it is a beautiful technology to develop."

4.4 Folk theories about themselves

During the interviews, respondents also constructed theories about themselves. The following paragraph discusses the two main folk theories that respondents expressed with regard to their own role in engaging the public.

[3] "Take like sweet cookies" is a literally translated Dutch expression, meaning it is accepted easily.

4.4.1 Rational scientists only involved in knowledge aspects

Most of the respondents described themselves as knowledgeable and rational. They attributed exclusively rational responsibilities to themselves. Respondents visualized their own roles and tasks only in the rational area, like generating and transferring technical knowledge within their area of specialization. These tasks were depicted in relation to public discussions on technological developments and the ungrounded perspectives brought forward during these discussions.

(1) *I:* *"And who should be, in your opinion, responsible for these public discussions?"*

R9: *"In the discussions scientists are active for generating and providing knowledge, thus for the* ***grounding on knowledge.*** *" [...]*

(2) *I:* *"Do you find it important to have this debate within society?"*

R15: *"**And the rational man tells how constitutes on a technical level.** When you talk with someone directly than you can explain them the background, but you cannot do that with the whole society."*

6 of these respondents directly claimed that, as scientists, they should solely be involved in rational, knowledge aspects and not emotional aspects. Respondent 14 constructed taking away publics' irrational fears not as a task of scientists, but that of psychologists and psychiatrists. Hereby, respondents distanced themselves from the irrational public, restraining themselves from participating in irrational societal discussions.

(3) *I:* *"How could you than best handle these fears?"*

R14: *"Well I think, that these kinds of irrational fears. I don't know if it has to be even the responsibility of the field because I think we as* ***scientists have to focus on rational aspects****. […] You could explain, even if you know, how it works what the dangers are, but* ***taking away irrational fears that is more a task of psychologists and psychiatrists****, communication-experts maybe."*

4.4.2 Scientists' need for specific societal interaction skills

In the interviews various respondents claimed that interacting with society is increasingly part of scientists' job activities. This interaction is in the first place constructed as a way to obtain subsidies, which are needed to fund scientific research activities. In the second place, societal interaction is constructed as a way to be responsible towards society by paying attention to the societal context and by explaining their research and its´ societal relevance to the public. Respondents put forward that existing characteristics of scientists are not sufficient for interacting with society. The traditional scientist has been described as little communicative and solely focused on its own ideas.

(1) I: *"Should scientists also have an eye for the societal and ethical context of their research?"*

R12: *[S323-324] "**Years ago you could silently sit in your room by yourself and nicely elaborate some ideas. Nowadays it is just a profession.** It is actually top sport because when you are not performing one year then you are immediately degrading from the Champions league, or whatever league. That is going very quickly. Therefore you should continue to participate. You should collect money continuously and continuously deliver quality."*

According to respondents, scientists must require new skills for sufficiently interacting with society. Communication skills have for instance been mentioned to be necessary. This new scientist is constructed as a person that can tell his message. In order to participate, this scientist has to position himself very well and subsequently sell himself and his research. Respondents claimed that through these characteristics, scientists are better in handling demands from society and will therefore be more successful.

(2) I: *"Is it difficult for to explain the research to others?"*

R2: *"And we were supposed to go there, so we made a poster to explain what is a protein, what is the role of the protein, why we wanted to do proteomics and then you stand there with your scientific poster and you are not so happy and start to speak with people and then they look at you and you realize that even the word molecule stays there. You know a necklace? You cut the necklace. **So that is really something you should learn**."*

(3) I: *"Is it difficult to think from the perspective of the patient?"*

R10: *[S408-411] "Thus the scientist is now someone that **can well collaborate**, **that can tell his message and that is become stronger and stronger.** I already see now that the young researchers that are successful are the people that can make clear in a few sentences what they are doing."*

(4) I: *"Should scientists also have an eye for the societal and ethical context of their research?"*

R12: *[S323-324] "You should collect money continuously and continuously deliver quality. That also requires that you position yourself very well. Keep on doing your story, building a network, reaching a lot of people. **That is what a modern scientist should actually do.**"*

Several respondents brought forward concerns about the increasing importance of these new skills. The following fragment for example, shows the worries respondent 10 expressed about losing brilliant and talented scientists. For this could result in missing out star discoveries in the future.

I: *"Is it difficult to think from the perspective of the patient?"*

R10: *[S408-411] "Those are not per se the best scientists.* ***That is also a bit scary.*** *That is really a selection item during interviews.* ***I think that very brilliant people that can discover great things, but cannot communicate their message, are not able anymore to find a job and that is maybe a shame.*** *Those who could bring the star discoveries in 30 years, but I'm wondering whether those will really get a chance. Those have to hope to get a professor who sees that and arranges money so that this person can still work, but it will become more difficult. So there are downsides of the system."*

Two respondents expressed that scientists´ role in societal interaction should be limited as they are not capable in managing this interaction. According to these respondents, gamma or communication scientists own the skills and abilities to communicate with society and should therefore be more directly involved in these practices.

(5) *I:* *"And who do you think has the task to communicate this message?"*

R11: *"People with a beta background do not understand.* ***Gamma scientists have more eye for how the broad society views things and how you should communicate with these people without having them in the curtains immediately.*** *Because that is the problem with beta people, they start to communicate in a way that the communication completely fails."*

5. Conclusion and Discussion

This chapter will further reflect on the research results presented in the previous chapter, and discuss these reflections in relation to the existing literature described in the theoretical framework. Based on these considerations, potential implications for future public engagement activities will be discussed and recommendations with respect to these implications are made. Furthermore, the methodologies that have been used for this study will be critically reviewed and recommendations for future research are formulated.

5.1 Reflection research results

The analysis of the interviews, described in the previous chapter, shows the various folk theories that respondents hold. These theories tell something about the underlying perspectives of respondents on society and their relation to this society. By looking at these theories and the way the theories are intertwined, insights on how respondents construct their relationship with society, were obtained. Based on the different constructions that have been recognized, three main themes are put forward in this paragraph. By describing these themes the main research question of this study, *"How do nano-medical scientists construct their relationship with society and how does that subsequently enable scientists to potentially handle this relationship?",* could be answered. In this paragraph the three themes will be discussed alongside existing literature on scientist-society relations and known folk theories of nano-scientists and scientists in general. Subsequently, potential implications of these constructions for future public engagement activities will be discussed and recommendations for improving the implementation of engagement activities will be given.

5.1.1 Societal role different in applied than in fundamental research

In general, respondents made a clear distinction between applied and fundamental research. In their talks, respondents separated a fundamental stage, in which knowledge is developed by curiosity driven research to better understand things, from an applied stage in which research is translated to applications. With regard to this distinction, the relation between scientists and society was described differently in these two stages.

When depicting fundamental research, respondents spoke about "pure" sciences. The wording "pure" was applied to show that researchers are working only scientifically, not affecting nor involving society. A lack of societal interference during the scientific process was assumed by respondents. "Pure" sciences were mentioned to be born from fundamental and not societal questions. The research conducted in this fundamental stage is furthermore described as not necessarily having an added value for society. One respondent for example indicated: "But if you are working on a very fundamental level with something you, if you are honest, cannot predict how it can ever be relevant for society". Due to the lack of societal relevance of fundamental studies there is, following respondents, a restricted relation with society in this research phase. Fundamental scientists only experienced an indirect relation with society, via the technologies that have been created through their knowledge. By depicting a limited relation between fundamental research and society, the interaction between the public and fundamental scientists were seen as of minor importance. This construction is comparable to the traditional approach of science and technology, in which people take comfort in the dominance of technical expertise (Kerr et al., 2011). In accordance to respondents' constructions, this approach describes the scientist-society relationship as science influencing society through the possible long term outcomes of scientific developments in the form of determinism (Grunwald and Hocke, 2010). Hence, societies' involvement in knowledge production is limited (Hessels et al., 2009). Viewing fundamental studies as not socially relevant, enabled respondents to construct their relationship to society as limited. Respondents subsequently withdraw themselves from paying attention to societal values and participating in public engagement activities. In line with this consideration, a study of Kerr et al. demonstrated that scientists highly value the dominance of the technical expertise and regard public engagement as unnecessary (Kerr et al., 2011). Felt shows that this importance of technical expertise was also supported by the public (Felt et al., 2009). The limited societal influence and involvement in fundamental stages is thus maintained by these constructions of both scientists and the public.

Most of the respondents indicated that a societies' role within technological developments was clearly situated at the applied level, in which nano-medical applications are created and subsequently introduced for societal use. The importance of society in this stage, as generating industrial and scientific opportunities, was repeatedly mentioned in the interviews. Respondents indicated that society could be an industrial opportunity by creating chances for the market and subsequently their own business. Ideas that exist in society are picked up, linked to a technology and a business is put up around it. Besides, scientific opportunities of society were mentioned. Following respondents, society could be a scientific opportunity through its values and ideas, which form a motivation for scientists' work. Developing something that is worthwhile for society was viewed by a group of respondents as a research motive. By theorizing society as a source of industrial and scientific opportunities, the importance of society within technological developments, was shown. This value is, however, restricted to stimulating professional success by creating motivation and generating new ideas. By attributing this role to society, a more two-way relationship is constructed between scientists and society in the applied compared to the fundamental level. Moreover, half of the respondents express a more mutual scientists-society relation by stating that the public has a pro-active role in communicating what they want and do not want within technological developments. Although a mutual relationship has been recognized, the relation with society was mainly described in a top-down manner. Similar to the constructions described in articles of Davies and Burchell, public engagement was constructed as top down communication or education for improving public understanding of science (Davies, 2008 and Burchell, 2009). Paragraph 6.1.3 will further elaborate on this aspect.

Implications and recommendations

The aforementioned reflections demonstrate, that a clear distinction between applied and fundamental research has been repeatedly depicted by respondents. Applied research has been constructed in the interviews as socially relevant, because it directly generates applications that could positively impact society. This relevance of society on the applied level is also illustrated by societies´ potential of generating industrial and scientific opportunities. By depicting applied research as socially relevant and fundamental research as not socially relevant, respondents clearly directed the significance and role of society within technology development to the application phase. Limiting societies´ involvement in the technological process to the applications of technologies steers the scientist-society relationship to the borders of the scientific process. An increased demand to be socially relevant in research has been constructed by respondents as possibly endangering core fundamental research activities. Respondents valued the decrease of fundamental research as alarming. They brought forward creativity and the subsequent creation of new ideas as arguments pro maintaining this field. In contrast with respondents´ constructions, fundamental research could be seen as valuable for society by contributing to publics´ basic knowledge level. In this way fundamental studies could deliver a positive contribution to society and therefore be socially relevant.

As the relationship with society has been described differently within the applied and fundamental stage, a different meaning is attached to public engagement in these two research phases. Respondents working in fundamental research, largely withdraw themselves from paying attention to societal values and engaging the public in their research. Yet, engaging the public in these fundamental research stages could be of importance for increasing societies' knowledge on "life" in general. Moreover, applied and fundamental research levels are often intertwined, with fundamental knowledge leading to applied knowledge and applied questions leading to fundamental research. Increasing publics´ fundamental knowledge could subsequently improve its´ understanding of applications and technologies in the future.

In order to stimulate public involvement in fundamental research, it would be sensible not only to engage this public but to engage the scientists as well. Public involvement demands a mutual relationship and therefore willingness and collaboration from both sides. Stimulating public engagement activities could only be worthwhile when both parties are willing to participate. When experts would recognize the importance of engaging the public for increasing publics' knowledge level, they will be more inclined to involve this public in their sciences. For engaging society in the fundamental area, it would be furthermore helpful to take the distinction and relation to applied research into account. In order for these activities to be successful, it would be sensible not to directly translate engagement practices performed in the applied stage to more fundamental research stages, but to adapt these practices to the specific characteristics of both fields and the perspectives of the researchers working in these fields. This study showed that fundamental researchers, compared to applied scientists, value the inclusion of societal values to a minor extent. A push towards public engagement in the fundamental field, could therefore lead to resistance.

5.1.2 Fear of existence through societal interference

In the interviews, worries that technological developments will be hindered or even stopped have been evidently expressed. Respondents' talks associated this fear with societal interference in various ways. Wrong risk identification by the public was for instance constructed as a potential barrier. Respondents indicated that imaginary risks or the generalization of risks through the public could result in a harsh attitude of the public towards technologies. It has subsequently been put forward that this public attitude could lead to the formulation of pointless rules, unnecessarily hampering research developments. In contrast with the hypotheses, the findings of this study indicate that, despite the higher risk acceptance in medical therapies, respondents did recognize a futuristic risk perception of the public. This folk theory has also been shown in a study of Rip, in which scientists expressed their worries about futuristic visions of the public as enlarging the possible roadblock of nanotechnology innovation (Rip, 2006). Bawa and Johnson confirm these findings, by showing that scientists constructed societal concerns as potential roadblocks for further development (Bawa and Johnson, 2008). A second way, in which concerns about the hindrance of technological developments through societal interference was expressed, is by respondents´ constructions of public engagement as a PR method. Respondents indicated that by engaging the public, positive views could be stimulated and negative views diminished, leading to general public acceptation. Constructing public engagement as a way to increase public acceptation, indirectly demonstrates the fear for a lack of public acceptation and subsequently stopping of current research developments.

Even though respondents expressed fear feelings about the potential hindering of their research developments, a majority of the respondents constructed, in line with what was hypothesized, technological developments as unstoppable. These findings are in accordance to an article of Rip, which stated that a majority of the nano-scientists are of the opinion that it would not be possible to stop the current nano-technological developments (Rip, 2006). This construction seems in contrast with the previously mentioned folk theory, because when developments are unstoppable, fear for their existence should not be needed. However, when studying this folk theory more closely, it becomes clear that these unstoppable developments were directly associated with unnecessary interference of society. Respondents stated that as the technology would develop anyway, societal involvement would not be useful. A study of Deuten showed, that expressing technological developments as unstoppable could be a way for respondents to enable them to pay attention to how to get it accepted, as technologies are developed anyhow. This construction derives from the importance nano-scientists attach to finishing their research aims. As a result, they become concerned about everything that indicates concern or resistance to this mission (Deuten et al., 1997). Scientists that participated in a study of Rip indicated that it is even unethical to halt this technological progress due to its economic and social potential (Rip, 2006). The unethical character of hindering technological process was not directly expressed in the interviews of this study. Contrary to these findings, two respondents in this study valued the impossibility to stop technologies problematic and worrying. These respondents indicated that society has to be in the possibility to show their wishes. This societal control is constructed as the setting borders in which science can operate. Society plays a role at defining these borders and the science community can determine the actual scientific and technological content.

Besides concerns about the future existence of developments in the research area, the fear for the disappearance of fundamental research in general, is repeatedly brought forward in the interviews. Various respondents directly mentioned their worries about the future continuation of fundamental studies. Respondents' statements show that their fear feelings arise from governments' demand to be more societally relevant. Conducting research that is important for society was brought forward as a way to be successful and the other way around. Respondents stated that as applied research is more societally relevant, this could potentially lead to a reduced attention for fundamental research. The science community increasingly addresses their concerns, about the endangering existence of fundamental research due to the rising need to be societally relevant, in the media (Sol, 2011). The potential decline of fundamental research is seen by respondents as severe. This type of research is acknowledged to be crucial for high quality research. It has been stated that pursuing direct application of science, will be at expense of revolutionary findings and diminish the creativity needed in fundamental research activities in order to generate innovative ideas (Sol, 2011). Although nano-medical research is usually recognized as being quite socially relevant, this study shows that it is an important issue in the nano-medical field as well. Not only the discontinuity of fundamental research, but also a loss of quality of this type of research has been mentioned in the interviews. According to respondents, the need to increasingly communicate with the public, asks for new characteristics and roles of the scientists. Communicative skills are, for instance, increasingly valued. A significant group of respondents constructed the necessity of these new skills, as a possibility to lose talented scientists that do not own these skills.

Constructing societal involvement as potentially hindering research activities enables respondents to distance themselves from society. By stating that engaging society could negatively influence the scientific process respondents show that public engagement should be limited and that care should be taken when involving society in scientific activities. A few respondents directly indicated that communication with the public should be done indirectly via gamma scientists. These constructions confirm the hypothesis, stating that nano-medical scientists were expected to view their own role within public engagement activities as limited.

Implications and recommendations:

The reflections described in this sub-paragraph show a black and white construction on technology development: the technology will or will not develop. Worries that these technologies will not develop, through interfering societal interventions, have been expressed by respondents. Society has been constructed by respondents as possibly wanting to stop developments. Specifically imaginary risk perception of the public has been indicated as hindering the development of technologies. Constructing social intervention in this way could result in a closed attitude of scientists towards society and resistance with regard to handling this relationship. Consequently, a reserved attitude towards participation activities could hinder the successful implementation of engagement activities.

Despite these fear feelings, a willingness to engage the public has been brought forward by respondents. In order to keep this willingness and to be able to further stimulate public engagement, it would be wise to pay attention to these fear feelings and take them seriously. This study showed that the fear feelings of respondents arose from respondents´ idea that a technology could or could not develop, with societal interventions possibly endangering the future development of this technology. Showing scientists that technologies can, besides develop or not develop, develop in different ways could possibly broaden their perspectives. Public engagement is constructed by respondents as possibly increasing public acceptation of technologies and consequently overcoming a possible societal roadblock. When societal interventions would only change the direction of the current developments of technologies, instead of totally abandoning them, they would probably be seen as less undesirable. Consequently, societal interference would be perceived more positively.

5.1.3 Dialogue model not yet taken up by scientific community

When studying the interviews, mainly top-down constructions of public engagement were found in respondents' talks. This finding is in line with the conclusion that most studies have drawn, namely that scientists still predominantly engage the public in one-way communication (Mogendorff et al., 2011). In contrast, it has been hypothesized that nano-medical scientist would increasingly construct public engagement in a two-way manner due to the controversial character of the field. A recent limited attention on these controversies, could possibly explain this difference. Similar to articles of Davies and Burchell, public engagement was specifically constructed as knowledge transfer for improving public understanding of science (Davies, 2008 and Burchell, 2009). One construction underlying this theory is depicting the public as unknowledgeable. Similar to the findings of a study of Stone, respondents expressed that the public is badly informed about nanotechnologies (Stone, 2010). Scientists´ low evaluation of public knowledge on science was also shown by Burchell (Burchell, 2007). These findings are in contrast to the hypothesis, which stated that a more capable model of the public was expected to be recognized by nano-medical scientists. This difference could be explained by the relative novelty and the subsequent unfamiliarity of the field. Respondents mentioned that the limited knowledge of the public should be enlarged by giving information. Similar to this construction, scientists that participated in studies of Levitt and Rip described public engagement as a way to educate people and remedy the deficits (Levitt, 2003 and Rip, 2006).

As public debates mainly focus on the risks of new technologies and critical views expressed by society, scientists are more inclined to address the positive aspects of a technology, to balance this discussion (te Molder, 2011). Some scientists are of the opinion that they have to impress the public and stimulate a positive public opinion. These scientists indicate that strong public support is needed for continuing new technological developments (Rip, 2006). These scientists constructed public engagement as a way to convince people. In articles of Levitt and Kyle and Dodds, respondents also constructed the improvement of public understanding by informing and educating as a way to increase public acceptation (Levitt, 2003 and Kyle and Dodds, 2009). In line with these previous findings, this study shows that respondents described public engagement as a way to improve public perception on the technology. As one respondent puts it, "I think it would be sensible to inform people about the worth of science and nature and the beauty and its enormous potential". In the interviews, societal involvement has been illustrated as a way to increase public acceptation of nano-medial applications and its potential impacts and to subsequently obtain successful innovation.

By depicting societies´ role as receiving knowledge, the involvement of society was directed at the borders of technology development. Constructions of engaging the public more closely within the scientific process were not expressed in the interviews. The way the scientists-society relationship has been constructed in the interviews, did not confirm the finding of Burchell that the top down discourse is more and more replaced by a two way model based upon dialogue, deliberation, partnership exchange in Western countries (Burchell, 2009). Respondents did not describe public engagement, like participants in a study of Barnett, as helpful for defining and reframing problems and identifying and implementing solutions (Barnett, 2000). An ideal shaping of a technology by a learning cycle involving scientists as well as the public was only limited expressed in respondents' answers (Grunwald and Hocke, 2010). Instead of a mutual learning approach in which both parties learn from each other through sharing knowledge, expertise and skills, an approach in which the public learns about science through information from scientists was depicted. Yet, attention has been paid to the relevance of societal ideas as potential opportunities for technological development. With regard to this view, ideas of society were not depicted as part of a learning process, but as interesting ideas that could be picked up by the scientific community to generate new and interesting scientific or technological aims.

From the abovementioned contemplations could be concluded that a view, in which public engagement is described as a dialogue, has been limited taken up by the respondents of this study. In general, respondents did not describe public engagement, like a minority group in a study of Davies did, as complex and context-dependent, and communication as a debate (Davies, 2008). The interviews point forward that respondents constructed a dialogue as difficult and even as impossible, because of the gap between them and the public. Davies also showed scientists´ claim that there is an enormous and almost impassable barrier between science and the public (Davies, 2008). In an article of Kerr scientists were found to distance themselves from non-experts with regard to their beliefs and actions (Kerr et al., 2011). These scientists depicted their own beliefs and actions as legitimate and objectively derived from the natural world. In this study, respondents regularly described themselves as rational and knowledgeable. An example is the following statement: "And the rational man tells how constitutes on a technical level". One respondent attributed, besides this role as rational scientists, the role of being a lay person with an opinion, to himself. The public was, on the other hand, described by respondents as having little knowledge and disinterested in obtaining this knowledge. Scientists that participated in a study of Petersen et al. also acknowledged the lack of public understanding about science (Petersen et al., 2009). Burchell showed that the beliefs of non-scientists are seen as subjective and derived from personal shortcomings and self-interest (Burchell, 2007). These findings are only partly confirmed by this study. In contrast to a study in Levitt, where the public is pictured as emotionally driven and fearful interpretations are hold against these emotions, this study indicates that fear feelings of the public are not due to emotions, but to their lack of knowledge (Levitt, 2003).Viewing the public as fearful, unknowledgeable and disinterested, does not confirm the finding that particularly in relation to biology and medicine improved perceptions of the capabilities of non-scientists to understand and discuss scientific matters are reported (Burchell, 2009). By attributing different characteristics to the public, respondents created a gap between themselves and the public. This subsequently enabled respondents to distance themselves from this non-rational public and their perspectives. As a result, scientists insulated themselves from social and ethical issues of their research. In line with these findings, Shelley-Egan showed that scientists were of the opinion that science and social and ethical issues are clearly separated and that they therefore cannot be responsible for dealing with broader social and ethical considerations (Shelley Egan, 2011).

The fact that the dialogue model is picked up by respondents to a minor extent, is also indirectly shown by respondents´ construction of technological developments as unpredictable. Respondents stated that as the developments in technologies are unpredictable, it would not be useful to evaluate these developments nor to include public perspectives during the process. A dialogue on the possible outcomes of technologies has been described by respondents as difficult, because they indicate that it is not possible to discuss all the potential technological developments and its outcomes.

In contrast to the abovementioned constructions, half of the respondents did recognize a mutual relationship with society by describing a role of the public in setting borders. There is however, not yet talk of a real dialogue. Although the public can indicate its wants, the scientific community determines to what extent these wishes will actually be taken into account. The objectivity of these activities, in pursuing social embedding in science, is therefore questionable.

Implications and recommendations:

A third theme that has been brought forward in respondents' constructions, are the traditional descriptions used by respondents to describe their relationship with society. Respondents depicted scientist-society relationships mainly in a top-down way. Public engagement has been constructed as knowledge transfer in order to diminish public fears and increase public acceptation. In order to improve current science-society relations, a more upstream engagement of the public is needed. Constructions which describe public engagement more upstream and in which a dialogue is created, have nevertheless been taken up by respondents to a minor extent.

In order to steer public engagement towards the dialogue model, both parties should be willing to do so. This study shows that although scientists acknowledge they should increasingly communicate with the public, they express their doubts on whether scientists are actually capable for public communication. In order to improve the engagement of the expert, the question could be posed to the scientists how he or she would like to be engaged. Furthermore, creating a dialogue was expressed to be difficult due to publics´ limited knowledge and their illegitimate and extrapolating statements. A discussion on which roles scientists and the public should have in order to be able to create a dialogue among them, could be worthwhile for stimulating new ideas on future successful upstream engagement methods. Reflecting on the role society could fulfill within this communication could prevent the existence of different expectations and therefore the impossibility to fulfill these expectations. Some of the participants mentioned a more pro-active role for society. They described a public role in showing their wishes and setting borders to developments. Although the public could indicate what their values, the scientific community determines to what extent these values will actually be taken into account. Starting up a discussion on how the public could be engaged in such a pro-active way, could be helpful for stimulating two way engagement activities.

Besides the publics´ and their own limited capability to interact via a dialogue, the incompatibility of objective science and irrational societal aspects has been brought forward in this study. Respondents separated the discussion on societal aspects from the scientific process, directing the relationship to society to the borders of their sciences. In order to successfully increase engagement of the public in the scientific process, the relation between these aspects should be discussed.

5.1.4 Relationship with society directed to the borders of the scientific process

The three themes discussed in this paragraph show that, although respondents acknowledge the importance of their relationship with society, they describe this relationship mainly as outside the actual scientific process. They depict a black and white contrast between objective knowledge production through science, and the contestation of subjective and unfounded views outside this scientific arena. That their relationship with society is constructed at the borders of science production is for instance demonstrated by constructing society as generating industrial opportunities. Even though society is seen as a source of industrial chances, involvement of society in incorporating these chances in the scientific process has been seen as limited. Furthermore, directing societies´ engagement to the application phase pushes society away from their engagement in core scientific activities. A reason respondents mentioned for not directly involving society in the scientific arena is that they are afraid that the futuristic risk perception of the public could lead to harsh regulations and therefore stop current technological developments. Moreover, respondents expressed that engaging the public in the scientific process is difficult due to a lack of knowledge and interest of the public.

In order to direct societies´ involvement towards the scientific arena, attention should not only be paid to how to engage the public, but how to engage the scientists as well. Scientists' willingness to engage in these activities could be hampered by existing fears about these activities. Showing scientists that instead of endangering the continuity of technological developments, societal interventions could also positively change the direction of these developments could be helpful in overcoming these fears. Furthermore, showing scientists that engagement of the public in fundamental stages could improve publics general knowledge level, leading to better understanding of the public on future applications, could increase scientists´ perception of the societal relevance of its research and therefore their willingness to engage society in their research. Moreover, scientists indicated that current capacities and characteristics of the public, but also of the scientist, make current communication activities difficult. Discussions on what roles and tasks of both society and the science community would be needed in order to create a successful dialogue within the borders of the scientific process should be held. Besides, attention should be paid to how the differences between the public and themselves, the scientific arena and outside this arena, could be overcome.

5.2 Limitations and recommendations

This paragraph reflects on the methodologies used in this study and discusses the possible limitations of this study. Based on these limitations, various recommendations for future research have been made.

5.2.1 Possible limitations

Respondents were hand-picked by the author in order to create a group which is as representative for the field as possible. In order to be able to select these respondents, an overview of the field has been made by the author. The possibility that this overview is incomplete, due to the complexity of the field or limited knowledge of the author on the field exists. Web-based investigations and recent publications were used as a basis for creating this overview. A lack of bundled information could have resulted in missing out important actors, who were not directly found in the information that had been gathered. When selecting the participants, the dominant position of multinationals within the development of nano-medical technologies, was not taken into account. Moreover, differences in participation response between the different respondents could have influenced the eventual group constitution. Of the potential respondents that have been contacted, the respondents in the industrial field were less inclined to respond or to respond positively than those working at academic or national research institutes. Consequently it is possible that the participants group, though representative for all the different parties involved, does not reflect the real composition of the different actors in the field.

The conversations during the interviews were conducted as natural as possible. Nevertheless, the fact that the interviews were recorded could have influenced respondents' answers. Depending on whether respondents believe their answers could have an impact on their professional activities, respondents could have talked less freely than in naturalistic settings. The fact that the author did not have direct interests in the content of the answers would, however, undermine this possibility. The analysis of interviews has been performed by no one other than the author. It is possible that other key themes would have been identified or notated differently by someone different than the author. The reliability of the data can nonetheless be said to be met, because the data has been analyzed and coded in a consistent and reliable way by the researcher.

5.2.2 Recommendations for further research

Based on the aforementioned potential limitations of this study, recommendations for future research could be made. Fifteen respondents participated in the study. As this is just a limited selection of the total group of scientists working in the nano-medical field, research on a bigger scale would be relevant in order to be able to generalize these findings. Further research would not only be useful to see whether these interviews confirm or contrast the constructions found in this study, but also to further deepen the insights in scientists constructions. The respondents repeatedly mentioned the limitations of creating a dialogue with society. Through additional studies, scientists could be further questioned on for instance ways in which this dialogue could be improved.

The respondents of this study work in different institutions, sectors and research areas of the nano-medical field. As differences between these institutions and areas exist, it would be interesting to investigate the folk theories that have been found, per domain. The aims that scientists pursue differ with respect to the domain they are working in. A different relation with society is therefore likely to exist between domains. Especially between industrial and academic and national research institutes and applied and fundamental research institutes, differences are expected to be found. This study showed some examples in which different constructions were applied by respondents active in the industrial sector and those working in the academic field. One of these examples is focused on the importance scientists attach to the societal relevance of scientific activities. Respondents involved in industry or application development, in contrast to the other respondents, constructed a more pro-active role for the public within technological developments. Future studies could be valuable for further investigating these differences.

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Appendix 1: Introductory letter

The following introductory letter, in both English as Dutch, has been send to the potential respondents via email.

Dear [NAME],

From November 2010 until last June I, Violet Steeghs, performed a project aimed at mapping the latest nano-technological developments and its possible societal implications in Japan, for the Rathenau Instituut. Through this project, I was able to combine my background as a molecular biologist with my specialization in science communication. Recently, I´m finishing the Master Applied Communication Sciences at Wageningen University. Due to my interest in nanotechnology and especially in nano-life sciences, my thesis research focuses on the field of nano-medicine. For this project I investigate, under the guidance of Prof. Hedwig te Molder, the relationship between scientists, working in the field of nano-medicine, and society.

Due to your activities in [field], I am very interested in your ideas about, amongst others, the societal relevance of research and the interaction between science and society. Hereby I would like to ask you whether it would be possible to visit your office and discuss your views on these aspects. Hopefully you are in the ability to collaborate.

Yours Sincerely,

Violet Steeghs, MSc
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+31641063541

Geachte [NAAM],

Van november 2010 tot en met afgelopen juni heb ik, Violet Steeghs,voor het Rathenau Instituut de laatste nano-technologische ontwikkelingen in Japan en de mogelijke implicaties van deze ontwikkelingen in kaart gebracht. Dit project maakte het voor mij mogelijk mijn achtergrond als moleculair bioloog en mijn huidige specialisatie in wetenschapscommunicatie te combineren. Momenteel ben ik bezig met het afronden van de Master Applied Communication Sciences van de Universiteit van Wageningen. Vanwege mijn interesse in nanotechnologie, en met name nano-levenswetenschappen, richt mijn afstudeeronderzoek zich op het nano-medische onderzoeksgebied. Voor dit project, onderzoek ik, onder leiding van prof. Hedwig te Molder, de relatie tussen wetenschappers, werkzaam in het veld van nano-geneeskunde, en de samenleving.

Gezien uw werkzaamheden in [veld], ben ik erg geïnteresseerd naar uw ideeën over onder andere de maatschappelijke relevantie van onderzoek en de interactie van wetenschap en samenleving. Graag zou ik u willen vragen indien het mogelijk is een keer bij u langs te komen en uw visie op deze aspecten te bespreken. Hopelijk bent u in de gelegenheid hierop in te gaan.

Ik hoor het graag van u.

Met vriendelijke groet,

Violet Steeghs, MSc
violet.steeghs@wur.nl
+31641063541

Appendix 2: List of Interviewees

Table 2: Overview of all the respondents interviewed for this study and accompanying information about their research field, sector they are working in, the organization they work for, their function and gender.

Respondent	Research field	Sector	Institute	Function	Gender
R1	Lab-on-a chip & regenerative medicine	Academy	TU/ Twente	Associate professor	Female
R2	Drug delivery systems	Academy / Industry	Leiden University / To-BBB	Professor / CEO	Male
R3	Nano-bio devices	Academy	TU Delft / Kavli Institute	Professor	Male
R4	Biomarkers, regenerative medicine	Academy / Industry	Erasmus Medical Center / Skyline Diagnostics	Professor / Science officer	Male
R5	Imaging biological tissues	Academy	TU Eindhoven	Professor	Male
R6	Drug delivery systems	Academy / Industry	Utrecht University / Cristal Delivery	Post-doc / CEO	Female
R7	Drug delivery systems & Regenerative medicine	Academy / Industry	Groningen University / BioMaDe	CEO	Male
R8	Nano-biosensing	FOM Institute	AMOLF	Professor / group member	Female
R9	Bio-sensing	Academy	Wageningen University Research	Professor	Male
R10	Regenerative Medicine	Medical Institute	Erasmus Medical Center	Associate professor	Female
R11	Drug delivery systems & Biomarkers	Industry	DSM Innovation Center	Chief Technology Officer	Male
R12	Drug delivery systems & Regenerative medicine	Academy	Radboud University	Professor	Male
R13	Regenerative medicine	Research Institute	MIRA	Professor / Scientific Director	Male
R14	Immunodiagnostics & Biomarkers	Industry	Future Diagnostics	Chief Technology Officer	Male
R15	Nano-bio devices	Industry	IMEC / Holst Centre	Principle scientist	Male

Appendix 3: Interview design

Introduction

- Showing gratitude for collaboration
- Introducing myself and the thesis project
- Inquiring whether it is possible to record the interview
- Mentioning the data will be used unanimous and confidential.

Technology Development and Assessment

- To what extent does this research influence society?
- Who is responsible for these outcomes?
- What would be the best way to manage the societal implications of nano-medical innovations?
- Are there currently any activities conducted to assess the technology? Could you give an example of such an activity?
- What is your opinion about these activities?

Public

- To what extent are people, outside the scientific community, informed about the developments within the nano-medical field?
- What are the interests and perspectives of non-scientists concerning this research?
- Do you take the perspectives of these non-scientists into account? Why and in which way?
- Could knowledge or ideas outside the scientific community play a role in this innovation area?
- What are the roles and responsibilities of the public with regard to these innovations?

Public debate and engagement

- To what extent is there societal debate on nano-medical innovations?
- Which views on the developments of nano-medicine are put forward in this debate? What is your opinion about these views?
- How are new nano-medical products perceived in society? To what extent is acceptation of nano-medical applications expected in society?
- How are scientific outcomes introduced into society?
- To what extent are patient organizations and end-users involved in the scientific process? In which way?
- What is your opinion on engaging non-scientists into your research (pro and con's)?
- How should non-scientists be involved?
- To what extent do you communicate about these scientific developments with non-scientists? Example?
- To what extent do these emotions be taken into account during technological innovation processes?

Own roles within public engagement

- Do scientists have, besides their professional duties, moral tasks as well?
- What is the role of scientists in engaging the public in technological developments?
- To what extent is it possible for scientists to combine moral tasks and public engagement activities with their main tasks?
- Are scientists the best persons to fulfill this task?