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Nanotechnology in Dutch science cafés: Public risk perceptions contextualised

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Abstract

Understanding public perceptions of and attitudes to nanotechnology is important in order to understand and facilitate processes of dialogue and public participation. This research quantitatively analysed risk perceptions and attitudes of Dutch science café participants (n = 233) and compared these with members of the Dutch public (n = 378) who had not attended a café but were interested in science and technology as well. A qualitative analysis of the meetings contextualised and enriched the quantitative findings. Both groups shared similar key attitudes and were positive about nanotechnology while the Dutch café participants were even more positive about nanotechnology than the group of non-participants. The perception that nanotechnology would lead to risk applications was only predictive of attitudes for the non-participants. The qualitative analysis showed that café participants and speakers considered discussion of the risks, benefits and related issues important. Further research could investigate how science cafés can play a role in the science–society debate.

Keywords

nanotechnology, public engagement, risk perception, science café

1. Introduction

Nanoscience and nanotechnologies – as emerging technologies – are expected to have a significant impact on society, since they make it possible to study materials at the molecular level. However, scholars, interest groups and policy makers worldwide have expressed concern regarding the risks of nanotechnology, where the presence of nanomaterials may have unintended and negative effects on health and the environment (Dutch Health Council, 2006; Royal Society and Royal Academy of Engineering, 2004). There has been increasing pressure (since 2001) to examine the

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social implications of nanotechnology and its applications, particularly in relation to the risks and consequences of the technology for society, and the resulting public opinion. Pressure has originated from various influential parties in the United States and the United Kingdom, as well as the European Union (Dutch Health Council, 2006; Roco and Bainbridge, 2001; Royal Society and Royal Academy of Engineering, 2004; Van Est et al., 2004), who are concerned that the public may not accept nanotechnology if the perceived risks outweigh the benefits.

At the same time, the need for dialogue, public participation and 'upstream engagement', that is, engaging the public in science issues from the stage of agenda-setting onwards, is emphasised (Einsiedel and Goldenberg, 2004; Leshner, 2003; Pidgeon and Rogers-Hayden, 2007; Rogers-Hayden et al., 2007; Wilsdon and Willis, 2004). Moreover, engaging the public has become an important goal for governments in the current science–society relationship, particularly in Europe (Gibbons, 1999; Pidgeon et al., 2009; Wilsdon and Willis, 2004), but also in other countries worldwide.

Various authors emphasise the importance of gaining insight into public risk perceptions regarding emerging technologies such as nanotechnology, in order to better understand the (changing) science–society relationship (i.e. Cormick, 2009; Currall, 2009; 'Keeping the public under the microscope', 2009; Koeman et al., 2004). Risk perceptions and how they correspond to the perceived benefits of nanotechnology are thought to be important precursors to attitude formation (Barling et al., 1999; Currall, 2009). According to scholars, understanding and facilitating the process of dialogue and public participation and keeping the public informed on both the risks and benefits of nanotechnology is crucial in gaining public support (Cormick, 2009; 'Keeping the public under the microscope', 2009; Wickson et al., 2010). A more sophisticated understanding of risk and benefit perceptions can therefore assist in the development of methods designed to increase public participation processes (Bayley and French, 2008).

Public risk perceptions and attitudes worldwide

Public risk perceptions of and attitudes to nanotechnology have been measured in various ways and have been associated with various variables including the perceived value of the technology (Gaskell et al., 2005), the perceived benefits (Satterfield et al., 2009), cultural background (Kahan et al., 2009), previous knowledge or awareness of nanotechnology (Currall, 2009) and trust (Siegrist et al., 2007).

Most research also suggests that the public's perceptions of nanotechnology is primarily positive, but results appear to vary across cultures, with US citizens, for example, being less concerned about risks than scientists (Scheufele et al., 2009), while Europeans appear to be more concerned than scientists (Siegrist et al., 2007). For example, Bainbridge (2002) reported enthusiasm about nanotechnology by science-minded respondents. In a meta-analysis, Satterfield et al. (2009) found that the perceived benefits outweighed the risks; however, about 44% of the respondents were 'not sure' about the risks or the benefits, which reduces confidence in this claim. In an experimental study, Kahan et al. (2009) also found support for nanotechnology, particularly among people with a pro-technology cultural orientation, who were exposed to information about nanotechnology. In contrast, Vandermoere et al. (2010) found that most people in Germany have an indifferent, ambiguous or non-attitude toward nanotechnology. Burri and Bellucci (2008) and Burri (2009) reported in a Swiss *publifocus* study a more balanced approach to nanotechnology and a pragmatic attitude among respondents. And, Priest et al. (2010) suggest that positive attitudes are more likely when it involves new technologies (such as nanotechnologies), while possible concerns may rise later, which is an argument for organising early upstream engagement.

Furthermore, survey research, primarily conducted in the United States and the United Kingdom, suggests that attitudes towards nanotechnology are determined by a range of factors, including religious beliefs (Scheufele et al., 2009), value differences (Gaskell et al., 2005) and deliberating cognitions and knowledge relating to the benefits and risks (Pidgeon et al., 2009). Research comparing German, Australian and US attitudes found that they were driven by hopes and expectations rather than by knowledge (Simons et al., 2009), while Vandermoere et al. (2010) suggest that for the German population, familiarity with the technology and religiosity were marginally correlated with positive and negative attitudes respectively. In Switzerland and Austria, dread risks and distrust explained most of the variance in perceived risks (Siegrist et al., 2007). Other research has suggested that respondents' values mainly determine attitudes towards nanotechnology (Kahan et al., 2009; Priest and Greenhalgh, 2012). For The Netherlands, it is not yet known how nanotechnology is perceived and which factors influence Dutch risk perceptions and attitudes.

Within the Dutch context, since 2004, various parties have advised the need for a public dialogue on nanotechnology (Hanssen et al., 2008; Van Est et al., 2004). In 2009, the government decided to organise a public debate in The Netherlands about nanotechnology, which took place in 2010, aimed at engaging the Dutch public with nanotechnology and to discuss with a wide a range of stakeholders the possible risks and benefits of applications (Van der Hoeven, 2009). The Committee for the Societal Dialogue on Nanotechnology in The Netherlands decided to open up the agenda for initiatives from all societal stakeholders. Via the virtual network Nanopodium, these stakeholders could apply for grants to organise activities that stimulated public debate or informed the public about nanotechnology. Within this framework, a national collaboration of Dutch science cafés and a debating centre organised a series of five debates about nanotechnology and its possible applications. The project was called 'The Nanotrail'.

In science cafés, scientists, stakeholders and the public can meet in an informal environment and participate in discussions about science (Dallas, 1999, 2006). Increasingly, in the United Kingdom and The Netherlands, scientific cafés are organised as a way to encourage an open dialogue between members of the public and stakeholders to express their opinions and attitudes on a wide variety of scientific and technological topics. In The Netherlands, just as in most countries, mainly volunteers organise these activities and, although never thoroughly investigated, it is assumed that science cafés attract people that are interested in science and technology issues.

In their study about attitudes towards nanotechnology news, Priest and Greenhalgh (2012) introduced the concept of 'attitudinal communities', which, according to them, refers to groups of people who share key attitudes towards a topic. In our study, we see science café participants as such a group sharing key attitudes. As the majority of the Dutch still do not know what nanotechnology is about (Nanopodium, 2009, 2010; Swierstra et al., 2011), and therefore, analysis of their attitude would be quite complicated to interpret, this specific study, which analysed an attitudinal community, provides valuable insight in perceptions and values that contribute to that attitude.

Thus, this study examined quantitatively the perceptions and attitudes of participants who attended a science café discussion on nanotechnology. By comparing these responses with those of a public, also interested in science and technology, but who did not attend these specific café meetings, we could examine differences between the groups, which provides more insight into what aspects influence attitudes and perceptions towards nanotechnology in general. Furthermore, we contextualised and enriched the quantitative findings by analysing the science café meetings qualitatively (cf. Bauer et al., 2007). As far as we know, this research is one of the first studies in The Netherlands that has explored public risk perceptions and attitudes regarding nanotechnology within a science café public.

2. Methods

Our research used both quantitative and qualitative methodology. According to Cormick (2009), a mixed methods approach contributes to a better analysis of factors influencing perceptions and attitudes of nanotechnology. Quantitative data were collected by means of a survey handed out during the meetings. Qualitative data were collected by means of recording the meetings and transcribing the conversations. In addition, a second set of quantitative data was collected by asking members of mailing lists of the science cafés and the debating centre – addressing people who are interested in science and technology issues as well, but who did not attend one of the meetings – to fill in the same questionnaire.

The meetings took place in five places in The Netherlands with scientists speaking about different aspects of nanotechnology and its possible applications. The first meeting was held on December 15th, 2009, in Nijmegen, the last was held on 8 April 2010, in Zeist. Other towns where the meetings took place were Rotterdam, Deventer and Leiden. The organisational setup of each of the meetings was comparable, starting with a lecture and continuing with a discussion after the break. All meetings could be followed via the Internet in a life-stream connection. Key speakers were all scientists working on an aspect of nanotechnology at one of the universities in The Netherlands. The meetings had an informal character and were open to the general public, free of cost.

The number of participants varied from 75 persons to 120 persons per meeting. A total of 455 persons visited at least one of the meetings with a total of 251 respondents (Science Café (SC) group) filling in the questionnaire (response rate = 55%). The high response rate may be explained by a higher interest in, and therefore willingness to co-operate in, (social) scientific research. The response rate of the digital survey was – as expected – much lower (5%), and 415 questionnaires (Digital group) were useful for analysis.

Quantitative measures

Our questionnaire consisted of various measures asking for respondents' (risk) perceptions and attitudes of nanotechnology and related topics and demographic variables. The measures were derived from previous research on risk perceptions of other technologies (see Dijkstra, 2008; Dijkstra et al., 2012; Pin, 2009). Accompanying all items was a 5-point Likert-type scale. For all measures, a factor analysis by means of a principal component analysis (PCA) was conducted and a reliability analysis was performed to indicate internal consistency.

General attitude towards nanotechnology consisted of four items in which respondents could indicate how they perceive developments in nanotechnology: if they feel attracted to developments, think that developments are important, feel involved with developments or are personally interested in developments (1 = Strongly disagree and 5 = Strongly agree). Factor analysis revealed a single factor for all items (with 62% of the variance explained and strong factor loadings ranging between .69 and .84). Thus items were averaged to obtain an overall attitude score ($\alpha = .79$).

Benefits and risks were assessed by four items asking for respondents' perceived benefits and risks for themselves, the average Dutch, society as a whole and future generations (1 = Mostly cons and 5 = Mostly pros). Factor analysis suggested a single factor (variance explained = 81%; loadings between .86 and .93). An overall risk perception score was obtained ($\alpha = .92$).

Feelings consisted of six items asking for feelings of enthusiasm, being at ease, trustfulness, tension, fear and worries (1 = Strongly disagree and 5 = Strongly agree). A factor analysis

revealed a single factor (variance explained = 68%; loadings between .48 and .89). Scores for the negative feelings were recoded and a total feelings score was constructed (α = .82).

Perceptions of nanotechnology consisted of six items asking if respondents perceived applying nanotechnologies as useful, safe, valuable, risky, positive and desirable (1 = Strongly disagree and 5 = Strongly agree). A PCA with oblimin rotation suggested two factors, the first explaining 62% of the variance, and the second, 19%. All items except 'risky' loaded onto the first factor (range = .44–.94), and the items 'risky' (.95) and 'safe' (−.61) loaded significantly onto the second factor. Since the factor loading for the item 'safe' on the first factor was relatively low (.44) and theoretically related to risk, we created two scales. Scores for the items useful, valuable, positive and desirable were averaged to obtain a scale where high scores represented a perception that nanotechnology applications will be positive (α = .93). Scores for the items safe (reverse scored) and risk were averaged to obtain a measure of perceived risk or a belief that nanotechnology applications will be risky ($r = .40$, $p < .001$**).

Trust in nanotechnology actors assessed trust in organisations or groups of people with four items asking whether respondents trusted organisations or groups of people when they assess the consequences of nanotechnology in an independent way, when they look at the consequences of nanotechnology from different angles, when they clearly indicate which interests they have in nanotechnology and when they communicate in an open way about nanotechnology (1 = Strongly disagree and 5 = Strongly agree). The items represented one factor (variance explained = 72%, range = .79–.87) and a trust scale was obtained by averaging the items (α = .87).

General trust in potential sources of information about nanotechnology consisted of nine items asking for trust in various types of organisations or people (1 = Trust not at all and 5 = Trust very much). A PCA using oblimin rotation suggested three factors which explained 36%, 18% and 13% of the variance, respectively. The first factor included organisations that we could label as 'other expert stakeholders' (universities, medical specialists, general practitioners, government), the second factor represented trust in communications (television, Internet, newspapers) and the third involved industrial connections (industry, researchers/scientists working for industry). Three scales were created to reflect trust in experts (α = .72), communications (α = .76) and industry ($r = .70$, $p < .001$**).

Self-efficacy consisted of five items asking how respondents would handle possible risks of nanotechnology, that is, if people considered themselves able to search for relevant information, able to anticipate possible risks, able to protect oneself against risks, able to react adequate when something goes wrong or able to help others if needed (1 = Strongly disagree and 5 = Strongly agree). A PCA revealed one factor (variance explaining = 69%; factor loadings between .58 and .91). A self-efficacy scale was created (α = .89).

Information search consisted of three items asking the chance that someone would search for information about nanotechnology, the chance to keep an eye on information about nanotechnology and the chance to search for the latest news in the future (1 = Very small and 5 = Very big). One factor was obtained from a PCA (variance explained 78%; factor loadings between .88 and .90). An information search scale was created where a high score represented a high tendency to search for information on nanotechnology in the future (α = .86).

Qualitative data analysis

For the qualitative analysis, the café meetings were transcribed verbally. Each meeting, except one,[1] lasted approximately 2 hours, including the break. We analysed the meetings in steps. We analysed the part before the break where the speakers gave their presentation. Major themes in the

presentations were distinguished followed by underlying topics and arguments. The same was done for the part after the break where the participants could ask questions. Finally, we grouped topics and arguments. Our interpretation was based on a contextual and iterative analysis rather than on frequencies. According to Kidd and Parshall (2000), validity of the analysis is enhanced following an iterative process when analysing focus groups which we believed can be applied to the discussions that take place in science café meetings.

3. Results

Quantitative analysis of public risk perceptions of nanotechnology

A missing value analysis on all 41 quantitative items revealed that the pattern of missing responses was completely at random (Little's Missing Completely at Random (MCAR) test was not significant at $p < .001$). After removing cases that did not provide answers to more than 70% of all 41 items (SC group: $n = 26$; Digital group: $n = 37$), missing values were estimated using the expectation-maximization (EM) estimation procedure in SPSS for all 41 items. A total of 233 cases in the SC group and 378 in the Digital group remained for use in all subsequent analyses ($n = 612$).

Both groups were compared on all demographic and background items. The groups were statistically similar in terms of age, marital status, parental status, education, the frequency with which they had heard of nanotechnology and whether or not they had previously participated in or organised a meeting about nanotechnology. The groups were, however, different on some background variables. The SC group compared to the Digital group consisted of significantly more males than expected, χ^2 (1) = 17.35, $p < .001$; less full-time workers and students and more pensioners, χ^2 (5) = 17.34, $p < .001$; and less socially, $t(1,610) = -2.40$, $p < .05$, and politically active individuals, $t(1,602) = -3.78$, $p < .001$. The SC group were also more likely to have previously searched for information about nanotechnology, $t(1,602) = 3.10$, $p < .005$; to have talked about it to others, $t(1,595) = 2.58$, $p < .05$; and to have previously attended a public hearing or lecture on nanotechnology, $t(1,595) = 3.73$, $p < .05$. Finally, 37% of the SC group visited the science café meeting for the first time, 36% previously visited scientific café discussions between two and five times and 27% were regular visitors (i.e. attended meetings more than five times).

To assess the differences in perceptions between the groups, a series of analysis of covariances (ANCOVAs) were calculated using the quantitative variables as dependent variables. Background variables that were different across the two groups were used as covariates in all analyses: that is, gender, social and political involvement, and frequency of searching for information before the café meeting, talking to others and attending public meetings about nanotechnology.[2] There were a total of 575 cases in all analyses (SC group = 205, Digital group = 370). The means for each dependent variable are shown in Figure 1.

As shown, means for most variables are above the midpoint of the scale of 3 for both groups, which indicates a positive judgement and valuing of nanotechnology. Only trust in industry was below the midpoint of 3 for both groups, while the means for self-efficacy were at the midpoint and risk applications were just rated above the midpoint.

Furthermore, Figure 1 shows that after controlling for the differences in the demographic variables, the SC group reported more positive general attitudes towards nanotechnology, $F(1,567) = 32.28$, $p < .001$, $\eta^2 = .05$; saw significantly more positive applications, $F(1,567) = 5.01$, $p < .05$, $\eta^2 = .01$; and were more likely to search for information on nanotechnology, $F(1,567) = 32.14$, $p < .001$, $\eta^2 = .05$ than the Digital group. Interestingly, there was a trend towards the Digital group trusting the expert stakeholders more than those who attended the café, $F(1,567) = 3.58$, $p < .10$,

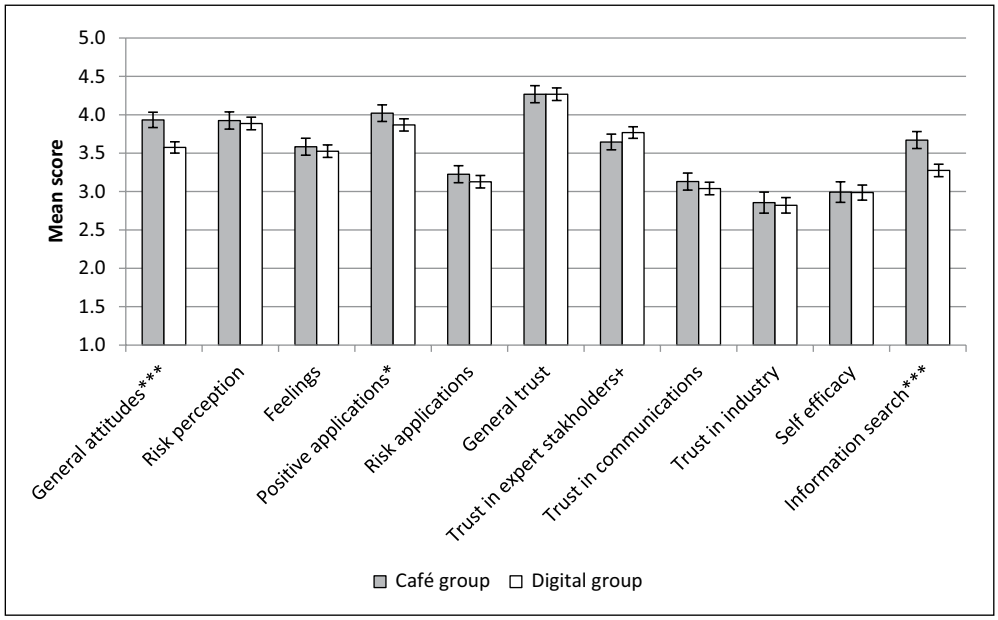

Figure 1. Graph representing means of each dependent variable.

$\eta^2 = .01$. There were no significant differences between the groups in terms of their perception of general nanotechnology risks or applications, feelings about nanotechnology and self-efficacy. There were also no differences in general trust and trust towards communicators or industry scientists. Overall, the results suggest that both groups' general attitudes and perceptions towards nanotechnology are positive, while the science café participants hold even more positive attitudes: they see more positive applications of nanotechnology and more often they will search for information in the future.

Predicting attitudes towards nanotechnology across both groups

To assess the unique impact of each variable on general attitudes, a hierarchical multiple regression equation was computed for each group separately. The first step included those variables where differences were found between the two groups (i.e. gender, social and political involvement, frequency of searching for information prior to the café, talking to others and attending public meetings about nanotechnology), and the second step included those variables that are thought to determine attitudes towards nanotechnology (i.e. risk/benefit perceptions, feelings, positive and negative applications and trust) and variables that are thought to relate to these attitudes (self-efficacy and intention to search for information in the future). Pearson's correlations between all variables used in the model are shown in Table 1 and the results of the regression analyses are shown in Table 2.

The correlations in Table 1 show that a more positive *general* attitude towards nanotechnology (in both groups) was significantly (and strongly) associated with increased perceived benefits and positive applications, and with more positive feelings. General positive attitudes were also moderately significantly associated with a belief that nanotechnology will not lead to negative applications for the SC group but not for the Digital group. Positive attitudes were also associated with higher general trust and trust in stakeholders and communicators for the SC group but not for the

Table 1. Pearson's correlation coefficient, mean and standard deviation for all variables across the groups.

		1	2	3	4	5	6	7	8	9	10	11
1	General attitudes		.32***	.36***	.44***	−.18**	.18**	.18**	.17**	.12	.23**	.43***
2	Risk perception	.43***		.51***	.62***	−.34***	.10	.16*	.20**	.33***	.24***	.18**
3	Feelings	.35***	.65***		.62***	−.55***	.02	.17*	.07	.34***	.28***	.04
4	Positive applications	.54***	.75***	.67***		−.42***	.20**	.31***	.23**	.41***	.28***	.17**
5	Risk applications	−.07	−.45***	−.56***	−.37***		.01	−.10	−.04	−.29***	−.31***	.02
6	General trust	.08	.04	.06	.12+	.08		.25***	.22**	.15**	.25***	.21**
7	Trust in expert stakeholders	.03	.25***	.24***	.23***	−.16*	.19**		.23***	.42	.16*	.04
8	Trust in communications	.04	.05	.10	.06	−.08	.16*	.31**		.20**	.09	.15*
9	Trust in industry	.21***	.38***	.44***	.38***	−.35***	.02	.42***	.29***		.32***	−.01
10	Self-efficacy	.22***	.32***	.45***	.33***	−.47***	.09	.25***	.22***	.33***		.23***
11	Information search	.30***	.07	−.01	.10	.09	.19***	−.02	.13*	−.01	.16**	
	Mean											
	SC Group	4.03	4.00	3.69	4.11	3.19	4.26	3.66	3.11	2.98	3.03	3.66
	Digital	3.53	3.84	3.49	3.83	3.14	4.28	3.78	3.07	2.79	2.98	3.28
	SD											
	SC group	.69	.82	.77	.70	.76	.75	.68	.81	.96	.92	.77
	Digital group	.86	.80	.80	.81	.77	.76	.72	.77	.97	.93	.80

SD: standard deviation; SC: Science Café.
Coefficients in the upper diagonal are the SC group and in the lower diagonal are the Digital group. $N = 612$. Range for all variables was 1–5.
$^{+}p < .05$, $^{*}p < .01$; $^{**}p < .01$; $^{***}p < .001$.

Table 2. Regression coefficients for predictors of general attitude towards nanotechnology across groups.

IV	Beta		*SE*		Beta	
	SC	Digital	SC	Digital	SC	Digital
Step 1						
(Constant)	3.46	3.22	.23	.22		
Gender	−.18	−.33	.10	.08	−.12	−.19***
Social involvement	.06	−.02	.05	.05	.09	−.02
Political involvement	.02	.01	.05	.05	.04	.01
Searching for information	.12	.17	.05	.05	.22*	.22***
Talking to others	.08	.19	.05	.05	.15	.24***
Attending public meetings	.05	.06	.05	.05	.08	.07
Step 2						
(Constant)	.95	−.52	.49	.43		
Gender	−.10	−.09	.09	.07	−.07	−.05
Social involvement	.02	.01	.05	.04	.03	.01
Political involvement	.04	.03	.05	.04	.05	.03
Searching for information	.07	.13	.04	.04	.14	.17***
Talking to others	.08	.13	.05	.04	.14	.16**
Attending public meetings	.04	.12	.05	.05	.07	.12**
Benefit/risk perception	.05	.13	.06	.07	.06	.12**
Feelings	.09	.06	.07	.06	.11	.05
Positive applications	.20	.40	.08	.07	.22*	.38***
Risk applications	−.01	.21	.06	.05	−.01	.19***
General trust	.04	−.03	.05	.04	.04	−.03
Trust in stakeholders	.10	−.07	.06	.05	.11	−.06
Trust in communications	.04	.04	.05	.05	.04	.04
Trust in industry	−.07	.01	.05	.04	−.10	.01
Self-efficacy	.01	.07	.05	.04	.01	.07
Intention to search	.23	.19	.05	.04	.27***	.18***

SE: standard error; SC: Science Café.
$N = 612$.
*$p < .05$; **$p < .01$; ***$p < .001$.

Digital group. More positive attitudes were significantly associated with higher trust in industry for the Digital group. Finally, increased self-efficacy and intention to search for information were significantly associated with more positive attitudes for both groups.

The results in Table 2 suggest that the variables that uniquely predict attitudes were similar across both groups with some exceptions. For the SC group and the Digital group, the most important predictor of their attitude towards nanotechnology was positive applications. Thus more positive attitudes were associated with the belief that nanotechnology would result in positive applications for both groups. Interestingly, the perception that the technology would lead to risk applications was only predictive of attitudes for the Digital group. Those who attended the café did not base their attitude on whether or not they perceived nanotechnology leading to risk applications. In addition, the intention to search for information in the future was associated with attitudes in both groups. Attitudes of the Digital group were also influenced by past behaviour reflected by

the items searching for information (in the past), talking to others and attending public meetings, meaning that the more active behaviour respondents showed in the past, the more this reported behaviour influenced their attitude towards nanotechnology. Finally, risk/benefit perceptions influenced attitudes of the Digital group, thus the more benefits they perceived, the more positive attitudes were shown.

Overall, the results suggest that attitudes for both groups are positive with mostly the same factors contributing to this attitude. The groups can be considered attitudinal communities sharing key attitudes towards – in this situation – nanotechnology. However, risks play a larger role in the way the Digital group's attitudes are composed.

Providing context of attitudes and risk perceptions

In this section, the results of the qualitative analysis of themes and arguments related to attitudes and risk perceptions are presented. Below, we first describe major themes brought up by the speakers and the type of questions asked by participants during the discussions. Thereupon, we present findings of two themes that can enrich our understanding of attitudes and risk perceptions: how speakers and participants discuss risks and benefits of nanotechnology and what need for dialogue they see because of the risks. Speakers and participants are identified by the meeting they contributed to, and when it concerns quotes, the line in the transcriptions identifies who contributes to the discussion. The setting of a science café does not allow for further identification of the participants.

Major themes and questions. All speakers introduced nanotechnology in general and discussed definitions of nanotechnology. Thereupon, most speakers focused on health and medical applications, often starting with explaining issues about their research. One of the speakers explicitly discussed the way government and policy makers take decisions about nanotechnology (Meeting 1). Another speaker (Meeting 3) started from an environmental perspective and the question of risks for the environment that can be expected. A third speaker (Meeting 4), also starting from a basic scientific perspective, discussed developments in synthetic biology and emphasised the usefulness and urgency for a societal public debate about nanotechnology. The speakers brought up a variety of themes and topics related to their various backgrounds and their areas of expertise. Topics varied from fundamental research about the workings of a part of a cell (Meeting 2) to very specific and concrete applications such as the lab-on-a-chip technology (Meeting 5), and experiments to test behaviour of nanoparticles in the environment (Meeting 3).

During the discussions, at each meeting, café participants asked questions mainly to clarify possible scientific aspects of nanotechnology. In addition, at each meeting various questions related to societal aspects were brought up. These questions varied strongly from the need for attention for benefits and unknown risks (discussed in various meetings) to questions regarding environmental aspects (Meeting 3) or the role of action groups against nanotechnology (Meeting 5).

Risks and benefits of nanotechnology research discussed. A first theme we identified is the way risks and benefits are discussed at the meetings. At all meetings, during the discussions, participants asked various questions regarding *risks and safety aspects*. In addition, all but one of the speakers explicitly mentioned that current developments are surrounded with uncertainties regarding risks of nanotechnology. At the meeting where the speaker did not introduce the risk theme, a café participant asked for the scientist's opinions about risks. However, the scientist did not consider this a topic for discussion and stated that the risks of nanotechnology would not differ from other technologies:

Participant: I wonder if you could tell something about the hazards of nanotechnology? […].
Speaker: […] My opinions are not much more informed than yours. Certainly, the things I talked about had to do with applying tools that can observe things on a nano scale. And those tools are, of course, not much of a danger to us. They are less of a danger to us than other things we use in the laboratory. I think, a lot of the questions about the safety of nanotechnology, will relate to particles that can be made, very small particles of metals or something like that. And, I don't know any more than you do probably about how those affect living things. […] There are many dangers that we accept in our day to day life, and my personal feeling about them, not based on any more information than you have or anyone else in this room is really that nanotechnology is no more or less dangerous than other things developed […]. (Meeting 2: 263–268)

This position is not shared by the other speakers in the other meetings who all considered risks a topic related to nanotechnology research, and all emphasised some need to discuss risks or inform people about these risks.

Both participants and speakers brought up various times *fear for unknown risks* as a related topic (Meeting 1, 3–5), and a comparison with other technologies, such as biotechnology, asbestos and ultrafine particles, was made. For example,

Speaker: Well, I am telling about the possibilities of nanotechnology and the benefits nano offers. New materials, new characteristics. But, of course, also risks are involved. Some of you might have heard of that. […] Thus, one has to be careful with inhaling small particles that can reach the cells and cause cancer. That is, of course, the image of fear that for everyone is related to asbestos. […] Therefore, one has to be very careful. (Meeting 5: 48)

Or, as one participant asked,

Participant: What determines the toxicity of nanotechnology?
Speaker: Small particles can build up in your body, and your body reacts to these particles, as happens with asbestos. For nanoparticles this could happen as well, but if and how this occurs is still not clear. That is why it is important to study […]. (Meeting 1: 102–103)

At the same time, the former speaker pled for *weighing up the pros and cons* as he said,

Speaker: … It is not possible to put everything into the same box. Thus, that nano is dangerous or nano is safe. No, one should very carefully study what characteristics are and try to identify its toxicity. We are with others working in the US to work out how to test that. (Meeting 5: 50)

Analysing risks is what other speakers also want. Risks should be 'proactively investigated', as one speaker (Meeting 3:183) added. And, in contrast to the public debate about biotechnology, which was referred to various times, both speakers and science café participants not only emphasised the necessity of a public debate about risks but also put *emphasis on the benefits* these new developments can bring. The following example exemplifies this:

Participant: Is there a reason to be more worried about nanotechnology than about microtechnology?
Speaker: The difference is a factor of 1000 times. Your need to be worried depends on the perspective that you take. Microtechnology, just as nanotechnology, also offers opportunities. (Meeting 1: 138–139)

The speaker continued and emphasised that the risks are estimated to be moderate; however, he argued that it is always necessary to stay alert and not to try something out of the blue. It is needed to guide developments carefully and to analyse risks. This is the lesson learned from the biotechnology acceptance, he said. Still, the speaker expected less discussion in the case of nanotechnology, since these applications influence our lives less directly. The discussion continued with a question from the moderator:

Moderator: Does the discussion about nanotechnology seem less concerned? Is that really the case?
Speaker: The difference is also partly due to a different feeling about it. Gene technology influences also the building blocks of life […]. …while, at the moment, nanotechnology is mostly referred to in relation to microtechnology.
Moderator: Does one have to be afraid of nanotechnology?
Speaker: Nanotechnology also offers opportunities. In the area of safety, when developing new medicines […]. (Meeting 1: 143–147)

Thus, in this meeting, feelings for gene technology and nanotechnology are perceived differently and the participant seems open to the suggestion that nanotechnology also offers benefits. In another meeting, one of the participants explicitly wanted to focus on benefits as well:

Speaker: I hold the opinion that we should use the possibilities of nanoparticles, but at the same time should review that there are possible risks involved as well. […] At the moment that we that we tell positive stories about applications and in five years it appears to be risky, then it is more difficult to have the technology accepted. It is better to deal with risks immediately and I am convinced that applications will be better accepted. […]
Participant: Do we not focus too much on the possible dangers? (Meeting 3: 210–214)

In sum, both speakers and science café participants discussed various aspects of risks and benefits. They argued that these themes and questions should be taken seriously, and it is clear that risks differ for various applications and are perceived differently by various groups of people. At the same time, both speakers and participants stated that regardless of the risks, developments should be possible now and in the future.

The need for dialogue discussed. A second theme we distinguished related to the need for societal dialogue because of the unknown risks. All speakers but one, more than once, explicitly paid attention to the *urgency and the usefulness of societal discussion and public dialogue*. According to the speakers, a dialogue can help to gain more insight into the acceptance of nanotechnology. For example,

Speaker: Nanotechnology develops itself in a revolutionary way. One of the ways to handle that development with care is to ask questions and to start a dialogue. (Meeting 1: 52)

Another speaker explicitly referred to the acceptance for nanotechnology and formulated the need for dialogue as follows:

> Speaker: … That is why it is needed to organise more meetings as these [science cafés] where it is possible to exchange information. In the end, it is important to know where we base our risk analyses on. And, to know what we accept and what we do not accept. It is clear that there are risks involved, but what risks do we accept and what risks are unacceptable? (Meeting 3: 136)

How this dialogue should be shaped according to the speakers differed somewhat between them, varying from informing people at science café meetings as the speaker above said to aiming at education programmes at schools (Meeting 5) and organising a dialogue by means of collecting and formulating questions about which society is concerned (Meetings 1, 4). In three meetings out of five, speakers explicitly discussed the role of governmental actors in the decision-making process (Meetings 1, 3, 4). Several times, a role was distributed to the Dutch Rathenau Institute, a policy advisory institute which started to pay attention to nanotechnology from 2003 onwards (Meetings 1, 4).

Although most speakers supported the need for dialogue about developments with societal actors, not all speakers considered themselves capable of fulfilling this *expert role*. One scientist argued that he lacked the expertise:

> Speaker: Finally, I want to talk about the significance for society. One has to be aware that nanotechnology, bio, synthetic biology, it is all in a stage of research. So, I always feel hardly competent to act in the broad societal discussion in society. It is if you predict panoramic views of 30 years ahead. […] I find that very difficult … (Meeting 4: 137)

Topics to be discussed within society related to *risks* and the *fear* felt for some applications, while some speakers emphasised the need to broaden the risk theme to other questions (Meetings 3–5). The possibility to stop developments was discussed (Meeting 4), while the need to listen to ethical issues and other broader societal questions were several times mentioned (Meetings 1, 4). Also a reference was made to learn from the mistakes with biotechnology (Meeting 4). All speakers emphasised that one need not be afraid, in contrast to the world depicted by Michael Crichton in the book Prey (Meeting 1) and *benefits* should be included as well. In one meeting, the *precautionary principle* – being able to stop research activities when needed – was mentioned as a way to control research (Meeting 4).

In sum, all but one of the speakers considered discussion about nanotechnology necessary, with and within society. Understanding risks is a reason, among others, to discuss risks and to get to know what risks are acceptable or not. Discussion of benefits should be included according to the speakers and some participants.

Overall, the qualitative analysis of the science café meetings showed that speakers and participants discussed both technological and societal aspects of nanotechnology. Science café participants indicated – next to asking clarifying questions – that they wanted to discuss issues of risks *and* benefits. Also most speakers emphasised the need to discuss risks and related topics – or inform others about or educate them – in order to know better what risks are acceptable or not.

4. Discussion

In this study, we analysed perceptions and attitudes about nanotechnology of a Dutch science café public and compared these with those of a non-attending public also interested in science and

technology. In addition, analysis of the meetings contextualised these perceptions and attitudes. The results form the basis for one of the first analyses of public risk perceptions and attitudes towards nanotechnology in The Netherlands and it is the first that has analysed science café participants' attitudes.

First, as found in most other US survey studies (cf. Bainbridge, 2002; Currall et al., 2006; Siegrist et al., 2007), both groups showed positive attitudes and perceptions towards nanotechnology and therefore shared some of the same key attitudes (Priest and Greenhalgh, 2012). We would suggest further research of such attitudinal communities, as this can provide valuable information about attitudes, especially since a majority still do not know what the technology entails. Furthermore, group comparisons showed that science café participants' general attitudes were significantly more positive than those of the Digital group. The SC group saw more positive applications and were more likely to search for information on nanotechnology after attendance, while the results suggest that the Digital group saw more risky applications. Investigating causes for these differences in more detail would be of interest for understanding how attitudes are formed since it is also known that greater familiarity with nanotechnology does not automatically lead to more positive views but may lead to more polarised views (Kahan et al., 2009).

Second, the qualitative data contextualise attitudes and risk perceptions of nanotechnology. The qualitative analysis provided more nuanced information about what themes and topics were regarded important as well as how both speakers and participants considered these. At the meetings, frequently, it was argued by both speakers and participants that attention to the risks *and* benefits of nanotechnology was important. This was the case both in meetings where no attention (from the speaker) for risks was given and in meetings where a participant asked to focus more on benefits as well. Thus, although the quantitative data showed positive risk perceptions, participants still wanted to discuss the risk theme and made various comments regarding risks and benefits of nanotechnology. We would therefore argue, in line with Currall et al. (2006), that risks and benefits must be addressed together since both influence the formation of perceptions and attitudes. Both speakers and participants agreed that discussion with society is needed to understand risks and related topics and how they are accepted.

Third, in the café meetings, aspects of nanotechnology were presented and discussed. The science cafés offered possibilities for engagement for an interested public. In this article, we did not present data that specifically analysed how participants consider these possibilities for engagement, although the data showed that both speakers and participants considered the possibility to discuss issues important for understanding risks. For a specific public, science cafés offer a place for debate and information. However, how exactly science cafés contribute to a continuing debate about nanotechnology or other technologies should be further explored. Offering engagement possibilities, such as in science cafés, is in line with research that showed that some groups of people demand an active role when it concerns new technologies (Dijkstra et al., 2012). However, at the same time, these findings also suggest that although people want information to be available, not everyone wants to participate all the time. Thus, although participation as a mechanism is often regarded in literature as a key solution to enhance decision-making, some considerations need to be taken into account. For example, Davies et al. (2009) distinguished two types of public engagement: one that influences policy making and one that does not. Davies et al. (2009) argued that the value of non-policy dialogues, such as science cafés, lies in having learning outcomes at the level of individuals (see also, Felt and Fochler, 2010) rather than influencing policy at the level of institutions which is one of the criteria Wilsdon and Willis (2004) proposed. In addition, Jasanoff (2011) and Pestre (2008) criticise public engagement that influences policy making when it has disconnected facts and values (Jasanoff, 2011) or when dialogue is used to support technological progress (Pestre, 2008). Therefore, these authors call for further analysis of this complex and entangled science–society

relationship. All in all, obtaining more insight in the multidimensional aspects of engagement to understand the changing science–society relationship better is welcomed.

To conclude, this study describes perceptions and attitudes of a specific Dutch public interested in science and technology and provides preliminary insight in what influences these Dutch perceptions and attitudes. A further step important for better understanding the process of engagement in this situation could be to more precisely analyse factors that drive Dutch public perception and attitudes, as Currall (2009) argues. Next to more qualitative research that can analyse factors in more depth, for example, longitudinal studies representative of the Dutch population could add to this knowledge.

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Notes

1. This meeting lasted 1.5 hours.
2. Although the Science Café (SC) group was found to have higher numbers of retired and lower numbers of students and full-time workers than the digital group, this variable was not used as a covariate. Gender was significantly associated with this variable, in that males in this sample were more likely to be pensioners and females more likely to be students, χ^2 (5) = 38.01, $p < .001$. Thus controlling for gender was assumed to account for differences across the groups in professional status. In addition, all dependent variables were not significantly different across professional groups, apart from one exception where housewives or house husbands had slightly more positive general attitudes towards nanotechnology than all other professional categories, $F(5,604) = 2.63$, $p < .05$.

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