Democratizing Nanotechnology Dialogs

From Attitude and Knowledge to Trust and Communication for a Sustainable Development of Nanotechnology

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Abstract

Nanotechnology is big business. With rapid innovation and expansion of the field, financial stakes are high. This study is based on the assumption that the development of nanotechnology in Sweden today is controlled by economic interests rather than democratic values and sustainable development. This is considered problematic, and the overall aim with this study is to propose alternative principles for governing nanotechnology development. Three concrete questions are answered: Which social actor(s) should be entrusted with governing nanotechnology? How well does communication about nanotechnology work within and across different groups of social actors? How could communication about nanotechnology be improved to further democratic principles and a sustainable development of nanotechnology? These questions will be answered in both descriptive (narrative) and interpretive (theoretical-analytical), as well as normative (with suggestions for improvement) ways. A limited, semi-structured, qualitative interview study has been conducted with nine respondents as a basis for descriptive answers. Findings from the theoretical field of Science and Technology Studies (STS) are applied in order to find theoretical answers. Normative answers are based on the theoretical STS framework, the author's personal expertise as an engineer in the field of nanotechnology, and other researchers' studies from primarily the UK and the USA. The conclusions show that the traditional categories 1) attitude towards, and 2) knowledge about nanotechnology are considered inappropriate for studying social aspects of nanotechnology. The author puts forward trust and communication as alternative and more democratic measures. The participants' accounts are used to argue why it is important that public participation permeates all levels of daily life, rather than being confined to specific events such as consensus conferences or citizen forums.

Sammanfattning

Nanoteknik är 'big business'. Stora summor pengar står på spel då detta innovativa teknikområde expanderar i snabb takt. Denna undersökning utgår från antagandet att ekonomiska intressen snarare än demokratiska värden och hållbar utveckling styr utvecklingen av nanoteknik i Sverige idag. Detta ses som problematiskt, och det övergripande målet är att föreslå alternativa principer för att styra utvecklingen av nanotekniken. Studien svarar på tre konkreta frågor: Vilka sociala aktörer bör få förtroendet att besluta över nanoteknikens utveckling? Hur väl fungerar kommunikationen inom och mellan sociala aktörer kring nanoteknik? Hur kan kommunikationen förbättras för att stärka demokratiskt inflytande kring och hållbar utveckling av nanoteknik? Frågorna får både deskriptiva (berättande) och tolkande (teoretiskt analytiska) svar, samt normativa (med förslag på förbättring). För att besvara frågorna deskriptivt har en begränsad, halvstrukturerad kvalitativ intervjustudie av nio respondenter genomförts. För att besvara dem teoretiskt har det teroetiska fältet av vetenskapsstudier, Science- and Technology Studies (STS) använts. För de normativa slutsatserna har den teoretiska STS-ramen, författarens egen expertis som nano-ingenjör, samt andra forskares studier från främst Storbritannien och USA använts. Slutsatserna visar att de traditionella kategorierna 1) attityder mot, och 2) kunskap om nanoteknik bedöms vara olämpliga kategorier för att undersöka nanoteknikens sociala aspekter. Som alternativa och mer demokratiska mått föreslår författaren tillit

och kommunikation. Deltagarnas berättelser används för att argumentera varför det är viktigt att allmänhetens deltagande sker på alla nivåer i det dagliga livet snarare än att vara begränsad till särskilda evenemang såsom konsensuskonferenser eller medborgarfora.

Acknowledgments

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Contents

1 Introduction

> *JL: What started your interest in nanotechnology?*
> *D1: Out of coincidence, I discovered that politicians don't know anything about nanotechnology, so I started reading about it. The sales of products related to nanotechnology are estimated at one hundred billion dollar this year.*
> *JL: That is quite a lot of money.*
> *D1: The fact that there aren't any politicians that know anything about this large technical area that is growing really fast is a bit worrying in my opinion. This means that the companies are the ones who set the terms for the technology. And I don't think it should be that way.*
> *JL: Mh.*
> *D1: Because they are the ones who benefit from it, rather than society in general. Sometimes there is a symbiosis, but more often there are conflicts. Sometimes you can get a better profit margin if you could get away with some things, so I felt that it was important that someone took a closer look at it.*

- Interview with Carl Schlyter, October 12 2009

During my studies of engineering nanoscience, I have regularly been asked to explain what nanotechnology is. Despite nanotechnology's potentially large influence on our lives, there is still no single valid definition of the word. One of the most common definitions is given in the Britannica online encyclopedia: Nanotechnology is concerned with the "manipulation of atoms, molecules, and materials to form structures on the scale of nanometres (billionths of a metre)" [31]. One nanometer is approximately the size of two to ten atoms (depending on the size of the atom), or 50.000 times smaller than the diameter of a human hair. At this order of magnitude, materials exhibit new properties, and a combination of several scientific disciplines is applied to describe the observed phenomena. Heisenberg's/Schrödinger's quantum mechanics and Einstein's theory of relativity replace classical and Newtonian physics, respectively, as we know it from everyday observations on the macroscopic scale.

The complexity of the field may invoke a feeling of unnaturalness, but not all nanoparticles are artificially manufactured. Nanoparticles are abundant in nature. Examples are biologically important molecules, air-borne particles, or functional materials such as the famous water-repellent nanostructures featured by lotus flowers as seen on the left (photograph by Michael Gasperl, September 2005). These structures, as well as other natural nanostructures, are being imitated to create novel materials such as self-cleaning windows and textiles.

Nanotechnology is widely perceived of as one of the most important emerging scientific fields. Large public and private research programs are conducted all over the world, and global nanotechnology funding from public sources alone is reported to hit 9.75 billion US$ during the year 2009. The London-based consultancy company Cientifica has given out a report on global nanotechnology funding, reporting a 130 percent increase in world-wide governmental funding between the years 2004 and 2008 [11]. Sweden alone has committed approximately €50 million in 2007, according to the ObservatoryNano project which was funded under the seventh framework program of the European Union [27]. Nanotechnology is now expected to more and more transition from a discipline of basic research to an applied technology. As global nanotechnology sales are expected to reach 27 billion US$ by 2013 [33], we are likely to see more and more applications of nanotechnology in our daily lives, with potentially large impacts on both individuals and society at large.

My own understanding of nanotechnology is of no relevance to this study. Drawing on the sociologist Brian Wynne's understanding of "democracy with respect to science", which he developed in his influential work of many years on relations between experts and lay people, I do not in this text want to "subsume citizenship to collective compliance with public meanings which are externally imposed, in a dictatorial manner, in the name of science" [52]. In other words, I do not want to impose my own understanding of nanotechnology to my research subjects, but rather work on the basis of each individual's own, personally, socially and culturally determined understanding. That is why I will now leave my introduction to nanotechnology as a research field and give an overview over what I will focus on in this work.

What I would like to address here is the suitability of current mechanisms of public participation in nanotechnology governance in a situation where scientific knowledge about long-term effects of nanotechnology is insufficient, and where slow, bureaucratic legislative processes lack behind rapid scientific innovation [30], thus allowing for what I want to call *chrematocratic* (from Greek chremata = money, and chratein = governance) rather than *democratic* governance of nanotechnology. By doing so I hope to help remedy something I perceive as fundamentally wrong: As an insider in the field of engineering nanotechnology, it is my impression that researchers develop nanotechnology products and applications with short-sighted interests in economic profit rather than based on consumer preferences or principles of sustainability. Where consumer interests are respected at all, they are not used as a basis for steering nanotechnology research and development, but rather for designing successful marketing strategies. Since I believe that our current economic system is inappropriate for dealing with long-term effects of new technologies, I have conducted this study in an effort to find alternative, more democratic ways of creating nanotechnology governance. My conviction is that it is important to focus on long-term effects of new technologies, and that it is important to involve the lay public in that process in a democratic society. With an ambition to analyze the lay public's own views about public participation and the ultimate goal of supporting a sustainable and democratic development of nanotechnology, I have identified three questions for this study, focusing on governance of, and communication about nanotechnology:

1. Which social actor(s)[1] should be entrusted with governing nanotechnology?

2. How well does communication about nanotechnology work within and across different groups of social actors?

3. How could communication about nanotechnology be improved to further democratic principles and a sustainable development of nanotechnology?

On top of striving for a theoretical understanding of the public's opinions about nanotechnology, I wish to achieve applicability of all conclusions drawn in this work. My ambition is to help democratize nanotechnology dialogs, rather than to merely enhance a theoretical discussion within the realm of social scientific discourse. For that reason, I apply an action research approach which is "an approach to social research, in order to understand how human beings interact, how they respond to events and each other in certain situations, aiming at improving a real situation. [Action research] is concerned just as much with the process of inquiry as with the 'findings' and is especially preoccupied with its longterm effects" [41], the key words for me being 'improvement' and 'longterm effects'.

2 Methods

In order to find answers to my research questions from an action research perspective, I found it necessary to directly interact with lay people on their own terms. In this chapter I account for the methods I have used in order to collect the data and establish the qualitative understanding needed to answer these questions. Assuming that my informants "know some salient things better than [I do]" [52] (emphasis in original), I have chosen to conduct a semi-structured interview study as a compromise between creating potential for deep understanding of complex questions and reducing potential for researcher bias [34]. In an interview study, two different approaches to creating knowledge and understanding can be applied. Direct questions could be asked in an effort to obtain direct answers. Alternatively, the participants' responses to related questions, such as trust in different social actors, could be used indirectly to infer information about their views on communication and participation.

A direct approach is suitable for large-scale quantitative analyses since it is fairly easy to evaluate. It is, however, also more likely to produce false results due to framing effects. Consider for example the following question: "Who should be responsible for nanotechnology governance?" By asking this question, we are implying for example that nanotechnology *should* be governed, or that there *should* be somebody responsible for governing nanotechnology. Framing is a very powerful mechansism in influencing attitudes and answers (for the effect of framing on attitudes about nanotechnology see e.g. [29, 12]), and care should be taken to reduce framing effects as much as possible. Steinar Kvale stresses, in his work on research methods, the difference between "knowledge collection" and "knowledge construction": We cannot expect an interview subject to be

[1] Under groups of social actors I understand different stakeholders within society, such as the lay public, nanotechnology experts, governmental institutions, the media, or corporations with interest in nanotechnology.

unaffected by the interview setting or the questions asked. In fact, one and the same question can be expected to evoke very different responses if formulations are altered ever so slightly - or if asked on a different day, in a different situation. We cannot expect to simply collect the knowledge already present and the opinions already formed by the informants [22]. For most participants, their interview for this study was their first conscious and extensive contact with nanotechnology, and some of them seemed to form or reform some of their opinions about nanotechnology during the course of the interview. Participants also reported that the interview influenced their awareness about and interest in nanotechnology. One of the participants (B4) expressed the intention to "go home and google it some more" after the interview.

The effects of framing can be reduced by striving to obtain knowledge in an indirect way [22]. With this method, greater care needs to be taken to reduce researcher bias. It is necessary to approach the material with an open mind and without preconceptions about expected results. I have for my study chosen this indirect approach, well aware of both its possibilities and limitations. I have been working carefully and conscientiously to reduce bias in order to let the participants' opinions be heard rather than my own opinions. This is especially important when approaching a problem as an action researcher, even in face of the non-specificity and openness of my personal agenda with this study: to support sustainable development of nanotechnology on the terms of the whole society (i.e. not my own). During the course of the project, I have worked carefully and methodologically to ensure openness. Being open and listening to what my participants had to say helped me further to let go of preconceptions about the lay public's perceptions of nanotechnology.

I have chosen to use a snowball approach for identifying participants for my study, after reviewing a variety of social sciences sites for recommendations about how to design an interview study. The Department of sustainability and environment is an official site of the Victoria state government (Australia), and presents information about snowball sampling [28]. The Research Observatory is a site published by the University of West England [34], and StatPac is a company with over 30 years' experience in designing surveys [39]. According to these sources, in a snowball sampling approach (also called chain-referral sampling), one or several initial participants are carefully chosen by the researcher. After their interview, those participants are asked to refer the researcher to other potential informants. The process is continued until saturation is achieved in the main questions of the study. The snowball approach is particularly useful when the characteristic of interest is rare in a given population, as is the case with knowledge about and interest in nanotechnology in Sweden. Research expenses and expenditure of time are greatly decreased by identifying "information-rich key informants" [28], at the "expense of introducing bias because the technique itself reduces the likelihood that the sample will represent a good cross section from the population" [39].

In this study, four participants were hand-chosen after web research as starting point for chain referral threads of interviews. Two of those threads (B and C) lead to further interviews, resulting in a total of nine interviews. One thread (A) could not be pursued due to a lack of referrals to voluteering informants. The last thread (D) was not pursued since the informant D1, Carl Schlyter, should be expected to be influenced by his political mandate as a representative for the

Swedish Green party in the European parliament. I have chosen to include Carl Schlyter's interview in this study, since he has for some years been engaged in developing nanotechnology regulation on a European level [37, 16]. His political position is an obvious source of interestedness, but also of specific insight about social and policy-relevant aspects of nanotechnology. Carl Schlyter did not want his interview to be treated anonymously, and I have seized the opportunity to ask a few specific questions to this participant (Appendix B). Acknowledging that Carl Schlyter might be influenced by his social role in the interview to a greater degree than other participants since he may be expected to act as a "politically motivated actor" who might "use [the] interview[] for [his] own political purposes" [1], especially in questions regarding nanotechnology governance, I have decided to treat this interview mainly as a source of additional, valuable insight for creating an understanding of the current political situation, and existing ambitions for public participation and nanotechnology governance. Consequently, interview D1 is not included in attempted categorizations and representations in section 4 and 5. An overview over the interviews for this study is given in Figure 1.

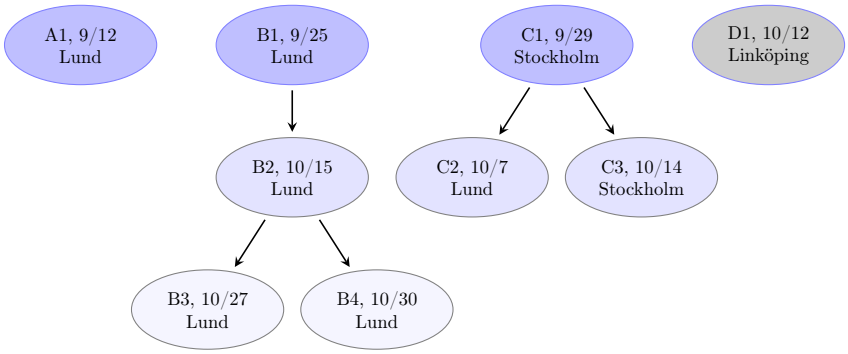


Figure 1: Overview over the interviews conducted for this study: Interview number, date (month/day), location. D1 = Carl Schlyter.

The participant selection process is of utmost importance for the validity of an interview study. It is necessary to realize that it is impossible, especially on a small scale as is appropriate for this thesis, to find a sample which is fully representative of the whole society in respect to nanotechnology. According to Wynne, who has studied technology and democracy for over 20 years, "every ... citizen is in principle a legitimate participant in what should be the deliberative negotiation of ... public [concerns and] meanings" [52]. Due to a low level of public knowledge about nanotechnology [2, 13], however, it is helpful to limit the study population to informants who have heard about nanotechnology, having an idea of what the word stands for without being experts and/or working in the field. Thus, framing effects from explaining nanotechnology to the participants and binding them to a given definition are eliminated. At the same time, experts are excluded since their perspectives and interests tend to already be well represented in designing research projects. I have also limited my study geographically to the area of Sweden in order to create coherence, and to be able to contribute to the current debate about public opinion and nanotechnology with a (small) Swedish sample. All participants were Swedish-speaking and all interviews were conducted in Swedish. Translations of citations from the inter-

views, as well as translations of the interview questions and the priming text (Appendix A and B) were carried out by Niklas Ljung, second-year student at the *Master of Arts in Translation* program at Lund university (Appendix D). The Swedish originals are available upon request [24].

Efforts to find initial participants from different social groups and with different educational backgrounds failed despite persistent efforts. It became obvious that people with a certain amount of knowledge about nanotechnology often have an academic background: All participants have finished, or almost finished an academic degree at a Swedish university, leading 7 out of 9 participants to perceive themselves as more educated about nanotechnology than what they perceive as the 'general public'.

Ultimately, the conclusions drawn in this thesis are valid only within the population of the nine participants who were interviewed. Still, acknowledging these limitations, conclusions can be carefully translated to a wider population of Swedish people with an academic background and a general interest in science and technology. Furthermore, since a large section of the European society does not care about nanotechnology one way or the other [23], this informed and interested public is likely to be the best approximation available today to estimate the needs of society at large.

All participants were asked a list of standard questions, carefully formulated to reduce framing effects by for example consciously avoiding emotionally charged expressions such as "risk" or "danger" (Appendix B). From these questions, secondary questions were asked where needed for clarification or deeper understanding of the participants' opinions. Interviews lasted between 23 and 53 minutes and were conducted in a neutral environment. The participants' first contact with the interviewer was an email with basic information about the interview and a request to participate (Appendix A). No further information about the study, or about my agenda with the study, was revealed before each interview.

I have chosen to transcribe all interviews, partly in order to facilitate interpretation without premature judgments about what is important in the interviews, and partly since the process of transcription itself is part of an important learning process for improving the quality of later interviews [22]. In particular, I have learned how important it is not to finish participants' sentences for them, and how to encourage participants to elaborate on a question without revealing my own opinions on a subject and thus influencing the participants' answers.

Transcription of the interviews was carried out as carefully and precisely as possible according to a transcription key as given in appendix C. The transcriptions produced 72 pages of dense information from a total of five hours and 17 minutes of dialog during nine separate interviews. The complete interview transcriptions are collected in a separate appendix [24].

For the purpose of readability and coherence, precise word-for-word transcription was attempted, with subsequent omission of unnecessary filler words such as "like", "so to speak", "sort of", "kind of", "so that", "well", and meaningless sound utterances such as "uhm", "mh", "hm", and "uh"[2]. These words were only omitted where they were perceived as being void of significance for the meaning

[2]List of original Swedish words and sounds omitted in the transcriptions: "liksom", "alltså", "så att", "så", "så att säga", "sådär", "då", "ja", "uhm", "hm", "mh"

of the respective statements, and their later interpretation. In those cases, even some repetitions were left out, if doing so increased the readability of the text. In other cases, repetitions were an expression of accentuation of a certain phrase or word by the participant. These repetitions are salient for the interpretation of the material and were therefore included.

It has been important for me to treat the material in an ethical way, ensuring the participants' integrity and personal interests. Two text passages have therefore been omitted to ensure anonymity of the participants. Furthermore, participants were given an opportunity to comment on my transcription of their interviews and on my use of citations from those interviews. One participants commented, but none of the participants requested any changes to be made or any restrictions to publication of their interviews if done so anonymously. Anonymity can also serve as a tool to reduce participants' conscious or unconscious personal interests in the study.

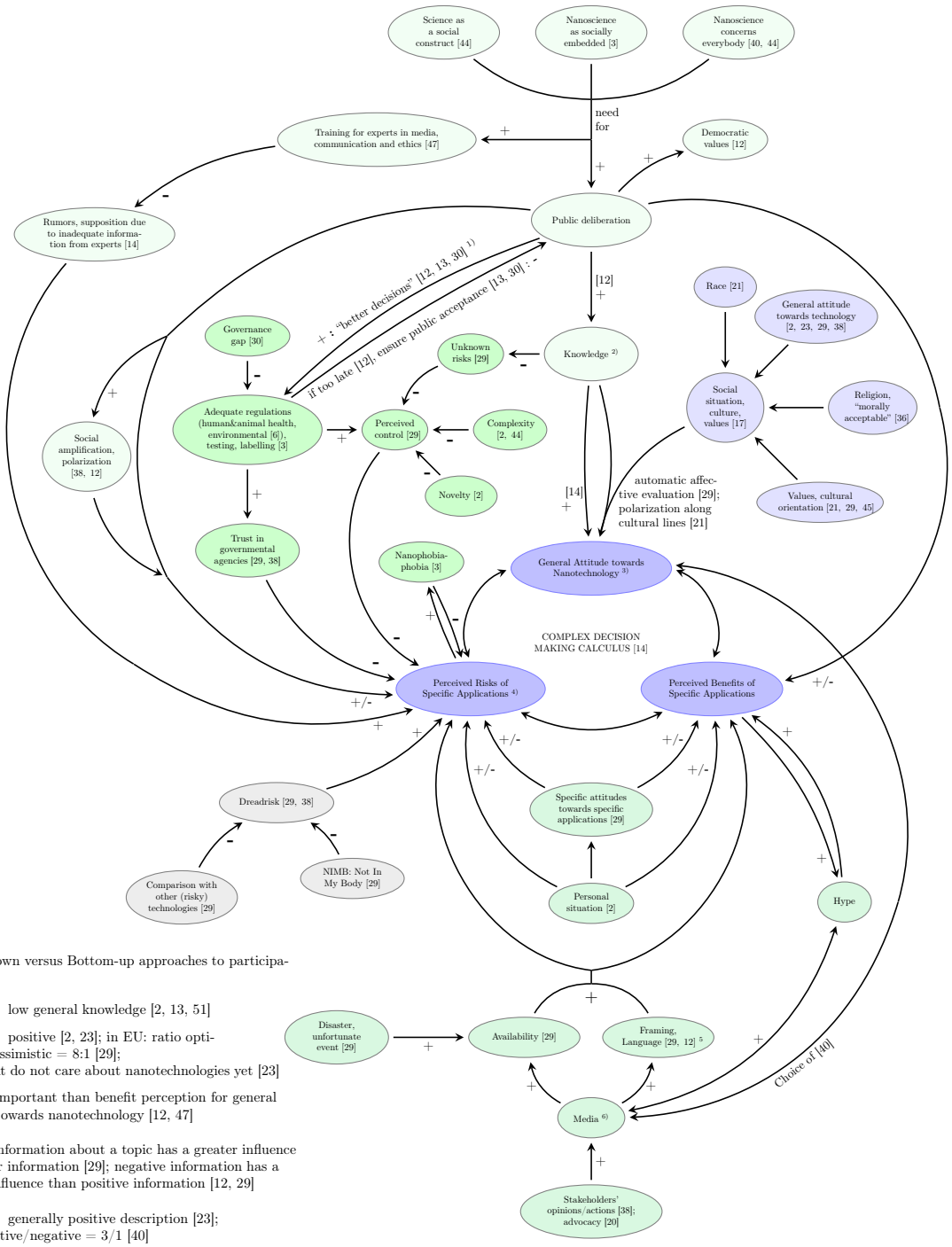
After transcribing the interviews and repeatedly reading the transcriptions, I have identified a number of factors which I perceived as being important for the participants. Color coding and subsequent clustering allowed me to methodologically extract information from the voluminous material. For a number of categories, I have attempted to translate my interpretation of the material into numbers. This translation should not be seen as an attempt to create statistical evidence, but rather as a way of representing my categorization. This representation could just as well have been done in words, but I have chosen numbers for greater clearness by means of graphic demonstration.

Similarly, I have developed an equation for representing the participants' perception of their own knowledge about nanotechnology (Section 4). Clearly, despite the mathematical touch of the depiction of this information, I claim no statistical reliability on the basis of 8 interviews. Again, I use a numerical representation as an illustrative tool to facilitate comprehensive representation of extensive amounts of information.

3 Theoretical background

Scholars from the field of Science and Technology Studies (STS), and more specifically from the field of Public Understanding of Science (PUS), have throughout the past decade dedicated considerable attention to the development of nanotechnology. They have been focusing on social, cultural and personal factors which might influence a person's opinion on nanotechnology, and on how public acceptance of nanotechnology could be improved. I will use their research to structure and interpret the answers obtained from my informants. Before I do so I will give a bird's-eye view of the field of study, and then go into detail and explain which parts I will use, and what I need them for. STS research is concerned with the intersection of science, technology, and society, and is often focused on historical developments of key technologies. In the case of nanotechnology, however, researchers have sensed an opportunity to study a technology as it evolves rather than to analyze its development in retrospect. Especially in the US, STS research results are often used by policy makers as a tool for decision making about science and technology implementation.

In Figure 2, I have attempted to map the current state of knowledge about



1) Top-down versus Bottom-up approaches to participation [30]

2) Today: low general knowledge [2, 13, 51]

3) Today: positive [2, 23]; in EU: ratio optimistic/pessimistic = 8:1 [29];
50 percent do not care about nanotechnologies yet [23]

4) More important than benefit perception for general attitude towards nanotechnology [12, 47]

5) First information about a topic has a greater influence than later information [29]; negative information has a greater influence than positive information [12, 29]

6) Today: generally positive description [23];
ratio positive/negative = 3/1 [40]

Figure 2: Overview over existing literature about nanotechnology and public opinion.

public perceptions of, and attitude towards nanotechnology as found in scientific literature. A wide array of studies have focused on the influence of a variety of social factors on public opinion about nanotechnology. Each social factor is here represented by a colored oval, connected by arrows where the literature reports interrelationship. Arrows point from the causing factor to the resulting factor. For the purpose of clarity, clustering of social factors was attempted by representing similar and strongly interconnected factors by the same color. Plus or minus signs alongside arrows indicate a strengthening or weakening effect on another factor. Where both signs are present, effects can be either strengthening or weakening. Arrows without signs indicate that literature reports a rather complex, non-quantifiable relation between the factors, such as between 'religion' and 'social situation'.

STS research concerning nanotechnology is concentrated on three interconnected aspects of public attitude: general attitudes towards nanotechnology, perceived risks of specific nanotechnology applications, and perceived benefits of specific nanotechnology applications. These three factors are connected by a "complex decision making calculus" [14]. It has been found that trust and perceived control reduce perceived risks of specific applications [29, 38], and that both can be enhanced by adequate regulations [7]. Unknown risks, complexity, and novelty have a negative impact on perceived control and will therefore increase risk perception [2, 29, 44], as will the existence of a governance gap [30], which describes a situation where adequate regulation does not exist since scientific advances and innovations progress in such a fast pace that legislative and regulatory processes lack behind. Perceived risks of specific applications are also influenced by dreadrisk, a factor which describes the phenomenon that certain risks are more feared than others. To analyze risks of new technologies, people can use a "Not in My Body" (NIMB) approach, which implies that as long as technology is safely kept outside of their biological system, it is considered less risky than for example particles that are taken up through the skin. Even comparison with other risky technologies might reduce a person's risk perception [29, 38]. Social situations, such as cultural values, religiosity, race, or their general level of optimism or pessimism towards technology are reported to have a strong influence on general attitudes towards nanotechnology through a process of "automatic affective evaluation", and polarization along cultural lines [2, 17, 21, 23, 29, 36, 38, 45].

Other important factors seem to be framing and availability. Availability of specific risk perceptions concerning nanotechnology depends in part on external events which might call for attention (e.g. accidents with harmful consequences, or recent scientific breakthroughs with possible solutions to important problems), and in part by how events and scientific facts are presented in the media. The mass media are also influenced by important stakeholders' actions and advocacy processes [20, 29, 38]. Social actors can sway the media's influence on themselves by their own choice of media. At the same time, their choice of media is influenced by the media they have been in contact with before. The media can also cause an amplification of hype, which in turn is created and amplified when benefits of specific nanotechnology applications are exaggerated.

Several scholars use a postmodern approach to nanotechnology. Postmodernism denotes a tendency within arts, culture, and science, which emerged during the second half of the 20th century as a reaction to modernism's trust in and optimism towards progress [9]. It implies that "knowledge is constructed,

not discovered: it is contextual, not foundational" [46] and thus that absolute truth and rationality are impossible [8]. In the context of nanotechnology, it prompts researchers to study nanotechnology as "a social construct" [44], and as "socially embedded" [3], since scientific knowledge cannot be detached from social phenomena.

Scholars also emphasize the need for social training of experts [47] to reduce the circulation of rumors and the formation of myths [14]. Public deliberation is requested for the sake of democratic values [12] since it is reported to lead to better decision making about nanotechnology regulation on the basis of more perspectives that are being incorporated. If regulation processes are initiated too late during the process of technology development, public deliberation will be void of influence, and deliberation exercises tend to merely serve the purpose of ensuring public acceptance rather than enhancing democratic participation [12, 13, 30].

Michael D. Cobb, Assistant Professor of Political Sciences at North Carolina State University, as well as Michael Siegrist, Associate Professor of consumer behavior at ETH Zürich, raise a discussion about the effects of public deliberation on perceived risks of specific nanotechnology applications. They state that, rather than always reducing perceived risks, deliberation could in some cases lead to social amplification processes, increased polarization and thus for some individuals even increased risk perception [12, 38]. Despite these cautioning remarks, there seems to be widespread agreement in the literature about the importance of public participation in the governance of nanotechnology. Adjunct Associate Professor at the NanoCenter of the University of South Carolina and cultural anthropologist Chris Toumey, being one of the supporters of a postmodern understanding of nanotechnology, stresses the importance of "social and cultural processes by which the scientific knowledge is constructed" [44], thus granting society an important role in shaping science and technology. Daniel Barben, Associate Research Professor within the Consortium for Science, Policy & Outcomes at Arizona State University, speaks of the necessity of foresight, engagement and integration in nanotechnological development [3], and Mark Philbrick and Javiera Barandiaran, both Ph.D. candidates at UC Berkeley in the field of Environmental Science Policy and Management, stress the "capacity of lay populations to deliver germane advice on highly technical subjects" [30]. José M. Palma-Oliveira, Auxiliary Professor at the University of Lisbon, suggests that experts might have an incorrect understanding of the public's feelings towards nanotechnology [29]. Elaborate models for public participation in the development of nanotechnology are created in the form of for example citizen forums or citizen juries (e.g. [30]). Now, we will move on to see in detail what STS research can do for public participation in technological processes, and how I may use this in order to answer my research questions.

3.1 Democratic governance and public participation

Applying a postmodern approach to nanotechnology development, and the idea that nanotechnology concerns everybody in one way or the other [40, 44] since everything is interconnected, prompts me to support a concept called "strong democracy" as it is proposed by political theorists such as Benjamin Barber [4] and Rune Premfors [32]. In a strong democracy, "*High* (frequent) citizen participation [has] a fundamental value" [32] since it leads to, in my (and the Swedish

publics' [18]) view, desirable features such as personal freedom and "mutualism that can overcome private interests" [4].

In the STS literature about nanotechnology, despite a commendable and obviously wide-spread concern with public participation, I was missing the general society's perspective on public participation. Sharing Wynne's criticism that most studies are focusing on scientifically imposed criteria such as risk and benefit perception [52], I was wondering whether STS researchers have become alienated from society by their academic perspective and whether they are using the right tools to find out the proper way to incorporate public opinion. As Barben et al. note: "ironically, as STS becomes better endowed with resources, more highly coordinated, and more entangled within innovation systems, it becomes more like its objects of study" [3]. In other words, STS researchers are increasingly distancing themselves from the lay public and they should therefore be expected to become decreasingly fit to represent society as they "move from a position of distant critical observers to the role of experts in social engineering or advisers of policy-makers" [19], and we should not blindly trust them to propose principles of democratic governance. I have conducted this interview study in an effort to involve the lay public in the discussion about nanotechnology governance since I believe that the only sustainable way of creating democratic governance of science and technology is to take public participation one step further: Public participation in the creation of mechanisms for public participation, just as Premfors requests that "a strong democracy should be shaped and justified by reforms created in democratic decision making progresses" [32]. If the public does not see strategies of citizen involvement as both relevant and trustworthy, they are likely to participate to a lesser degree, and the outcome will be less democratic and less relevant to policy makers. In section 5, I will attempt to find an answer to my first research question (*Which social actor(s) should be entrusted with governing nanotechnology?*) by interrogating the differences and similarities between the public's and STS researchers' opinions about how public participation should be designed.

For achieving democratic governance, it is further important that actors from all groups and levels of society are able to contribute to the discussion about "what questions knowledge should be addressing, and thus, what (combinations of) knowledge should be in play" [52] (emphasis in original). This is true for decisions about nanotechnology research as much as for designs of PUS studies. Based on these reflections, and on hints about insufficient communication in the literature (e.g. Toumey et al: it is "troublesome ... that there is insufficient dialog at the student level between the sciences and engineering, ... and the humanities and social sciences" [43]), I have invested the issue of communication among different social actors with great importance. I have formulated research questions 2 and 3 above (*How well does communication about nanotechnology work within and across different groups of social actors? How could communication about nanotechnology be improved to further democratic principles and a sustainable development of nanotechnology?*), since I believe that without proper communication among all social actors, there will be no co-decision making about knowledge creation. In Barber's words, without "ongoing talk" there will be no "mutuality" [4], leaving the field open for private interests to steer technology development.

As mentioned in section 2, my participant population is all but representative of the whole society. To really achieve public participation in the creation

of mechanism for public participation according to the ideas of strong democracy, the dialog which is created in this study would need to be expanded to a much wider population. Nevertheless, the concerns and preferences expressed by participants in this study can serve as a first indicator for what could be important to focus on in future studies, which could be carried out by other researchers with more time on their hands. The question of communication will be addressed in section 6 where I will use both the theoretical frame of STS, and my interview material to first analyze the present communication situation in Sweden and finally make recommendations about how communication could be improved.

Before turning to those questions of nanotechnology governance and communication, however, I want to use the next section to connect to earlier research within the field of public understanding of nanotechnology, and critically analyze common premises for designing studies, and interpreting results about the social aspects of nanotechnology.

4 Deconstruction of Attitude and Knowledge as valid concepts for the discussion of nanotechnology and society

We now move on to use the STS literature to categorize answers from my informants. In this section I will suggest a new way of understanding and categorizing lay people's attitudes towards nanotechnology. In Figure 2, we have seen that earlier research on the social aspects of nanotechnology has centered on attitudes towards and perceptions of nanotechnology, with a central focus on risk and benefit perception as associated with specific nanotechnology applications. Another central factor in many studies is the participants' level of knowledge about nanotechnology, which is often attempted to be linked to attitudes. Why have the two factors knowledge and attitude been chosen as a basis for discussion about the social aspects of nanotechnology? It seems that this focus is a consequence of perceiving the lay public in the context of the "judgmental dope" model. In this model, the lay public is seen as irrational, automatic, and "subordinated to institutions of modernity" (science is described as an example of an 'institution of modernity') [15]. The main purpose with such an understanding seems to be to "ensure confidence from consumers, workers and investors" [13], though STS researchers themselves might be unaware of this possible application of their work in for example policy making. In this section, I want to argue that this blindfold focus on attitude and knowledge is not only rather irrelevant, but it is also problematic from a democracy-related point of view, since the categories attitude and knowledge are "imposed [on society] in a dictatorial manner" [52], as mentioned earlier. It is obvious that research requires some kind of categorization. Even if we fully embrace the postmodern notion of interconnectedness, it is impossible to analyze everything at the same time as a single complex of interconnected factors. Acknowledging these limitations, I want to argue that categorization can be improved by acting on the assumption of basic democratic principles.

According to the 2008 Economist Intelligence Unit's index of democracy, Sweden is the most democratic country in the world, with an impressive score of 9.88 out of 10.00. The parliament of Sweden lists the following characteristics for a democratic society: popular rule, freedom of the press, freedom of speech, rule of the law (everybody is equal in front of the law), and freedom of association [35]. The Swedish National Encyclopedia also lists division of power as an important feature of democracy [26]. I will now attempt to apply these principles of democracy to the discussion about nanotechnology and society, and want to show that communication and trust emerge as alternative categories to study with the ultimate purpose of improving public participation on all social actors' own conditions so that "politics is something done by, not to, citizens" [4]:

- Freedom of press, speech and association: These liberties are tightly connected to free and well functioning communication, as they present both the basis and the outcome of good communication or "talk".
- Popular rule, and rule of the law: In section 3, I have mentioned that Premfors sees public participation as crucial for a "strong democracy". It is my opinion, more precisely, that participation is a necessary precondition for the democratic principles "popular rule" and "rule of the law". I have also mentioned that, according to Barber, "ongoing talk" is necessary for doing politics [4]. In other words, communication is crucial for participatory democracy.
- Division of power: If this democratic principle is applied to nanotechnology governance, we need to conclude that not one social actor alone can be responsible for nanotechnology governance. At the same time, not all social actors can perform all social functions within a society. Therefore, the power of decision making should be distributed to several groups of social actors, with intensive collaboration among the groups. But division of power can only be successful if the relations between the different groups are characterized by mutual trust. The participants' different levels of trust in social actors can be an indicator for how this democratic principle should be applied to the governance of nanotechnology, i.e. which social actors should be entrusted with responsibility for governing nanotechnology.

In the remainder of this section, before turning to the discussion of trust, communication, and public participation with the help of the material from my interviews (Section 5 and 6), I want to address some issues with the previously dominant categories *attitude* and *knowledge*.

Both scientists and lawmakers are concerned about public opinion and its effects on the development of nanoscience and nanotechnology: "[It] is essential ... to ensure confidence from consumers, workers and investors" [13]. Nanotechnology is sometimes compared to biotechnology, a technology which has been subject to heated discussions and polarized opinions. Those working with nanotechnology and those supporting (nano)scientific development are worried that public opinion and discussion on nanotechnology could develop in a similar way. Barben et al. describe this phenomenom as "nanophobia-phobia" [3]. This anxiety for how the supposedly irrational, uneducated lay public will react

to the novelty and innovation of nanotechnology explains the strong focus on whether public attitude towards nanotechnology is positive or negative and how the public perceives of risks and benefits.

It is unclear, however, whether these strong concerns about public opposition are justified. Participant B2 perceives of nanotechnology as being "easier to control" than for example genetic modification of organisms [24]. The question of whether public opinion on nanotechnology is polarized or not aroused my interest while reviewing the existing literature, but I had to realize that no clear-cut answer existed to this question. Steve Currall, Professor of Management, and Dr. Juan Madera have kindly made additional results from their study about public acceptance of nanotechnology [14] available. These results show that public opinion about nanotechnology is somewhat polarized in the UK: the standard deviation for perceived risks and benefits of nanotechnology was 26 percent and 28 percent respectively. This level of polarization might prompt us to be aware of possible deficiencies in communication as discussed in section 6, but it is hardly sufficiently significant to justify an effuse "nanophobia-phobia".

As a result of the design of my study, I expected to find strong, polarized opinions, since in a snowball approach of sample selection, it is likely that participants will recommend persons with strong and pronounced opinions. However, participants showed mostly differentiated opinions, acknowledging both positive and negative aspects of the technology, and thus indicating a low level of polarization in the sample population. From this observation, the question emerges whether polarization in a wider, more representative Swedish population is even less polarized on the subject of nanotechnology than what has been reported from the UK.

The academic community is divided on the subject whether knowledge about nanotechnology influences peoples' attitude towards nanotechnology. Earlier studies report a complex relationship between knowledge about and attitude towards nanotechnology [21, 29, 14]. While Currall et al. claim that more knowledge in the form of transparent information from the researchers will prevent polarization on the basis of misinformation and might therefore lead to a more positive attitude towards nanotechnology [14], Professor of law Dan Kahan found that increased levels of knowledge will actually lead to increased levels of polarization of opinions along cultural lines [21], just as Cobb and Siegrist et al. suggest social amplification and polarization as a possible result of public deliberation [12, 38] (Figure 2). This disagreement among scholars indicates that the category 'knowledge' might be problematic.

Just as Wynne wants to "critically examine the elephant in the room" by asking the seemingly obvious, but seldom covered question "What is ... 'science'?" [52], I also want to examine an elephant in the discussion about nanotechnology by asking "What is knowledge?". This is not a trivial question and we need to ask "How do we measure knowledge?", and "Who determines the criteria after which to measure knowledge?". To exemplify this point, I have compared different perceptions of the participants' knowledge to each other and will show that they are not congruent.

The first perception I want to discuss is my own interpretation of the participants' knowledge about nanotechnology. This interpretation is based on my own knowledge and understanding of what is right and important on the basis of four years of studies in engineering nanoscience. It is also dependent on my interpretation of the participants' testimony, and on the entire interview situ-

ation. On these terms, I have compiled a rough estimate of the participants' specific knowledge about nanotechnology *as I perceive it*. In an effort to reduce subjectivity, I have broken down this category into three main components and eleven subcomponents. I will use the mean value of the components to represent what I will call the "participants' knowledge according to my assessment" (Table 1). The three components are (subcomponents in parentheses):

a) Sources of knowledge (level of education, scientific journals, popular scientific journals, mass media, other sources such as internet research or public lectures)

b) Knowledge about nanotechnology applications, and

c) Knowledge about scientific aspects of nanotechnology (nanotechnology definitions, quantum mechanics, nanoparticles in nature, technical knowledge about specific phenomena or applications).

Participant number	Sources of knowledge about nanotechnology	Knowledge about nanotechnology applications	Knowledge about scientific aspects of nanotechnology	Participants' knowledge according to my assessment
A1	8	5	1	5
B1	6	3	1	3
B2	4	3	1	3
B3	6	6	2	5
B4	6	4	0	3
C1	5	2	0	2
C2	4	6	2	4
C3	7	4	2	4

Table 1: My assessment of the participants' knowledge about nanotechnology.

Second, I have tried to assess the participants' own perception of their knowledge about nanotechnology, after noting that they frequently voiced concerns about their *insufficient knowledge* on the subject of nanotechnology. As discussed in section 2, I have chosen to represent the participants' perception of their own knowledge in the form of an equation:

$$f(x) = y - x + 5 \tag{1}$$

where x = number of times a participant mentions that he/she has insufficient knowledge about nanotechnology to answer a question or voice an opinion, and y = number of times a participant mentions that he/she has greater knowledge than what he/she perceives to be the general society. f(x) represents the "participants' knowledge according to their own perception". The addition of 5 serves the elimination of negative numbers.

Figure 3 shows a normalized comparison between the two different perceptions of the participants' knowledge. It is obvious that they differ greatly, thus further supporting my claim that knowledge might be an inappropriate criteria for discussing nanotechnology and society, since the question *Who's perception of knowledge is the right one?* arises. For future studies, it might be interesting to examine the lay public's perception of whether knowledge presents a valid and useful concept, for example by analyzing whether participants think that

more information and knowledge will bring the rest of society's opinion closer to their own opinion, and compare those answers to their perceived level of knowledge.

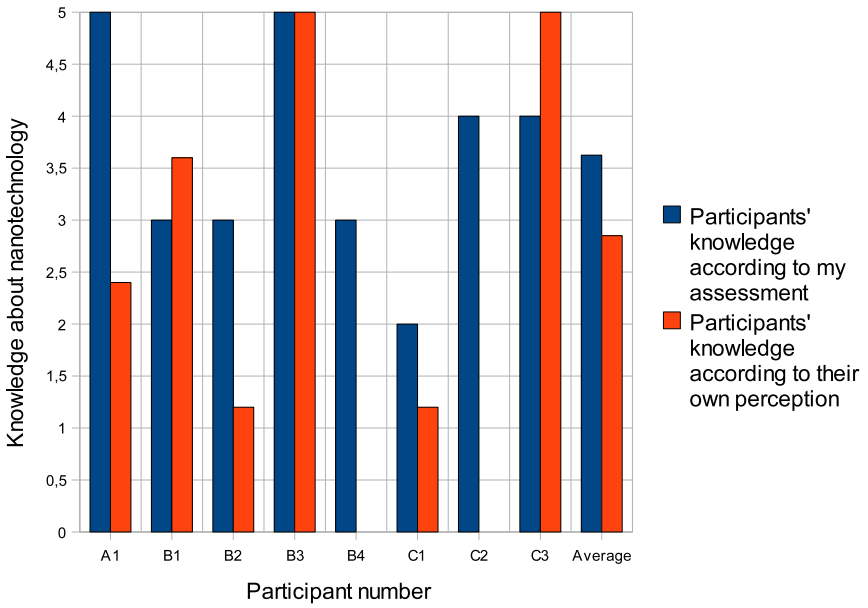


Figure 3: Differences in perception of knowledge: the participants' own perception versus my perception of their knowledge.

A second elephant in this room, to use Wynne's language once more, is the concept of "attitude towards nanotechnology". Siegrist et al. suggest that it might be "problematic to examine general attitudes toward nanotechnology", because public perception of nanotechnology is shaped by general attitudes towards technology [38]. Where specific knowledge is insufficient, prior experiences and existing opinions about other technologies are used to make sense of nanotechnology [29]. Thus, reports about a widespread fundamentally positive public attitude towards nanotechnology, in the US as well as in Europe [2, 29, 23], might just mirror a wide-spread trust in technology in general as having positive impacts on one's life. Maybe there is no such thing as "public attitude towards nanotechnology" at this time, and maybe there never will be due to the inherent complexity of nanotechnology. Participants themselves understand that the concept "nanotechnology" might be too broad to allow them to have a distinct positive or negative opinion: "Nanotechnology is a name that covers such a vast variety of different types of technologies, so to just (inaudible) definition of the area of nanotechnology, is so wide that the effects are quite extensive since a lot of effects are included" (C2). It is possible that smaller definitions of the technological areas which fall under nanotechnology might allow lay people to form their own opinions about specific technological areas. Due to the high level of complexity, grasping the whole concept of nanotechnology seems to be out of reach for most people.

In this study, I have attempted to use the participants' statements about na-

notechnology to roughly assess and compare their attitudes towards technologies in general, towards new technologies, and towards nanotechnology. Table 2 summarizes my assessment, represented by a numerical scale from one to seven, with one being most negative and 7 most positive: 7 stands for a positive attitude, 5-6 for a positive attitude but with awareness of possible risks, 4 for an ambivalent attitude or no opinion on the subject, 2-3 for a negative attitude but with awareness of possible benefits, and 1 for a negative attitude. N/a implies that no statement was made that could allow for an assessment and representation of the particular factor.

Participant number	Attitude towards technology in general	Attitude towards new technologies	Attitude towards nanotechnology	Mean value	Standard Deviation
A1	6	N/a	6	6.0	0.0
B1	3	2	1	2.0	0.5
B2	4	3	3	3.3	0.3
B3	6	6	6	6.0	0.0
B4	5	5	5	5.0	0.0
C1	4	N/a	2	3.0	0.7
C2	4	5	4	4.3	0.3
C3	5	5	5	5.0	0.0
Average	5	4	4	4.3	0.2

Table 2: Participants' attitude towards technologies in general and nanotechnology in specific, on a scale from 1 (most negative) to 7 (most positive).

A comparison of the three factors indicates a strong correlation in this sample: The mean standard deviation between the participants' attitudes towards nanotechnology, new technologies, and technology in general, in this representation, is as low as 0.2, or 3.33 percent. 57 percent of the participants do not view nanotechnology as a unique technology, but rather as "a kind of continuation on the development of everything getting ... smaller and smaller" (B4). "This is actually not a new thing, it is just, like, physics and a lot of other applications, or areas, and all of it has just been put together" (B3). All participants seem to draw on other, to them more familiar, technologies to create their views about nanotechnology, whether they think of nanotechnology as a unique technology or not.

86 percent of the participants think of nanotechnology as a new technology. New technologies in general are perceived of as positive, exciting, advanced and useful on the one hand, but also frightening, insecure and uncontrollable on the other hand: "A person who hasn't heard of nano ... I guess would think it's a cool, new thing, or maybe if it has practical properties that person would think of it as a good product. But then again, people are always a bit skeptical about new and unknown things and nano keeps pushing the boundaries, it is a new technology in many ways" (Carl Schlyter).

The results from this study are thus congruent with earlier studies in that participants do not exhibit opinions about nanotechnology as a distinct technology [38, 29]. When choosing "attitude towards nanotechnology" as a category to study, the answers we are finding might actually be answers about attitudes towards a cluster of several technologies, or even technology in general. Even more complicated, since "attitudes" are influenced by many different factors (Figure 2), we might also find (or fail to see) that our answers are actually about factors such as social and cultural situations [17].

Even more problematic than the categories attitude and knowledge themselves is the connection often made between the two. Participants in the present study suggest a wide array of different, incompatible connections between knowledge and attitude. Participant C1 thinks that more information and knowledge will help people to see risks and problems with nanotechnology and lead to a more negative opinion. Participant B2 agrees initially, but thinks that an even greater level of knowledge could have the opposite effect. Participant B3 expects that a higher level of understanding could lead to greater participation in the scientific process: "If people ... were to become aware of what kind of technology it is, and more people were to open their eyes and maybe started thinking about what it could be used for. Find new way of using it". An assumption that more knowledge will lead to a more positive attitude is based on the judgmental dope model as discussed in section 4. But as Carl Schlyter notes: "the question of using a technology or not has to do with a lot more than just science". The point is that lay people invoke different meanings in science and technology than experts do since they have different understandings of what constitutes "salient knowledge" [52]. It is therefore impossible to "make the [anxiety] go away with the help of information" (Carl Schlyter). In Wynne's understanding: Concern about technological development is based on a frame of understanding which is different from the one which experts try to impose on the public by feeding them with more information and trying to foster an "intellectual climate", as requested by participant C2.

A comparison between my assessments of the participants' specific knowledge about and their attitude towards nanotechnology shows no obvious causal relationship (Figure 4) in this small sample. No correlation between attitude and knowledge about nanotechnology applications, or between attitude and knowledge about scientific aspects of nanotechnology has been found either. A weak correlation might be seen between attitude towards nanotechnology and the variety of sources of information used by the participants. If this is true, however, it is unclear whether a variety of information sources would affect a person's attitude towards nanotechnology or whether a more positive attitude would prompt a person to search more information on the subject, with a greater variety of applied sources of information. As discussed above, this insecurity about the connectivity between attitude and knowledge is supported by both experts' and participants' discordance about how (if at all) knowledge and attitude influence each other. If this connectivity does not work, then how can we understand people's attitudes towards nanotechnology? I want to suggest a new way of understanding social aspects of nanotechnology for which we will need to focus on trust.

4.1 Trust as an alternative indicator

Instead of knowledge and attitude, I have argued that *trust* could be used as an alternative indicator for establishing guidelines for public participation in the governance of nanotechnology. Trust in governmental agencies (social trust) has earlier been reported to be "a strong predictor of nanotechnology risk perception" [38]. Social trust is an especially interesting factor to study in a Swedish population, since social trust has been reported to be among the highest in the world [49]. For this work, I want to complement the discussion about social trust with categories of trust in other social actors: experts, general society, and

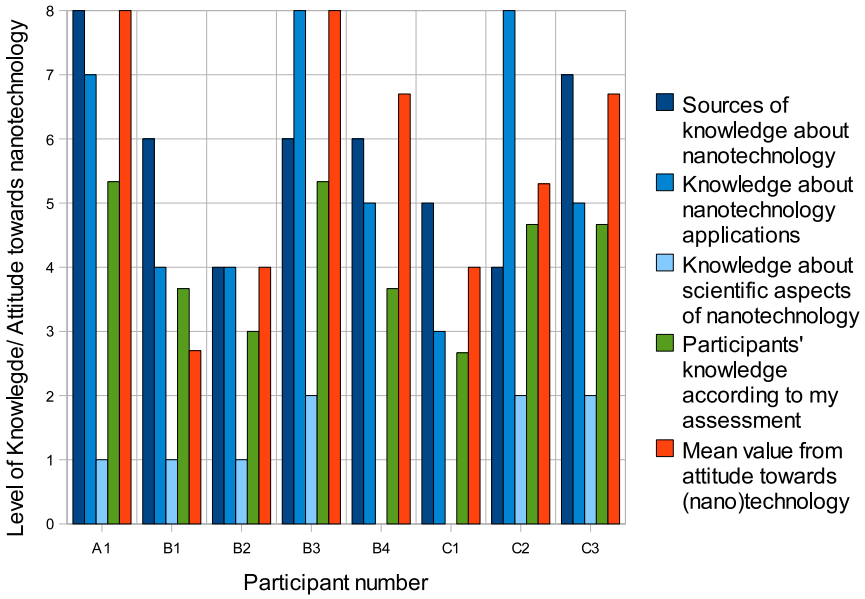


Figure 4: Comparison of the participants' knowledge (according to my assessment) about and attitude towards nanotechnology. All categories are normalized to a maximum of 8 in order to facilitate comparison.

oneself. I will also use the participants' trust in the media and in corporations. Evidence for the participants' level of trust was mainly found in their answers to the following interview questions:

- What are your immediate thoughts when you hear the word "nanotechnology"?
- Why do you think people react positively/negatively to nanotechnology?
- Can you think of a situation or event that would change your views on nanotechnology?
- Is it your opinion that you as a person have the power to affect the development of nanotechnology?
- Do you have any ideas on how public discussion about nanotechnology could be improved?
- Do you know of any serious attempts to respect general opinions in society when it comes to regulating the use of nanotechnologies?

For the purpose of representation, I have put together all utterances which I interpreted as relating to one or several categories of trust and rated each of them as a positive or negative indicator of the participant's specific level of trust. I have then made a comprehensive assessment of trust in different social actors on a three-level scale, where 1 represents low trust, 2 represents medium

trust and 3 represents high trust in the respective group of social actors. The results are represented graphically in Figure 6.

I have also attempted to compare the participants' levels of trust in governmental agencies and experts with their mean attitude towards (nano)technology. For this comparison, I have multiplied the assessment of the participants' trust by two for better comparability with their attitude (Figure 5). A standard deviation of 25 percent suggests a weak correlation between the participants' mean attitude and their level of social trust. A somewhat stronger correlation, standard deviation 12 percent, is seen between attitude and trust in experts. This correlation has to my knowledge not been examined in a larger, more representative study, and will therefore have to be treated as a basis for further discussion. It seems reasonable, however, that highly educated participants correlate trust in scientists and engineers to their own opinion about nanotechnology.

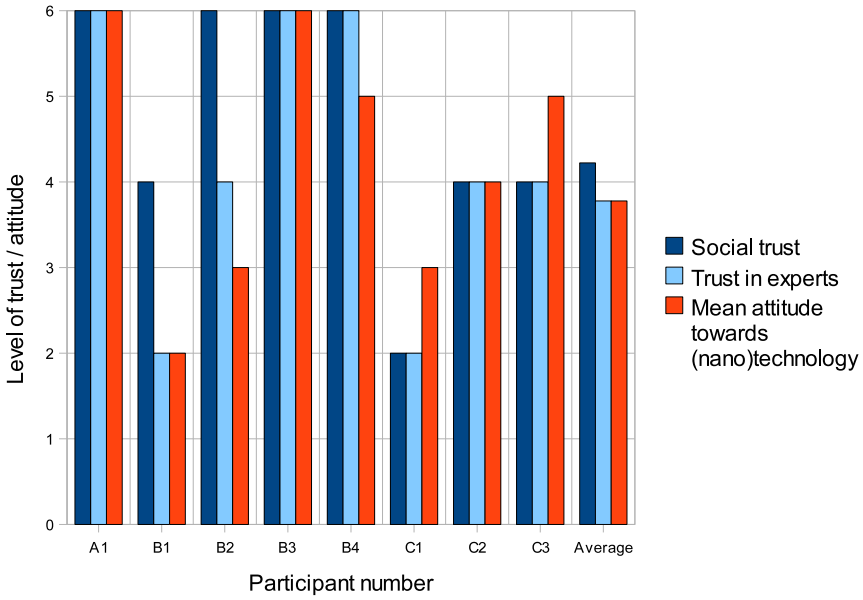


Figure 5: Comparison of participants' social trust, trust in experts, and their mean attitude towards (nano)technology.

One can imagine a large number of different targets for public trust with a number of different influences on public attitude towards nanotechnology. Besides social trust and trust in experts, trust in general society and trust in oneself have been examined, but no significant correlation to public attitude has been found on this limited scale of research. However, it is interesting to compare how different categories of trust relate to each other. From Figure 6, it might be suggested that, in this sample, social trust and trust in experts on the one hand are related to one another, and trust in society and trust in oneself are related to one another on the other hand. It is possible to imagine that high levels of trust in governmental agencies and experts would lower a person's trust in both oneself and the general public, and vice versa, as an expression of an authority vs citizen antagonism. It would be interesting to explore this question on a

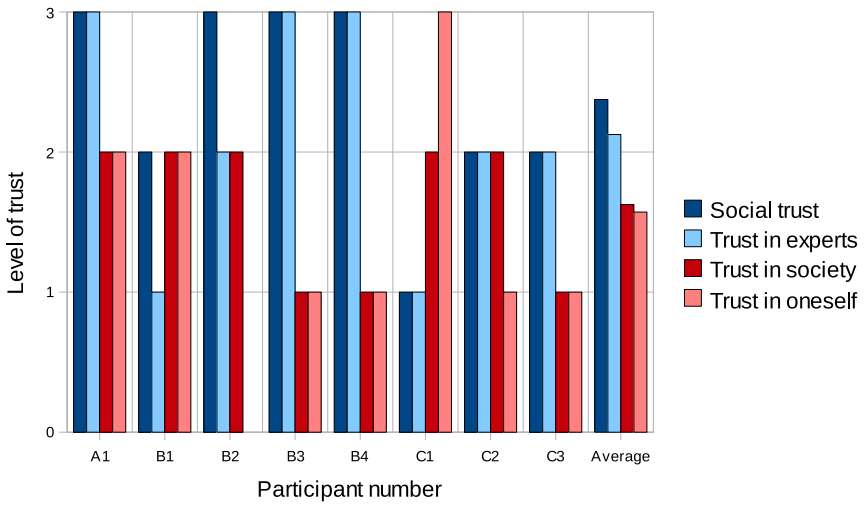


Figure 6: The participants' level of trust in different social actors.

larger, more representative scale, and to assess possible consequences of such an antagonism if it is found to be present. I will now go on to discuss how different levels of trust are relevant for designing governance of nanotechnology, and what conclusions about democratic governance can be drawn from the material collected for this study. Implicit in the following text is the fact that trust is relevant to more than ensuring positive attitudes. In the next section, I will link trust to democratic involvement, and will look closer at who can be trusted.

5 Trust in social actors: implications for democratic governance of nanotechnology

Unlike some earlier research (e.g. a study by the European Commission [13]), I am in this study not interested in finding ways to ensure a positive public opinion towards nanotechnology. Rather, I am interested in enhancing democratic principles as outlined in section 4, and in proposing ways to enhance the public's feeling of empowerment, safety, and contentedness, independent from any level of nanotechnology implementation. As previously stated, I consider public involvement in decision making about technological development a necessity in a democratic society. My aim in this section is normative as well as descriptive: this section tries to answer the question of which social actor(s) should be entrusted with governing nanotechnology, from the participants' point of view.

As discussed in section 2, I am using an indirect approach to generating knowledge and understanding from my interviews in an effort to reduce framing effects. Under the assumption that, as discussed in section 4, trust is a necessary precondition for successful governance, the participants' level of trust in different social actors can be used as an indicator for how nanotechnology should be governed. Earlier research on public trust and nanotechnology has been used to argue that trust in governmental agencies is important for a positive attitude

towards nanotechnology [29, 38]. In this study, while acknowledging the importance of trust for designing democratic governance, the public's actual attitude towards nanotechnology is of no relevance (Section 4). Instead, I will focus on whom the general society trusts in regard to nanotechnology governance, whether the answer to that question can be used to make recommendations for how governance of nanotechnology should be structured, and which role the public itself should play.

As seen in Figure 6, the participants' level of social trust (trust in governmental agencies) is higher than both trust in experts, trust in society and trust in oneself. The difference between the level of social trust and trust in experts is small, as is the difference between trust in society and trust in oneself. A larger difference can be seen between the two groups (social and experts vs society and self). The negligible difference between participants' level of trust in themselves and society might indicate that they see themselves as part of the general (lay) public, despite their perceived higher knowledge about nanotechnology (Section 4).

The distribution of trust among these four categories differs widely between the participants. While some participants exhibit high trust in both governmental agencies and experts (especially B3 and B4), others trust their own judgment rather than the authorities' (C1), or show distrust only towards experts (B1). The outcome of this analysis is therefore expected to depend greatly on the specific group of participants.

The high level of social trust in the Swedish society, however, is also supported by the 2007 Pew Global Attitudes survey, according to which Swedes have the second highest level of social trust (after Chinese) in the world [49]. Together with the fact that none of the participants has explicitly requested greater personal influence, these findings suggest that governmental agencies are well trusted and that they can, and should, play an important role in nanotechnology governance: "Regulating with the help of authorities feels safe" (B1).

There are, however, some limitations to how well governmental agencies are able to represent the public in the question of nanotechnology governance. While participants do have trust in the political process as a successful channel for public participation ("The government usually pulls the brakes when there are strong opinions about something." B3), they also feel that they can "have a very, very small effect on [the development and control of nanotechnology]" (C2). The low level of public interest in nanotechnology [23] presents a problem for public participation through democratic political processes: "it takes quite a lot. Or a large opposition for there to be created any laws at all. But maybe nanotechnology ... doesn't arouse those kinds of feelings. People still see it as something neutral, that is they haven't been able to make up their minds about it yet" (B4). Thus, stronger opinions would be needed in order to better respect the public's views. One could argue that if the public does not have any strong opinion at this time, there would be no need to incorporate their attitudes in the governance of nanotechnology, and that they instead should be represented by other social actors. This claim might be especially steadfast if larger studies would support the results from this study showing that participants have low levels of trust in general society. Yet, I see three main objections to that claim, questioning the accuracy and validity of the participants' perceived levels of trust in society, politicians and experts respectively, and thus restoring some

responsibility for nanotechnology governance to the public despite a current lack of pronounced opinions:

My first objection is that participants' lack of trust in general society might actually be caused by a lack of communication, as will be discussed in section 6. Suspicion takes the place of understanding and openness when social actors are isolated from each other by insufficient interaction and communication, when other people are conceived of as irrational and incompetent (as judgmental dopes [15]). However, in a democratic society, governmental agencies are supposed to represent the general public in all questions, including technology governance. A high level of trust in governmental agencies should therefore imply a high level of trust in the Swedish democratic society which is responsible for establishing the same agencies. Why are governmental institutions perceived of as more trustworthy than general society in dealing with nanotechnology? Are they expected to have higher levels of knowledge than the public? According to Carl Schlyter, this is not the case. The difference in levels of trust in society and governmental agencies might be based on an imbalance of communication between politicians and other social actors on the one hand and among non-political actors on the other hand. A higher level of communication from political actors to the rest of society might create a misconception of political actors as having greater knowledge than other members of the society.

This thought leads to my second objection: We need to ask if politicians and governmental institutions have the right competence to handle the question of nanotechnology governance. Carl Schlyter says that "the politicians don't know anything about nano" [24]. It is likely that politicians exhibit similarly low levels of knowledge about, and devotion to the question of nanotechnology as does the society at large. This low interest stands in stark contrast to the comparatively high level of public trust. Do politicians, in lack of better knowledge, trust in a different entity and hand over their responsibility of handling nanotechnology risks and benefits? If yes, who or what is this entity? According to Carl Schlyter, "the politicians only [meet] with companies" [24]. If politicians are highly influenced by industry and corporations, their decisions about technology will be based on those industries' and corporations' (short-term) economic interests. This practice would most certainly not be in the public's best interest, since 7 out of 9 participants[3] exhibit very low levels of trust towards corporations and other actors with economic interests, who "are ... paid to create a positive opinion" (C1). It would be interesting to conduct a study to map politicians' trust in different actors who are relevant in questions concerning science, technology and society in an effort to gain understanding of how they are influenced in their decision making about development of nanotechnology.

My third objection is concerned with experts' lack of both sufficient knowledge and disinterestedness. As a matter of course, nanotechnology experts will have the greatest knowledge about the technical side of nanotechnology among all possible actors. This fact is presumably a reason for the high level of trust which they receive from participants in this study, despite the fact that most interviewees are aware that new technologies, such as nanotechnology, are linked to insecurities which even experts cannot have a comprehensive overview over. "[They don't quite know] the consequences of what they are doing " (B4), even experts cannot know exactly how the technology will affect us and our

[3]Carl Schlyter is here included.

environment in a long-term perspective. Participants understand that experts sometimes misjudge risks and opportunities ("sometimes the scientist is the one who is wrong", Carl Schlyter).

In addition to these doubts about experts' omniscience, I want to question the dominant paradigm that a higher level of knowledge about a technology will lead to better decisions for a sustainable development on the terms of all stakeholders. In some cases, high specific knowledge might lead to blindness concerning aspects of a question which lie outside an expert's field of competence and an unwillingness to collaborate with experts from other disciplines. In other cases, risks and opportunities may be set back behind arguments of progress and innovation. Participant B1 compares nanotechnology to nuclear technology, where "when the first atom bomb was exploded, they had calculated the risk of the earth being destroyed to one in a thousand ... and they went ahead and did it anyway".

Last but not least, experts are today not disinterested in a Mertonian sense, the driving force behind scientific research is today often not an ambition to extend scientific knowledge, but rather the experts' personal motivations: "The people that use the technology naturally have an interest in presenting it as something interesting" (B1). Researchers are dependent on public and private funding for their research projects. As nanotechnology research becomes more and more focused on possible applications (A1), private and industrial financing increases, and with it the industry's influence on nanotechnology research. Carl Schlyter points out that today "ninety five to ninety percent [of research in nanotechnology consists of applied research], ... companies finance research for applications and products ... . Only five to ten percent consists of impact assessments regarding ecosystems, the environment or heath issues". He regards this as an "an extreme imbalance" when concerning a new technology such as nanotechnology where long-term effects are still largely unknown (Carl Schlyter). As mentioned above, since this study indicates that industry suffers from low public trust, the industry should not be allowed to play such an important part in steering the development of nanotechnology, and we should therefore also question experts' ability, in the present situation of nanotechnology research, to decide on principles of nanotechnology governance, or to conduct research unconstrained by regulations.

Who then should be responsible for governing nanotechnology? Society does not have sufficient interest, nor knowledge, nor trust in itself to tackle such a complex question by itself. Governmental agencies receive greater trust from the public, but suffer from a similar lack of knowledge and interest. Experts are trusted for their higher knowledge, but lack comprehensive understanding of both possible positive and negative consequences. Financial interests further influence the judgment of both experts and politicians. Taking these reflections into consideration, it seems that no single actor has the right competence to tackle the complex question of nanotechnology governance alone. The fact that both governmental agencies and experts receive high levels of public trust should not be neglected, and they should of course play an important role in the governance of nanotechnology. But neither of them should be left alone with important decisions. A broad approach, involving as many stakeholders as possible, should be in everybody's best interest, and seems crucial for a democratic

society and sustainable development of nanotechnology. "One always has to analyze the pros and cons of the risks that must be dealt with" (Carl Schlyter). In fact, this is a very complex analysis, for which knowledge and experience from many different areas and perspectives will be necessary. Interviewees suggest a number of possible collaborations between social actors:

a) Experts and society
Despite the experts' problems with insecurity about long-term consequences and lack of disinterestedness, some participants see their high level of specific knowledge about nanotechnology as important and request more and better information directly from the experts working with nanotechnology: "[An open, public debate] means that the ones who are in the know, the experts, have to find a good way to communicate with people in general", for example by holding public lectures (C2). Participants particularly demand openness about unknown risks and insecurities (for example C3). However, in order to succeed with that strategy, the experts themselves will need to be aware of risks, requiring a high level of critical thinking. According to my personal perception, current science and engineering educations fail oftentimes in incorporating critical thinking in academic curricula to a sufficient extent, and most experts lack in critical attitudes towards their own scientific work.

b) Experts and the media
Participant A1 wants to see a better collaboration between experts and the media: "there has to be a better ... connection between scientists and the media". It is possible that the media can play a facilitating role - both informing the public about scientific advances and possible risks with new technologies, and asking relevant questions of the experts which might increase the experts' awareness about long-term effects of new technologies as well as about public opinion. Participant B4 thinks that "[people] are very influenced by media". A recent study by Chapman et al. indicates that media-communication might also be beneficial for the experts' scientific career: "Press-released papers are more downloaded and cited" [10]. However, participants are not united in this question, due to different levels of trust in the media. Participant C2 does not want to entrust the media with communication of scientific issues: "when [science] is mentioned in the papers, it is often completely misrepresented, which means that you have no respect at all towards science journalists". An unpublished investigation by Christel Thunell, journalist and science communicator for a project at Lund university, from the year 2006 shows that science journalists often lack higher scientific education. Thunell also mentions that, in her role as science communicator, her duty is to publicly promote scientific work by for example writing positive press releases, rather than openly and critically illustrating all aspects of current research programs.

c) Experts and politicians
Another possible collaboration mentioned by participant B2 is between experts and politicians: "it is important that the ones that will later make decisions about it ... are able to study a wide discussion among different kinds of [experts]". Since politicians are expected to represent the public in questions of science and technology governance, but lack specific knowledge about the sub-

ject they are supposed to be governing, it might be beneficial if their power could be combined with experts' knowledge. A prerequisite, however, would be impartiality of the involved experts. They would need to be independent from both industry and the governmental agencies involved with regulation of nanotechnology in order to be able to give as qualified and disinterested advice as possible. They would also need to be aware of the limitations of their own knowledge, which once again stresses the importance of critical approaches among the experts towards their own research. Furthermore, there would be a need for increased financial support of risk management in order to reduce the current imbalance between commercial research and research on health and environmental effects with the new technology: "the type of research that is aimed towards [affecting people's daily lives] does not ... have access to the same resources as the type of research that is aimed towards commercializing the use of nanotechnology" (C1).

d) Experts from different fields
Participants also see the need for experts from other fields to be involved in the discussion about nanotechnology: "I think it would be good ... to include more people in the debate, the ones that develop the technology have to be part of a discussion about it. Not just those who are developing it, other kinds of scientists might also review the effects of the technology on other areas, for example doctors of medicine, biologists or chemists" (B2). STS researchers take this thought one step further and propose "ethnographic intervention", an integration of natural sciences/engineering and social sciences/humanities, thus creating interdisciplinary "participant observer[s:] ... 'lab-based sociologist[s]' or 'embedded humanist[s]' " [3].

It is interesting that, apart from this connecting point between the participants and the STS community, none of the participants suggests any of the methods mainly brought forward by STS researchers - or recalls any of those methods being implemented in society. Popular suggestions from the STS community include different forms of citizen forums (e.g. [30]), consensus conferences (e.g. [48]) or citizen juries. Joly et al. write that "we should not be too optimistic about public engagement in nanotech" [19]. In my opinion, however, the potential value of public engagement depends greatly on the form in which this engagement is attempted. While STS researchers want to create elaborate systems for public participation in technology governance, which might be interpreted as "new source[s] of legitimacy through public debate" [19], participants seem to call for incorporation on a more basic level. In my view, STS methods seem to be more elitist and rather detached from society's routines of everyday life, thus creating problems of implementation [30, 19]. Participants on the other hand wish to implement public participation in all levels of social interaction: The experts should cooperate directly with society, but also with the media, the politicians and other experts. This cooperation does not need to be limited to specific events such as consensus conferences. Rather, with an understanding that public participation is the basis for a strong democracy, it can be automatically incorporated in all decisions without a formal framework.

It remains to see whether the methods proposed by the STS community can be successful in shaping nanotechnology research and regulation [30] or whether

we should reevaluate the methods used and try to create public participation on the terms of the public, by asking them in which way they want their opinion to be incorporated, and by asking policy makers which kind of input from the society would be easiest to take into consideration on an everyday basis.

Most problems with nanotechnology governance seem to be problems of insufficient communication within and across different groups of social actors. Only with well-functioning communication can the above suggested collaboration, as well as other forms of collaborations, be realized. In section 6, I will address the importance of communication in a democratic society, and ways to improve communication about nanotechnology in a effort to support a sustainable development of nanotechnology.

6 Communication as a prerequisite for a democratic and sustainable development of nanotechnology and nanotechnology governance

In section 4, I have claimed that the democratic key liberties freedom of press, speech and association can be perceived as both the basis and the outcome of good communication. Where these liberties are restricted, communication itself will be outlawed and greatly restricted. Well-functioning communication on the other hand will counteract dictatorial efforts to curb any democratic liberties by supporting cooperation within society and thus creating a stronger societal body. According to the Swedish National Encyclopedia, communication is also important for personal development: "Human beings as a species have an essential need to communicate; it is a prerequisite for a complete psychological, social and cultural development" [26]. Last but not least, communication is also linked to ethical concerns, such as the principle of informed consent on which many of our ethical frameworks are grounded today. Without communication, it is impossible to obtain informed consent, resulting in violations of citizens' fundamental rights. Participant B2 says that "people in general have the right to know about these things before they happen", and that opposition is created when the public feels that a technology "has been forced upon them" so that they "have not been able to make their own choices about [nanotechnology], or able to discuss [nanotechnology]".

The profound importance of communication justifies a discussion about how well communication about nanotechnology functions in Sweden today. The quality of communication can allow us to get an idea about how democratic our current system of nanotechnology governance is, and how it could be improved by enhancing communication. As proposed above, economic interests might today have a pivotal role for guiding technology development, possibly overriding democratic principles. I will in this section first identify indicators for what good communication is, then analyze the present situation for nanotechnology in Sweden with the help of my sample population, and finally make recommendations for improved communication based on the interview material and a larger study about ethical, legal, and social aspects of nanotechnology [47].

According to the Britannica Online Encyclopedia, the English literary critic I.A. Richards gave one of the first definitions of communication as a social behavior in 1928: "Communication takes place when one mind so acts upon

its environment that another mind is influenced, and in that other mind an experience occurs which is like the experience in the first mind, and is caused in part by that experience" [31]. Translating this definition to communication about nanotechnology, I can see five important factors for assessing the quality of public communication, which I will discuss more thoroughly below:

- Level of polarization of opinions about nanotechnology
- Rational versus intuitive understanding of nanotechnology
- Openness towards differing opinions about nanotechnology
- Knowledge about nanotechnology
- Trust in general society in regard to nanotechnology governance

It is to be expected that in an open, diverse society, there will be a large variety of opinions on a subject, especially on a subject such as nanotechnology with potentially strong effects for human society and non-human nature. With good communication, it should be expected to find differentiated opinions, rather than polarization of opinions, since in the words of I.A. Richards "an experience occurs [in one mind] which is like the experience in the [other] mind". If we assume a low level of public polarization (Section 4), we might conclude that communication is well-functioning and needs no improvement. However, a lack of polarization might also be a result of a general lack of opinions [23] as discussed in section 3.

As a result of good communication, citizens would be expected to not only themselves acknowledge both positive and negative aspects of and possibilities with nanotechnology, but also to view other opinions as important and valid rather than dismissing them as irrational. In a society with good communication, there would be no perceived irrationality, since everybody would understand the other positions' motivations. The judgmental dope model [15] would be void, since there would be an understanding for the importance of social relations as creating seemingly irrational, automatic, and therefore emotional reactions to new technologies.

While most participants have, like participant B2, a "neutral attitude" towards nanotechnology, and exhibit differentiated opinions, acknowledging that "it is not necessarily a good or a bad thing, but ... rather something that can be used in different ways" (A1), they seem to perceive themselves as more rational, less intuitive, and less influenced by emotional reactions than other lay people despite the fact that they often use emotionally charged adjectives such as "cool", "very, very fascinating", or "frightening" (B4). Participant C2 claims not to be influenced by emotions ("I don't think I have a strong opinion about it", C2), but does also acknowledge that nanotechnology is associated with "an exciting new-technology vibe" (C2).

The phenomenon is best exemplified by participant B2: "some people promote it as a completely new technology that will revolutionize a lot of things while other people might be critical or negative towards it ... but I personally feel that I know too little about it to have a decided opinion". This participant believes that the public has distinct opinions about nanotechnology, unlike him/herself who doesn't have enough knowledge for a well-grounded opinion. But since the participant does not believe that what he/she perceives to be the

general society has greater knowledge than him/herself ("I probably ... know as much or as little ... as the average person"), it must be concluded that the general society is perceived as forming opinions on the basis of less well-grounded information, and thus as being more intuitive and less rational than the participant regards him/herself. Better communication should be expected to reduce this tension between self-perception and perception of other members of society.

Tensions of perception between self and society also arise around the issue of openness towards dissenting opinions. Participants seem to perceive themselves as more open to other opinions than they actually are. As indicated above, most participants are very careful about pointing out that nanotechnology can have both risks and benefits, and that they themselves do not have strong, polarized opinions. They seem to accept other opinions when they point out that "I think that if you know a little about what nanotechnology is, you see it as something both negative and positive" (A1). However, this quote from participant A1 also indicates that single-sided opinions are not accepted since they would be based on ignorance. Some participants expect the general society to be polarized (B4, C1, C3). They also perceive other opinions as either "conservative" (B4) or as "blind faith" (B1), as "not natural" (C3), as influenced by "biased information from the producers" (B3) or the mass media (A1), and as characterized by hype and myth formation (B1, B2): "people are easily ... scared" (B3).

In section 4, I have argued that the concept of knowledge is problematic in itself, especially when seen as influencing social actors' attitudes towards nanotechnology, since different perceptions of knowledge are likely to produce very different results. Independent of which perception of knowledge is applied however, it is clear that knowledge about nanotechnology in most parts of society is low [2, 13]. In the Swedish National Encyclopedia, we can read that "Communication demands a language or a code wherein the information is expressed and also a physical medium through which the information is communicated" [26]. When talking about technology communication, a common language could consist of a minimum level of knowledge about the actual technology. A low level of knowledge about nanotechnology in the lay public indicates a lack of a common language for communication about nanotechnology and will thus impact this communication.

A physical medium for communication could come in different shapes, the most obvious one being either direct face-to-face communication or communication through media such as newspapers, TV shows, and radio broadcasts. Which medium of communication is the most suitable depends on the participants' trust in different media. Participants' levels of trust in the media differs widely as mentioned in section 5, but participants differentiate also between different forms of media channels. While some participants request a discussion about nanotechnology on an as complete level as possible (C3), others ask for explanations in "terms that are easy to understand" (B4). To satisfy everybody's individual need for communication, a variety of information channels is necessary, and communication through the mass media should be completed by direct face-to-face communication. This direct communication should occur both within and among groups of different social actors. In discussions between experts and lay people, the experts can benefit from feedback given by the lay people, allowing them to adjust methods of presenting information about current research to better fit the needs of the recipients. Experts can also learn about the lay publics' concerns with current research practices, and research

agendas for future nanotechnology development. Of course, it is not enough if social actors know about other perspectives. Acceptance and implementation are further preconditions for a democratic sustainable development of nanotechnology. Still, "face-to-face communication has been found to be one of the most powerful ways of increasing cooperation" [5] and does therefore deserve considerable attention in the debate about improving nanotechnology dialogs.

The importance of trust for designing nanotechnology governance has been outlined in section 5. Trust has also been reported to be influenced by communication in different situations. Professor Ben-Ner, specialist in human resources and industrial relations, finds that "communication increases trusting and trustworthiness" [5]. More specifically, Gail Fann Thomas, Associate Professor at Monterey Graduate School of Business and Public Policy, writes about the role of communication in the development of trust within organizations [42], and Dr. Sally Wilde about trust and communication in medical questions [50]. Supported by those studies, I will use the participants' level of trust in different actors to get an understanding of communication between those actors and the rest of society.

As discussed in sections 4 and 5, participants have a rather low level of trust in both themselves and the wider lay public. They prefer to endow political institutions and experts with the responsibility to govern nanotechnology rather than engaging themselves and/or other lay actors in the process. It is possible that communication from governmental agencies and experts to the general society is actually sufficient, while communication among other members of society is inadequate. This conclusion goes against the participants' call for more information from the experts and institutions. That call, on the other hand, is likely to also be influenced by the high level of trust in those actors. Maybe this circle of trust and communication needs to be broken in order to motivate the public to actively participate in the discussion about new technologies. This might also have the effect of breaking the perpetuation of the judgmental dope model [15] being applied to the lay public, not only by scholars of PUS, but also by other members of society. A high level of trust in society would indicate effective and productive discussion about nanotechnology, and would facilitate cooperation despite differing opinions. A word of caution is spoken by Thomas et al. who suggest "that the relationship between communication and trust is complex, and that simple strategies focusing on either quality or quantity of information may be ineffective for dealing with all members in an organization" [42] or as in this case, all members in a society.

The above observations lead me to conclude that communication about nanotechnology within society might be insufficient. Participants request more science communication from experts ("Of course, the scientists need to be part of the debate", A1), which certainly is important and helpful for the purpose of creating greater awareness about nanotechnology, as well as for providing the lay public with tools for participating in discussions about, and governance of, nanotechnology. However, "nanotechnology outreach will not work if it is a one-way delivery of knowledge from the scientific community to the rest of the world" [44, 19], neither is it compatible with the principles of democracy, in particular the principle of popular rule (Section 4). In compliance with Kahan et al. [21], Carl Schlyter notes that "everything isn't solved by informing the

public". His conclusion is that nanotechnology needs to be regulated in order to "make sure that people aren't exposed to any risks". But protecting regulation is not enough in a democratic society. Even regulation needs to be designed according to society's needs and therefore based on an open debate and public participation. I will now go on to discuss how communication among the general society could be improved, according to the participants' suggestions. I will also compare these suggestions to recommendations made in the final report about the European Nanologue project [47]. The project was funded by the European Union under the sixth Framework Programme, and provides perspectives from both research and civil society. Nanologue suggestions emerged during workshops about ethical, legal, and social aspects (ELSA) of nanotechnology.

a) Knowledge as a tool for communication

As discussed above, awareness and knowledge about a technology can serve as a tool for facilitating communication. Participants would like to see TV programs on the topic of nanotechnology (C3), and labeling of products which contain nanoparticles (Carl Schlyter), in an effort to create greater awareness about nanotechnology in general, and about nanotechnology as we encounter it in every-day life in particular (B4, Carl Schlyter). In addition, "the schools ... should give people the preparation that they need" to facilitate a public debate about nanotechnology (Carl Schlyter). Nanologue participants, as well as participant B4 in this study suggest that "information about new tech e.g. [nanotechnology] should be available at schools even early levels" [47] in order to "arouse ... an interest" (B4) as early as possible. From a democratic perspective, wide-spread knowledge and awareness about nanotechnology are also important in order to break down established power-structures, for example between producers and consumers: "[It is really hard] to know how to deal with [commercial information] when you have such a poor knowledge about [nanotechnology]" (B1).

b) Communication from experts

Insufficient knowledge about nanotechnology can lead to a perception of technology as "a ... closed world" (B4). Participant A1 says that "information about all kinds of science must generally be communicated to society, so that everyone has access to it. All too often it feels like research is locked up in this academic bubble". One way of bringing out scientific knowledge to the lay public and "building nanoliteracy" [43], as Toumey calls the process of spreading knowledge about nanotechnology, would be for experts to "learn to communicate ... with the rest of society" (C2). Scientists should "have training in media, communication and ethics" [47] in order to support cooperation between experts and other social actors as suggested in section 5. Scientists should hold public lectures (C2), and "[they] should be encouraged to engage with educational institutions at all levels" [47]. Nanologue participants want to "make engagement/communication a condition of grant" [47]. Public funding can be used as an effective way to influence the development of nanotechnology according to the needs of the whole society: "society ... influences the direction of the research ... with the help of economy" (A1). Special allocation of funds for developing science communication could also be helpful: "There should be independent funding for including ELSA communication and funding for dialogue

between Government, business and wider society" [47]. It remains to decide where this additional funding should come from.

c) Openness

Communication between experts and lay people is void if it is not characterized by openness (B1) and honesty (C3) about possible risks and concerns. The experts need to be "be more open about what they are actually doing" (B1) and "what they know and what they don't know" (B2). According to the SOM institute at Göteborg University, which produces annual surveys about society, opinion, and mass media, honesty is one of the most important factors of social life, with 80 percent of the participants rating honesty as "very important" [18]. This figure should be contrasted by the importance of technological development: only 23 percent see this factor as being "very important". Nanologue participants stress that "there has to be a 'move beyond publishing' to get away from just publish or perish" [47]. The current academic system is characterized by competition and secrecy, since everybody is "afraid that other scientists might steal their ideas" (B1). Furthermore, there has to be a greater focus on cost and benefit analysis in science education. Nanologue participants request "trans-disciplinary education of Natural/social scientists" [47]. A cooperation between social and natural sciences might also allow engineers to develop greater "humbleness about their own lack of knowledge" as requested by Carl Schlyter. Participant C3 believes that it is in the scientists' own interest to be able to openly "discuss the whole picture", since such a discussion would allow them to "be able to describe what [their research] is all about" instead of being "stuck in ... negative statements" in "a period of negative reactions" (C3).

d) Debate among experts

A critical discussion about nanotechnology presupposes input from a variety of social actors. Participants want to see more research on health and environmental effects of nanotechnology (A1, C1), so as to allow experts to "deal with anxiety" (Carl Schlyter). For this purpose, it is necessary to involve experts from other natural sciences (B2). A broad dialog and debate among experts is also crucial since a "breakdown in consensus among [experts may trigger] ... public concerns" and offer "various public interest groups their point of entry into ... a large-scale public debate" as in the case of public debate about recombinant DNA technology in Great Britan [25]. If experts are unified on a subject, their cultural credibility and lay peoples' high level of trust (Section 4 and 5) provide them with an overwhelming power-advantage compared to the lay public. When experts are divided on issues of health and environmental risks, a less intimidating climate is created for lay people to engage in the discussion about nanotechnology. Participant B2 also suggests that a broad discussion could be helpful in informing policy makers about important issues, and thus serve as a basis for discussion about nanotechnology regulation.

e) Critical thinking

Participant B4 suggests that the problem of insufficient debate about nanotechnology is "a deep-rooted problem", a cultural problem. Cultural norms influence our behavior to a considerable extent, prompting us to trust in certain authorities, such as experts and governmental institutions. Instead of being passive and

count on experts and politicians to do whatever is in everybody's best interest, Participant B4 says that "people have to wake up and make up their own minds about things". To spur people to scrutinize all aspects of science and society, Nanologue participants want to see "critical thinking introduced into all levels of education" [47]. Furthermore, they want to accomplish a broad and critical debate by "creat[ing] a forum with an international remit to bring together Scientists/Media/Public/Business" [47].

7 Discussion

I have in this thesis discussed the issue of democratizing nanotechnology governance. I have expressed my opinion that nanotechnology governance today is characterized by short-sighted private and economic interests, and that rapid innovation outruns research on environmental and health effects as well as the development of adequate regulation [30]. In an effort to improve and actively democratize nanotechnology dialogs, and to support a sustainable development of nanotechnology, I have posed three questions concerning governance of, and communication about nanotechnology. In my endeavor to answer these questions, I have conducted a semi-structured interview study, using snowball sampling to identify nine participants from a population of educated Swedish citizens with a general interest in science and technology. After careful transcription, I have attempted to graphically represent some of the information contained in the extensive interview material.

Based on a postmodern view of knowledge creation, as well as on the concept of strong democracy, I have challenged the current focus of STS research on the categories attitude towards, and knowledge about nanotechnology. I have argued that STS researchers are influenced by their role as advisors of policy makers [19], and that a focus on attitude and knowledge springs out of application of the judgmental dope model in which citizens are conceived of as irrational agents who need to be educated in order to understand the salient benefits of technological innovation [15]. Since scholars are divided on the subject whether more knowledge about a technology will lead to a more positive attitude towards it, I have examined the categories attitude and knowledge more closely. I have found that different perceptions of knowledge may exist and that these differences in turn are likely to influence studies focused on social actors' knowledge about nanotechnology. I have also found that attitudes towards nanotechnology might be determined by attitudes towards technology in general rather than representing opinions about nanotechnology in particular.

This work is an attempt to introduce the idea of democracic knowledge making to the realm of science and technology studies by creating public participation in designing the very mechanisms for public participation [32]. I have argued that categorization can be improved if it is based on democratic principles, and that trust and communication arise as alternatives to the categories attitude and knowledge. After exploring my participants' levels of trust in different groups of social actors, I have found that their trust in governmental agencies and experts is higher than their trust in society and themselves. However, I have also argued that this finding does not automatically legitimate politicians and experts to decide on nanotechnology development solitarily since neither of those two groups can be assumed to be either disinterested or om-

niscient. Instead, they are likely to be strongly influenced by the industry and by private economic interests. From these considerations, I have suggested that a broad approach to nanotechnology governance will be necessary to achieve a democratic technology development which is based on principles of sustainability. Supported by the participants' wish for collaboration between experts and other social actors *on a daily basis*, I have concluded that *public participation needs to permeate all levels of technology governance at all times. We need to replace private interests with common interests, just as we need to replace shortsightedness with longsightedness.*

For achieving the necessary changes, I have found that communication about nanotechnology needs to be improved on all levels of social life. After analyzing polarization of opinion, rationality, openness, knowledge, and trust in the participant population, I have argued that communication is insufficient for my sample population. By reason of democratic principles and basic human rights (such as the right to informed consent), I have argued that two-way communication on equal terms among different social actors is crucial for a democratic technology governance. On this account, it is necessary to acknowledge every social actor's competence - and *legitimate interest* - to participate in the discussion about nanotechnology. In such a complex question as nanotechnology development confronts us with, every individual actor is to be considered expert in some crucial way [29]. At the very least, every single person is expert about his or her own opinions and preferences concerning nanotechnology.

Finally, I have accounted for the participants' suggestions for improved communication, and compared those to suggestions made earlier in the context of the European Nanologue project. The participants' main proposals include a call for more, and open, information about nanotechnology as to increase both knowledge and awareness. This could be done for example by improving education. Public engagement is seen as important for creating a multi-faceted dialog about nanotechnology, as is a more critical attitude towards scientific research. More research on health and environmental effects is deemed crucial for increasing both experts' and lay peoples' critical awareness of issues concerning nanotechnology development, and thus indirectly for enhancing communication about nanotechnology.

My personal interpretation of the conclusions outlined in this study is well expressed by participant B4:

> *I sometimes feel that it is almost like we are all being tricked, but then, we don't have any opinions of our own about anything, we just listen to what other people are telling us (inaudible) and we don't think critically about any of it.*

As a result of this study and personal experience, I see critical thinking as being insufficiently applied by virtually all social actors. In my view, experts lack a critical understanding of social aspects of technology, of limitations to their own knowledge, and of their vulnerability to manipulation by private interests. Similarly, based on Carl Schlyter's account, I assume that politicians lack a critical attitude towards their connections with industry representatives, and their lack of detailed scientific knowledge, and interaction with experts. Even

lay people are often influenced by preconceptions rather than critical thinking and open-mindedness. In order to develop a critical attitude, we will need to understand where our own attitudes come from, and we will need to understand how we and others influence technology development.

I therefore think that education will play an increasingly important role in determining whether we will achieve democratic technology governance and development or whether we will remain trapped in chrematocratic processes. By emphasizing the importance of education, I do not mean to imply that the lay public is irrational and in need of greater knowledge and understanding of a technology. Rather, I wish to see mutual education of experts and other social actors. Open discussions can serve as points of access for a broader understanding of technology issues, acknowledging complex social (and scientific) interrelationships in a postmodern sense.

In my opinion, collaborative knowledge creation between different social actors can spawn tools for constructive and democratic communication as outlined in section 6. Communication then serves as a platform for a critical debate about the premises of public participation as well as about technology development itself. By engaging different social actors in this process rather than merely STS researcher, we might be able to prevent a use of public participation as "a new way of educating 'lay people' ", and as "a more sophisticated way of promoting public acceptance of new technologies" [19].

Working with this project has been very rewarding for me and has allowed me to participate in an interdisciplinary, critical process of knowledge creation. My study has given me an opportunity to widen my own constrained horizon by gaining insight in both my participants' views on nanotechnology, and methods and procedures of social science research. In particular, I have learned how to conduct an interview study, and how to go about analyzing and representing large amounts of qualitative data. Unfortunately, by necessity of the short time frame, this study has been very limited. If I had more time at my disposal, I would want to complement this study with material collected from other social groups. I would want to interview working people such as cashiers and construction workers in order to get a more comprehensive understanding of nanotechnology dialogs among different social groups. I would especially like to develop concrete, easily applicable tools for improving communication about nanotechnology in order to contribute to democratizing nanotechnology dialogs with the ultimate aim to support democratic governance and sustainable development of nanotechnology. For now, I want to round off with a summary of recommendations made in this thesis.

7.1 Recommendations for supporting a sustainable development of nanotechnology

- Introduce critical thinking in all levels and subjects of education.
- Educate the experts in communication and ethics.
- Apply a variety of information channels to confer information about technological development, especially face-to-face communication. No one-way delivery of knowledge from the experts to the lay public.
- Ensure openness about possible risks and concerns with (new) technologies.
- Establish opportunities for mutual education of experts and other social actors to open up for collaborative knowledge creation between different social actors.
- Prioritize transdisciplinary education (natural/social sciences).
- Ensure that public participation happens on a basic day-to-day level and permeates all levels of technology governance at all times.
- Replace private with common interests.
- Replace shortsightedness with longsightedness.
- Acknowledge every social actor's special competence and legitimate interest in questions of technology governance.
- Increase research on environmental and health issues related to nanotechnology.

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Appendices

A Priming text

Email subject: “interview on nanotechnology”

Hello [name],

my name is Johanna Lönngren. I am a student at the Nanoscience program at The Faculty of Engineering at Lund University. Presently I am in the process of writing my master thesis about society's view on nanotechnology and I would be grateful if you would take part in my interview.

Being engineers, when we develop new products we often make assumptions about society's reactions to a new technology or a new product, based on our own notions. Therefore I will in my thesis attempt to qualitatively map society's opinions about nanotechnologies. This includes recording a number of representative opinions in interviews and interpreting these with the help of social and cultural theories.

Your name has been given to me by [name of referring participant]. He or she recommended you as a suitable person for an interview for my thesis. The interview will last approximately one hour and questions will be asked about your personal views on nanotechnology. I will buy you coffee or lunch at a café of your choice. (I will be happy to meet you in [city where addressee lives].)

All interviews will be recorded in order to transcribe them and to raise the quality of the analysis. All personal information will be treated with absolute confidentiality. The participants' names will be replaced with numbers where quotes are used. All participants will in addition be offered the opportunity to comment on my usage of their utterances in my thesis in November, before it is published. However, my examiner, Knut Deppert who is a professor at The Faculty of Engineering at Lund University will need to have access to the participants' contact information to be able to verify how well I have conducted the interviews. A short summary of the results of the study will be sent to all participants in January.

I will be happy to explain the details of the thesis after the interview. At the end of the interview I will also ask you to recommend one or two new contacts that I might be able to ask to interview.

If you are interested in helping future engineers in founding their product development on other views than their own, please suggest a time for an interview as soon as possible, as the timeframe for my project is limited to one university semester.

Thank you for your time, and for considering to participate.

Kind regards,
Johanna Lönngren
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B Interview questions

Briefing

Before starting the interview, I thanked interviewees for their participation. I asked for permission to record the interview and informed them about how I will work to ensure anonymity and confidentiality. Additional small-talk and answers about the study itself were avoided as much as possible in an effort to minimize framing effects.

Opinions about nanotechnology

1. I would like to start by asking you to explain to me in what contexts have you heard about nanotechnology.
2. What are your immediate thoughts when you hear the word "nanotechnology"?
3. In your opinion, what products produced with the help of nanotechnology will be common in the year 2050?
4. Is nanotechnology an important part of the production of these products?
5. A lot of companies use the word "nano" in product names and in commercial ads (for example iPod nano) Do you think this is a successful strategy? Why?/why not?
   What is your opinion about using the word "nano"?

Other opinions

1. It has been claimed that nanotechnology has the potential to:
   a) solve a lot of our present problems
   b) create serious problems
   What is your opinion about this?
2. Why do you think people react positively/negatively to nanotechnology?
3. Where do you think people who have a strong positive or negative view on nanotechnology have heard about it?
4. How do you think people who have a strong opinion about nanotechnology would react to your views?
5. Can you think of a situation or event that would change your views on nanotechnology?

Discussion

1. Do you think an open, public discussion about nanotechnology is a positive and/or important thing? Why/why not?
2. Do you consider yourself a part of general society?
3. Is it your opinion that you as a person have the power to affect the development of nanotechnology?

4. Do you have any ideas on how public discussion about nanotechnology could be improved?

5. Do you know of any serious attempts to respect general opinions in society when it comes to regulating the use of nanotechnologies?

Other technologies

1. Do you know of any serious attempts to respect general opinions in society when it comes to regulating any other technologies?
   If so: what is your opinion of these attempts?

2. Would it be possible to use the same strategies in regulating nanotechnology?

3. Please compare nanotechnology to any other type of technology.

Debriefing

At the end of the interview, I asked participants whether they would like to add anything in addition to what had already been said during the interview, and whether they themselves had any questions about my work. I also asked for additional contacts for further interviews (see section 2) and reminded them not to reveal details about my study and the interview to potential participants before I have been able to conduct those additional interviews. I reminded participants that they would have an opportunity to comment on my transcription of the interview, and that they would receive a summary of the study after its completion. By way of conclusion, I once again thanked them for their participation.

B.1 Specific questions for Carl Schlyter

The following questions were asked *after* the standard set of questions, in an effort to avoid earlier answers to be influenced by these specific quesitons.

1. For some years now you have been working for a regulation of nanotechnology. What got you interested in this issue?

2. In 2004, the European Commission published a report titled "Towards a European Strategy for Nanotechnology" [13]. What is your opinion about it?

3. The commission claims that they want to take public opinion into account, but when I read the report, I get the impression that it is rather a question of adapting public opinion to their views and securing a positive opinion towards nanotechnology. What are your thoughts on that?

4. What do you think is needed to achieve a sustainable development of nanotechnology?

C Transcription key

Adapted from S. Kvale, *Interviews - Learning the Craft of Qualitative Research Interviewing* (2009) Thousand Oaks, CA: Sage [22]

...	longer break
a	speaker emphasis
()	comments on non-verbal sounds or unclear utterances
aa	especially elongated vowels
a-	sentence or word break off
[]	interviewer notes during transcription

The complete interview transcriptions are collected in a separate appendix [24]. They are available upon request.

D A note from the translator

My name is Niklas Ljung and I started studying languages at the University of Lund in 2005. Since then I have studied both English and Spanish. In 2008 I began studying translation at the master's program of translation studies at the University of Lund. I translate texts of all kinds, but the majority of the texts I work with are technical. Working with this translation has been an interesting project that has increased my knowledge about nanotechnology and how it is perceived in society.