Gender differences in the evaluation of a risky technology

Empirical research on the human evaluation of nanotechnology

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Abstract

Research has been done on the gender differences in the evaluation of nanotechnology by Dutch TU Delft students. The research was executed using a questionnaire which was designed to examine if there are gender differences in the judgement of nanotechnology and if so, which variables play a significant role in this causal relations. Based on the factor analyses of the collected data, structural equation models (SEM) were estimated for the data of the whole sample, for the data of men and for the data of women. The analyses included the following 15 variables: gender, level of science education, studying nanotechnology, age, evaluation of nanotechnology, health and environmental effects, economical benefits, costs, level of trust in the government, level of trust in the industry's concern with the environment, level of trust in the industry's concern with safety, positive affect, negative affect, subjective knowledge, objective knowledge.

The estimated SEMs showed that there is a significant gender difference in the evaluation of nanotechnology, as men evaluate nanotechnology more positive than women. This gender difference is largely explained by the variable on the expected effects of nanotechnology on health and environment. Other variables that have a significant effect on the evaluation of nanotechnology in the overall model are: age, gender, education, if the respondent has studied nanotechnology, trust in the industry's concern with the environment. It was also found that the variable gender affects several relations between variables, meaning that the relation between these variables is different for men and women. The variables of which the direct relation with the evaluation of nanotechnology is affected by gender are 'trust in the industry's concern with the environment', 'expected costs' and 'studying nanotechnology'.

The outcomes of this research suggest that it is essential to include women in the boards of the development of risky technologies. Women are for example less positive about the effects of nanotechnology on the health and environment, indicating that women pay more attention to the negative effects of the technology which makes them essential for responsible innovation. The results furthermore indicate that future research on the evaluation of risky technologies should take the underlying relations and variables into account because gender can influence the relations between the variables which results in different SEM's for men and women.

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1 Introduction

This introductory chapter will discuss the underlying motivation for this research, on the gender differences in the evaluation of a risky technology, and it will discuss the problem that it aims to solve.

1.1 Background

Averil Macdonald, who is an emeritus professor of science engagement at the University of Reading and current chairwoman of UK Onshore Oil and Gas, found that men are almost twice as likely to support shale gas then women. The research of the University of Nottingham also showed that only 65 per cent of the women knew that shale gas is the fossil fuel that is produced by fracking vs. 85 per cent of the men. These were the results of a survey among almost 7000 people in the UK and Prof Macdonald argued that women are concerned about fracking technology, but that they often lack the scientific understanding of the topic. She stated that "women don't take issues on trust" and "Scientific language does not resonate with them [women]. They do not engage with it. What they do connect with is the impact they think science or technology will have on them and their family". Prof Macdonald also said that the UK is "extremely bad at encouraging women to engage with science" and she pleads for more science education [1][1], [2][2].

Averil Macdonald got criticized in the media for these claims and she was accused of reinforcing sexist stereotypes [3], [4]. It has, however, been found that women and men do evaluate a new risky technology differently to some extent [5], but no unambiguous explanation for this difference in evaluation has been formulated. It could be, like Averil Macdonald said, due to the fact that women don't take issues on trust and that they have had less science education and therefore have less knowledge of technologies. Studies have suggested that there are other variables than a difference in knowledge level and trust that result in differences between males and females when evaluating a technology. It can for example be related to differences in emotions, values etc. [6], [7], [8], [9].

A better understanding of whether there are gender differences in the overall evaluation of novel technologies and if so, why, could help with the acceptance and development of fracking and with the responsible development and acceptance of any other risky technology that is introduced onto the market. Where a risky technology is a technology that comprises a relatively high probability of: damage, injury, loss or any other negative occurrence. With the overall evaluation is meant what the overall opinion of people is about nanotechnology and in the rest of this paper the overall evaluation will also be indicated with the word 'evaluation'.

Due to the fact that this research is executed in The Netherlands where shale gas is not being extracted and will not be extracted until 2023 [10], this research examines gender differences in the evaluation of a different risky technology. Nanotechnology is

[1] http://www.telegraph.co.uk/news/earth/energy/fracking/11949613/Women-dont-understand-fracking-leading-scientist-claims.html
[2] https://www.theguardian.com/commentisfree/2015/oct/23/fracking-shale-gas-women

the risky technology that was selected for this research since it is already being used in The Netherlands and in addition literature suggests that there are gender differences in the evaluation of nanotechnology.

1.2 Research Problem

The research problem with which this thesis is concerned is about the ambiguity of the influence of gender on the evaluation of risky technologies. Many studies have examined the influence of gender on risk assessment and on the evaluation of risky technologies but only a few have examined the underlying reasons [6], [25], [26]. Studies on the underlying reasons for the gender difference in the overall evaluation of nanotechnology even seem to be non-existent in literature. This thesis therefore aims to provide a better understanding of the underlying relations between the overall evaluation of nanotechnology and other variables including gender. This research can thereby provide insights on the direct and indirect influence of gender on the evaluation of nanotechnology.

1.2.1 Practical problems

The most important practical problem that is related to the research problem is that the concerns of citizens can be well-grounded. Concerns that are well-grounded should be taken into account by the company that introduces the risky technology and the company should use these concerns to develop a more responsible technology. Therefore it is important to pay more attention to these concerns and since women are underrepresented on boards of companies, their concerns may be neglected [11], [12]. Industry is suffering from another practical problem which arises when a risky technology is introduced on the market and if opposition of citizens forms a barrier which results in a delay of the implementation. Delay of implementation always results in additional costs for either the company in charge or the government as was also the case with fracking in the UK [10].

A better understanding of the impact that the demographic factor gender has on the evaluation of a risky technology could be used to both increase the acceptance and generate more responsible technologies as women may contribute a valuable but different point of view than men.

1.3 Research Objective

The term 'risky technology' is a very general term, and due to the fact that a limited amount of time is available for this research project it was chosen to focus on one risky technology. The risky technology that was selected is nanotechnology because literature already suggests that there are gender differences in the evaluation of this technology [13], [14], [15] .

Nanotechnology is a technology that works with particles between 1 nanometer (nm) and 100 nm in size[3]. This technology has recently been introduced in The Netherlands and it is a good example of a risky technology since it is controversial, relatively new and citizens perceive it as risky [14], [15]. Arguments of opponents are mainly based on the concerns that it is known that nanoparticles can behave differently than large-sized particles of the same chemical substance, but the exact effect of this

[3] To put this in perspective: a human hair has a width of 80.000 nm [71]

different behaviour is not known. On cellular level, for example, nanoparticles can potentially easily enter cells and impede or affect vital cellular functions [16], [17]. But on the other hand, nanotechnology also creates new opportunities and advantages like better treatment and diagnostic tools in healthcare [18], [19]. So an important question is if men and women evaluate a risky technology differently because they have different preferences concerning the values that play a role (safety, health, environment, etc.) or that they do not have the same knowledge on the matter.

Therefore, the main research objective of this thesis is to *determine if there is a gender difference in the overall evaluation of nanotechnology and if so, to gather insights about the mediating variables*. By reaching this objective policies on introducing new (nanotechnology)products and applications on the market can be adjusted accordingly and organizations can, thereby, increase the public acceptance of a risky technology by either preventing the counteraction, by incorporating the opponent's values into the campaign and the product, or it can take the doubts away in discussion. Other research suggests that gender diversity in management teams can improve the performance of companies and this study may also provide insights on the importance of women in decision making processes to achieve responsible innovation [20], [21].

1.4 Research Questions

The main research question and the related subquestions will now be discussed.

Main research question

Do women evaluate a risky technology, such as nanotechnology, differently than men and if so, why?

In order to understand why women evaluate technologies differently than men, it is important to know which variables have an effect on the evaluation of risky technologies. Therefore, the first subquestion focuses on the variables that influence the evaluation of risky technologies in general. Subsequently it has to be investigated which of these variables are relevant in the case of gender differences in the evaluation of risky technologies and which variables have to be included in this research. Due to the fact that a risky technology is a general term, this research will take a look at the evaluation of nanotechnology, which is only one risky technology, see section 1.3. To answer the research question a survey study will be performed, making it possible to test the hypotheses that follow from the literature review. Therefore a quantitative questionnaire will be developed to collect data on how men and women judge nanotechnology. To be able to conduct this research in a structured way, the following subquestions have to be answered:

Subquestions

1. Which variables have been found to influence the evaluation of risky technologies in the literature?
2. Which variables are relevant in the context of gender differences in the evaluation of risky technologies and which variables should be included in this research?

3. Does the executed quantitative research show that there are differences in how women and men evaluate nanotechnology and if so, which variables are responsible for this difference?
4. What recommendations can be made based on the findings of this study?

The answers to the first two subquestions will contribute to the design of the questionnaire. Subsequently the quantitative research is executed by collecting the data and analysing the collected data. The data will be collected using a cross-sectional survey because a limited amount of time is available. The collected data then has to be analysed in such a way that potential differences in the judgement of men and women manifest themselves. First factor analyses need to be executed to confirm if the measured items of the questionnaire indeed load on the latent variables as expected. After the factor analyses a structural equation model will have to be estimated to obtain an insight in how the variable ‘overall evaluation of nanotechnology’ is influenced by all the other measured variables [46]. The third question is, therefore, devoted on determining if there actually is a gender difference in the evaluation of nanotechnology and if so, can it be deduced from the data which variables are important for this difference.

Finally the fourth subquestion only needs to be answered if a gender difference in judgement of nanotechnology is found, it focusses on how the results can be implemented in new policies for both introducing a risky technology on the market and for improving risky technologies to make them more responsible. However, if no gender difference in the evaluation of nanotechnology is found, the research may contribute to further research concerning the study of Avril Macdonald because they did find a gender difference in the evaluation of fracking.

Due to the fact that this research only focuses on nanotechnology it will be difficult to extrapolate any recommendations to other risky technologies. This research can on the other hand provide valuable insights and expectations which can be tested for other technologies.

2 Literature review

Gender differences in the evaluation of risky technologies has been captured by empirical research in a large number of surveys. This chapter will first discuss what is already found in literature on gender differences in risk-taking/perception/assessment/evaluation in general. Subsequently the evaluation of nanotechnology will be reviewed, the research gap will be identified and at the end a conceptual model is introduced.

The articles used in this literature review were acquired by doing a computerized search of scientific literature via Google, Google Scholar, and Research Gate. The following keywords were used: *"risk assessment"*, *"risk perception"*, *"risk-taking"*, *"risk assessment and neuroscience"*, *"risk assessment and gender differences"*, *"risk perception and gender differences"*, *"risks of nanotechnology"*, *"uses of nanotechnology"*, *"risks of nanotechnology"*, *"acceptance of nanotechnology"*, *"concerns of nanotechnology"*, *"gender differences in the risk assessment of nanotechnology"*, *"gender differences in the judgement of nanotechnology"*, *"gender differences in the acceptance of nanotechnology"*, *"gender differences in the evaluation of nanotechnology"*. The references of the obtained articles were checked and subsequently included if they contained relevant information concerning the gender differences in the evaluation of nanotechnology or risky technologies in general (snowballing approach).

2.1 Gender differences in risk assessments

The amount of risk that people are willing to take can differ from person to person; some persons need a lot of benefits to weigh out a minimum amount of risk, where others are willing to take a lot of risks for just a small reward. It should however be noted that the risk taking behavior of people does also depend on risk ethics (fairness, consent, etc.) but this is often not included in studies on risk assessments [26].

Literature suggests that gender plays an important role in risk assessment differences of human beings and Byrnes et al. [5] conducted a meta-analysis of 150 papers on risk-taking tendencies of males and females. This analysis resulted in the conclusion that male participants are, in most cases of risk taking, more likely to take risks than female participants. Another study that supports this conclusion examined the perceived risk of males and females in five areas: health/safety, financial, recreational, social decisions and ethical. Where the questions on ethical issues were related to the following activities: buying illegal products, cheating, forging and stealing. It was found that except for the social decisions case, the males perceived less risk [22].

Women have furthermore been found to be more concerned with harm/care, fairness/reciprocity and purity/sanctity than with in-group/loyalty and authority/respect in comparison to men [9]. As a consequence females will probably find risky technologies morally less acceptable than males if they have a bad influence on one of these values. The statement that women find the value of harm/care more important than men is also supported by Gurmankin et al.(2005) who explored how subjects judged the importance of the prevention of 8 medical conditions with a defined probability. It was found that there are consistent gender differences: females were less sensitive to probability and as a consequence they were more sensitive to differences in the severity of medical conditions [24].

The main challenge in studying the relation between gender and the evaluation of risky technologies is the fact that there are so many variables that can have an impact on the evaluation, for example: culture, scientific knowledge, trust in industry and government etc. [7], [6]. This also came forward in the research of Flynn et al. who found that approximately 30% of the White male American population evaluated the risks from various environmental health hazards to be a lot less than the rest of the American population, which is called the “White-male effect”. After comparison of this group with the rest of the sample, it was discovered that the group of white males with the lowest risk-perception were better educated, had higher incomes and were politically more conservative. The results thereby suggest that this gender difference is developed due to sociopolitical factors and not so much due to race [25], [26]. These papers were, however, only concerned with risk perception and other research, concerned with the citizens’ evaluation of hydrogen fuel stations, indicates that psychological variables are eventually better predictors of the evaluation of the ‘risky’ hydrogen fuel stations than socio-demographic variables. This does not mean that this is also valid for the evaluation of nanotechnology but it could be that the psychological variables are eventually better predictors. The psychological factors that were found to be important predictors for the hydrogen fuel station evaluation are: expected societal effects, expected environmental effects, trust, positive affect and negative affect [6], [27], where affect can be defined as a positive or negative evaluative feeling towards an external stimulus/event e.g.: a hazard [26], [28].

2.2 Gender differences in the evaluation of nanotechnology

Although not much is known about the potential risks of nanotechnology, some research has been devoted to the people’s risk perception of nanotechnology. Smith et al. [13] conducted a random digit dialing telephone survey in the United States to determine the knowledge of nanotechnology and the risk perception in 2006. The research focused on the change in risk perception before and after respondents were given information about the potential benefits and risks of nanotechnology. The outcomes of the research suggested that the respondents that were more likely to switch from “don’t know” in the preinformation case to “benefits outweigh risks” in the postinformation case were male, highly educated and Republican. The respondents who, on the other hand, shifted to the perception “risks outweigh benefits”, were likely to be female, less highly educated and Democratic [13]. This suggests that an increase of the received information on nanotechnology results in bigger gender differences in the evaluation of nanotechnology.

Satterfield et al. [29] conducted a meta-analysis of surveys on the public perception of the risks and benefits of nanomaterials. They summarized the different variables and their significance concerning the perception of nanotechnology and showed that the research (up to and including the year 2009) mainly focused on demographic variables. Gender and education were studied the most and were found to be significant in most cases. Research on the demographic variable age showed conflicting results, but the variables income and race seem to be significant as three out of 5 papers found a significant relationship between the attribute and the evaluation of nanotechnology. The only non-demographic attitudinal factor that was examined more often and was found to be significant in all studies is trust.

Another study (published in 2011) on the attitudes of the public and experts towards nanotechnology suggests that gender, information and religion play an important role [15]. A recent study by Capon et al. also suggests that there is a significant gender difference in the risk perception of nanotechnology, as females were more likely to regard nanotechnology as a risk in all applications [14]. A paper on the public opinion of nanotechnology furthermore found that also religiosity was significantly (negatively) related to the perception of the usefulness of nanotechnology but religiosity did not have a significant influence on the support for the technology [30]. The mentioned studies on the influence of religiosity all examined US citizens, a study that on the other hand examined people's evaluation of nanotechnology in Germany found that religiosity has no or only a marginally significant effect on people's evaluation of nanotechnology. The fact that Germany is a more secularized state was interpreted as the reason for the contrasting outcome and it was even suggested that religiosity may be mediated by moral covariates (such as pro-science and technology attitudes) in a more fully specified model, regardless of secularization [31], [32]. In addition, the study determined that the strongest correlate of the evaluation of nanotechnology is the attitude toward science and technology, followed by nature interference, familiarity and gender.

The underlying reason for the gender differences in the evaluation of risky technologies was, however, not discussed in these papers. The studies therefore indicate that more research is required to obtain a better understanding of why there are gender differences in the evaluation of nanotechnology.

2.3 Conceptual model

It can be concluded from this literature review that there is a lot of uncertainty concerning the many variables that can potentially influence people's evaluation of risky technologies, e.g. age, culture. The literature on the evaluation of nanotechnology provides the following demographic variables: level of education, political affiliation, age, income, race, religiosity, knowledge and gender. Besides these demographic variables literature also provides some psychological variables: trust, expected societal effects, expected environmental effects, attitude toward science and technology, nature interference, familiarity, positive affect and negative affect.

The amount of variables is already reduced due to the fact that only one risky technology (nanotechnology) is taken into account, which means that the 'evaluation of nanotechnology' is the dependent variable in the rest of this research. This thesis furthermore focusses on the differences in the evaluation that are induced by gender but the influence of the other demographic variables cannot be neglected and will have to be taken into consideration. The potential effects of the demographic and psychological variables on the evaluation of nanotechnology will now be discussed and depending on both the significance of the variables, as found in literature, and the expected relevance for this study they will be included in the conceptual model of this thesis.

2.3.1 Demographic variables

Gender was found to be of importance in the discussed literature on the evaluation of nanotechnology by the public. Many studies indicate that women are less likely to positively evaluate nanotechnology than men [13], [14], [29], [31] and the same result is expected for this research. Besides gender many other demographic variables have been found to influence the evaluation of nanotechnology. The level of education has been studied extensively and it was found to be significant in most cases, suggesting that higher educated people evaluate nanotechnology more positively than lower educated people [13], [29]. These relations can therefore also be expected for this study.

Race, income, political affiliation, information and religiosity have also been found to influence the evaluation of nanotechnology. Race seems to be significant in most research on the evaluation of nanotechnology and it is suggested that especially white males are more likely to evaluate nanotechnology more positively [25], [29], [33]. In literature the demographic variable race is measured by asking the respondents if they are white or non-white (race), but this is a sensitive topic in The Netherlands and it is expected to lower the response rate of this research. In addition the focus of this research is on the influence of gender and not on the influence of race, it was therefore decided to exclude the variable race from the research. Due to the fact that the questionnaire of this study will focus on Dutch students of the TU Delft (see section 3.2.2 for a detailed explanation), the variable income can be neglected. In addition the research that indicated political affiliation to be significant was executed in the USA which has two distinct political parties. The Netherlands, on the other hand, has a broad spectrum of political parties and therefore it was decided to neglect the variable political affiliation since people's political affiliation does not manifest itself as a straightforward choice between left or right.

Literature suggests that the received information has a significant effect on the evaluation of nanotechnology and it is therefore also expected to be significant in this study. The variable information will, however, not be included directly in this study because determining the influence of information on the evaluation of nanotechnology is not the goal of this study. It is assumed that most students of the TU Delft will have received similar information prior to the survey and that variations in the received information will solely occur between students who have studied nanotechnology, if it is included in their curriculum, and who have not studied nanotechnology. Consequently a variable concerning the studying of nanotechnology will be included in the conceptual model.

Finally the variable religiosity will not be taken into account because it is expected that the variable gender has a bigger influence on the evaluation of nanotechnology since multiple studies indicate that religiosity has no significant effect on the evaluation of nanotechnology [31], [32].

2.3.2 Psychological variables

Literature on the evaluation of risky technologies has been found to study the following psychological variables: knowledge, familiarity, attitude toward science and technology, nature interference, expected societal effects, expected environmental effects, trust, positive affect and negative affect. These variables will now be discussed in the stated order.

Studies on the evaluation of nanotechnology have found that knowledge plays an important role. The studies have, however, found diverging results about the influence of knowledge on the evaluation [13], [15], [29]. The way in which knowledge is measured may have an effect on the relation that is found with the evaluation. A study by House et al. on the evaluation of genetically modified food, measured the effect of knowledge in two different ways: through a true-or-false knowledge test and through a scale on which the respondents could rate their knowledge level (from very little to a lot) [34]. House et al. calls these the measurements of objective and subjective knowledge respectively and found that these measurements were not strongly correlated, which suggests that it may be two distinct variables. It was furthermore found that the subjective knowledge was positively related to positive evaluation while the objective knowledge was not related to the evaluation. These findings are supported by another study that used the same type of knowledge measurements and found that both types of knowledge had a positive effect on the positive evaluation, but that the subjective knowledge level was a better predictor of the positive evaluation of hydrogen fuel stations [6]. Most studies that examine the knowledge that people have of nanotechnology, only examine the subjective knowledge and diverging results were found for the relation with the perception of nanotechnology [15], [29]. A study that did examine the objective knowledge, but not the subjective knowledge, of nanotechnology found that knowledge levels of nanotechnology were largely unrelated to the evaluation of nanotechnology [35]. Due to the diverging results it is necessary to examine both types of knowledge in this study. It can furthermore be expected from these studies that the subjective knowledge will be a better predictor of the evaluation than the objective knowledge. It is furthermore assumed that familiarity is contained in the variable knowledge and it is also assumed that the attitude towards science and technology in general can be neglected as it will most likely be similar for students of the TU Delft. It was decided to not include the variable nature interference in the conceptual model because it is similar to values which are also not included in this study to reduce the complexity.

The perceived or expected benefits and risks of a technology mostly have a significant positive and negative influence on the evaluation of a risky technology, respectively [26], [36], [37], [38], [39]. Nanotechnology is regarded as one of the most promising technologies of the 21st century and is expected to have a big impact on the economy [40]. It is furthermore known that nanotechnology can be unhealthy and harmful to the environment which means that there are risks but the technology can, on the other hand, also improve healthcare which can be seen as a benefit; Appendix A provides detailed information on the applications and safety concerns of nanotechnology. Although nanotechnology is already present in current products, new applications of nanotechnology are still being developed. Huijts and van Wee [6] carried out a factor analysis of data on the judgement of hydrogen fuel stations and found that the expected effects loaded on two factors: ‘societal and environmental effects’ and ‘local effects’. The effect on the economy, the costs, the usefulness and the safety were items that were loaded on the factor ‘local effect’ as the questions were concerned with a local hydrogen fuel station. The four items can be taken into account in this study without the local aspect. It can be expected that the perceived/expected effect on the economy and the usefulness load onto one factor ‘economical benefits’ and the costs could be a separate factor. It is also plausible that a factor similar to the ‘societal and environmental effects’ factor of Huijts and van Wee will occur, which mostly included the expected risks and will now most likely include the safety item as well. It is expected that the first factor has a positive effect on the positive evaluation of nanotechnology and that the last factor has a negative effect.

Trust in the organizations that are responsible for a technology usually results in a positive effect on the evaluation of the technology [6], [41], [37]. Siegrist for example found that trust in institutions that use gene technology had a positive effect on perceived benefits and a negative impact on perceived risk of the technology [37]. People need to have trust in the government to impose the correct safety regulations and trust in industry to develop and preserve safe applications of nanotechnology and therefore a positive relation is expected between the two trust issues and the positive evaluation of nanotechnology.

It has been found that positive and negative affect both have a distinct impact on the evaluation of several technologies [6], [42]. One of the studies even concluded that one of the strongest predictors of the evaluation of having a hydrogen fuel station locally implemented, are positive and negative emotions which were summarized as the two factors positive and negative affect [6]. It can be expected that positive and negative affects also have a positive and negative effect on the positive evaluation of nanotechnology, respectively.

2.3.3 Expected interrelations between variables

The different variables may also affect each other and not only influence the evaluation of the technology directly. The interrelations between the variables that may occur will now be discussed; first the demographic factors and their effect on the psychological variables and subsequently the effects between the psychological variables.

The demographic variables may have an effect on all the psychological variables. For example the study by Smith et al.(2008) found that the respondents with higher levels of education were significantly more likely to have heard about nanotechnology ($p < 0.0001$) which seems to suggest that education has an effect on knowledge. In this study it will therefore be assumed that the level of scientific education has a direct positive effect on the knowledge that people have on nanotechnology. A study on the consumer evaluation of genetically modified food also found that as the education level increases the objective knowledge increases [34]. Men and women may furthermore have different levels of knowledge.

Siegrist also found gender differences for the variable trust (and for perceived benefit and evaluation of gene technology) [37]. Another study indicates that trust in industry and trust in the government are both important in the development of a positive evaluation of hydrogen fuel stations and in this study it was found that men have more trust in the municipality than women [6]. It is therefore expected that men have a more positive evaluation of nanotechnology as well, because they have higher levels of trust than women.

In addition, a significant relation was found between gender and negative emotions toward nanotechnology suggesting that women are more likely to feel negative toward nanotechnology [32] and therefore this relation is also expected in this research. As was already mentioned it is also suggested in literature that men perceive less risks then women. Besides the gender differences in perception, women also find safety/health and environment more important than men and men find productivity-related items (i.e. perceived usefulness) more important than women [9], [43]. It can therefore be expected that in addition to the fact that men and women have a different risk perception, of for example health effects, they also ascribe a different weight to the factors.

Finally, the psychological variables are expected to influence each other as well. Literature provides some suggestions but not directly for the evaluation of nanotechnology [6], [7]. Through these suggestions and through logical reasoning several interrelations can be expected. The objective knowledge is expected to influence all the other psychological variables, as an increase in objective knowledge may for example mean that people know more about the expected effects of the technology. Subjective knowledge may also have an effect on the expected effects and costs and it may even influence the positive and negative affect. Trust may have an effect on affect and on the expected effects and costs of the technology (the same expected effects as subjective knowledge).

It is expected that the psychological factors can entirely clarify the influence of the demographic variables and no direct effect of these variables on the evaluation of nanotechnology is expected. This expectation is based on the fact that Huijts and van Wee already suggest that gender does not have a direct effect on the evaluation of hydrogen fuel stations [6]. They furthermore found that the socio-demographic variables age, distance to the fuel stations and information did not have a direct effect, only the variable house-ownership had a direct influence on the evaluation of hydrogen fuel stations. This latter variable is however not expected to be relevant in this study.

All the variables and their expected influence on the evaluation of nanotechnology have now been discussed and graphical representations of these expected relations are depicted in Figure 1 and Figure 2. The model makes it possible to not only study the gender difference in the evaluation of nanotechnology, but to also study the interrelations between the variables on which the evaluation depends and thereby obtain insights into the moderating effects of gender which have not been studied before.

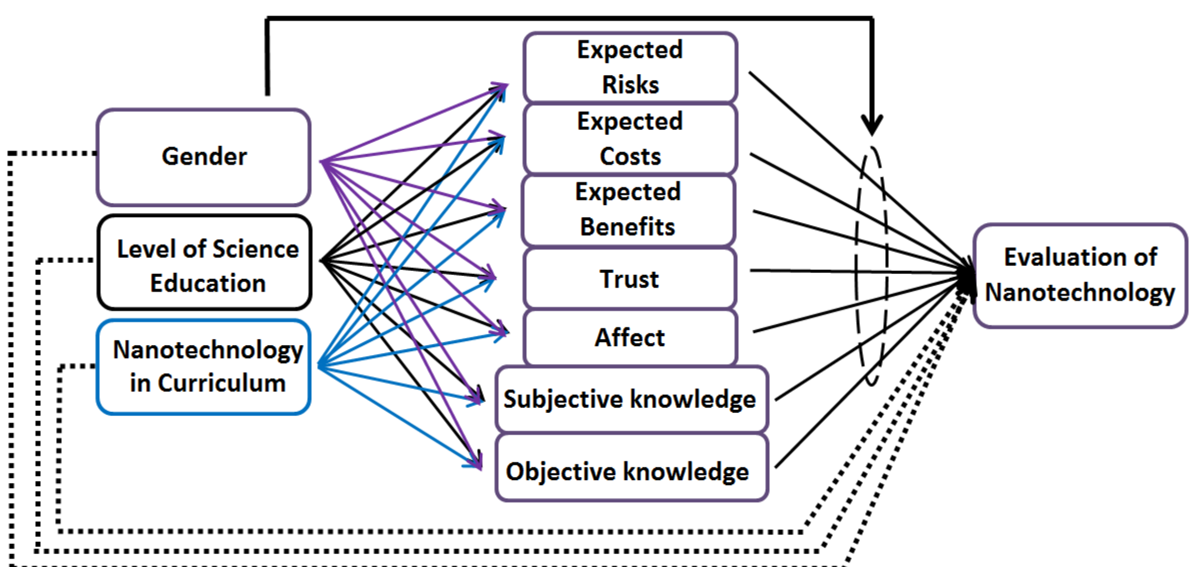

Figure 1. Conceptual model of the judgement of nanotechnology without the interrelations of the psychological effects; the dashed lines are effects which are not expected to be significant. Several arrows are colored to make it easier to distinguish the different effects.

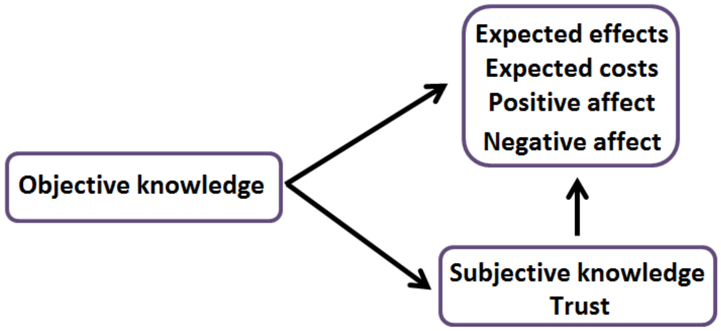

Figure 2. The interrelations of the psychological effects of the conceptual model, the variables that are expected to have the same interrelations are placed in one box.

3 Research Method

This chapter will describe the research methods that are used to meet the research objective of this thesis by answering the third and fourth research questions. Subsequently the methods for the data collection will be discussed.

3.1 Research Strategies

To answer the third and the fourth question the research needs to be descriptive and assumptions about causality need to be made, because the aim of this project is to determine if there is a causal relation between gender and the evaluation of nanotechnology and if so which variables play a role. A survey study is a good way to test the hypotheses that have been defined from the literature review, since it is descriptive and causal orders between variables can be assumed. These outcomes can, however, not be empirically investigated.

Due to the limited amount of time a cross-sectional survey is the best type of research for this thesis, since the data can be gathered at one moment in time and from one and the same group. Another advantage of a survey is that it can include a large group of people which will result in an outcome that can be generalized.

It should however be noted that although a survey enables systematic gathering of data, from a target population, there are some disadvantages which have to be taken into account. For example, respondents can leave certain questions unanswered if they do not understand the question or do not want to answer it. This problem of unanswered questions can easily be solved by requiring that the questions need to be answered before the respondent can continue with the questionnaire. In addition, questions that people do not want to answer should be adjusted or deleted as they can result in unfinished questionnaires as people do not continue with answering the questions. A pre-test is a good solution for this problem as it can reveal questions which respondents do not want to answer. Another difficulty of a questionnaire is the fact that research subjects tend to give ‘socially acceptable’ answers, which results in what is called social desirability bias of the data. The tendency to give a socially desirable response is a major issue when the research involves socially sensitive issues such as politics or personal issues like the consumption of alcohol or income [44], [45]. This bias is not expected in this study since it is not about such socially sensitive issues.

3.2 Data Collection

3.2.1 Survey

A survey can be implemented in many different ways but the papers on risk perception and the evaluation of nanotechnology generally use Likert scales [6], [25], [13], [14], [15], [46]. A Likert scale is a symmetric five point scale (1-5) with a neutral option in the middle and the two opposites on the outer values e.g. 1 – very important and 2 – not important at all. The Likert scale is used to measure attitudes and due to the 5 options, it is possible to take a closer look at the attitudes of respondents than with simple yes/no or agree/do not agree answers. The attitude of respondents is the result of their overall evaluation, therefore the Likert scale is a good fit for this thesis since the aim is to determine how people evaluate nanotechnology.

One important aspect that should not be forgotten is the fact that knowing if a respondent is male or female is essential to this thesis and a dichotomous scale can be used to monitor this [46]. But besides gender, also information on other socio-demographic factors needs to be collected to verify if the sample is a good representation of the population under investigation and to examine if other factors play a role in the evaluation of nanotechnology. Therefore questions concerning demographic factors (e.g. age, education) have to be included in the survey to be able to give a good answer to the third research question.

3.2.2 Sampling approach

The sample is a subset of the target population and the target population of this research consists of all the adults in the Netherlands. The research is motivated by the statement that women judge risky technologies differently than men because they have had less science education, but literature suggest that there are also other variables that result in gender differences in the evaluation of technologies. It was therefore decided to focus the survey on Dutch students of the TU Delft because this subgroup makes it possible to investigate gender differences with a reduced effect of differences in knowledge level, since the students can be assumed to have nearly the same level of education. Nonetheless, the slight differences in knowledge on nanotechnology and the level of education (BSc or MSc) will still have to be measured to develop a good model.

The number of TU Delft students is quite big (more than 20.000) and an appropriate sample size should be determined. Hair et al. [47] discuss how the probability of correctly rejecting the null hypothesis, referred to as the power of the statistical inference test, depends on three factors: alpha, sample size and effect size. Alpha is about the probability of rejecting the null hypothesis when it is actually true, which is also called the Type I error, and the effect size is the about the expected size of the effect. The difficulty with sample size is that an increase in sample size always results in greater power, but with a too high power the statistical test will become too sensitive, meaning that almost every effect becomes significant. At an alpha level of 0.05 the power reaches an acceptable level at a sample size of 80 or more for a moderate effect size. In general it is recommended in literature to use a minimum sample size of 200 respondents for SEM studies since analysing small samples in SEM is problematic [48]. It was therefore decided to use a minimum sample size of 200 respondents which needs to contain a minimum of 80 respondents for the subsamples of men and women.

To attain those respondents in a short period of time it is most convenient to use an online survey and in this research the survey will therefore be web-based. Online surveys can unfortunately be perceived as junk mail and to avoid this pitfall the survey may need to be distributed with the help of authorities; professors and the student association Curius. People can also be persuaded to participate by briefly explaining what the aim of the research is at beginning of the survey or by approaching the students on campus. If the online survey, however, appears to generate a low response rate, hardcopies of the survey will be distributed as an expedient.

3.2.3 Measurements of the variables

The demographic variables gender is measured by letting the respondents indicate if they are male or female (gender). The second demographic variable 'level of science education' is measured by asking the respondents the question: 'Are you doing a Bachelor or a Master?'. It is expected that any differences between Bachelor and Master students will only have an effect on the knowledge variables.

The questionnaire will not provide any information on nanotechnology but due to the fact that several studies at the TU Delft discus the topic nanotechnology, a portion of the students at the TU Delft will have obtained an increased amount of information on nanotechnology. This may influence some of the variables in the model, therefore an extra dummy variable is added to the model as a predictor. The question associated with this variable is 'did you study nanotechnology during your studies?'.

The psychological variables are then measured with scales running from 1 to 5, which are based on measurements done by Huijts et al. [6]. The evaluation of nanotechnology is measured with four scales: I find the use of nanotechnology (a) 1 a very bad – 5 a very good idea, (b) 1 a strong deterioration – 5 a strong progression, (c) 1 useless – 5 very useful, (d) 1 no important at all – 5 very important'.

Expected safety and health effects were measured with 5 scales concerning the effect of nanotechnology on: (a) the environment, (b) the health of citizens, (c) future generations, (d) the safety of citizens and (e) the health of people that use products that contain nanotechnology. The expected/perceived economical benefits of the technology were measured with 4 questions concerning the effect of nanotechnology on: (a) the economy, (b) the number of jobs, (c) welfare, (d) the usefulness of products. The scales for both factors went from 1 a very negative effect – 5 a very positive effect. Finally the expected/perceived costs were measured with 3 scales concerning the costs of: (a) the use of nanoproducts, (b) the development of nanotechnology applications, (c) the recycling or disposal of nanoproducts. The scales went from 1 very high costs – 5 very low costs. All the questions, which can be found in Appendix C, did not provide any information on the actual effects, benefits or costs to avoid the introduction of any bias.

The level of trust in the government and the industry was determined by questions that were concerned with the amount of faith that respondents had in the two parties and their role in the decision making process and the regulation of the technology. Three questions were asked to determine how much the respondents trusted the government: (a) to take responsible decisions on the use of nanotechnology, (b) to take the well-being of residents sufficiently into account when allowing the use of nanotechnology and (c) to provide legislation for safe waste processing of products that contain nanotechnology. The scales went from 1 very little trust – 5 a lot of trust.

The trust in the industry was measured with 6 questions concerning the level of trust in the industry to realize and to preserve a safe development and production process of nanoproducts. The questions used a scale from 1 not at all – 5 very much and asked if the respondent was confident that the industry: (a) has enough knowledge to produce nanoproducts in a safe manner, (b) has enough knowledge to develop nanoproducts in a safe manner, (c) has the intention to make sure that the developed nanoproducts are safe, (d) pays attention and performs safety checks to be certain that the production processes stay safe, (e) develops nanoproducts that are environmental friendly when being used, (f) develops nanoproducts that do not harm the environment once they are disposed as waste.

The positive and negative affect measurements were done with a scale from 0 not at all – 5 very much, based on measurements of Huijts et al. [6], [49]. The respondents were asked to what extent certain feelings were invoked in them when they thought of nanotechnology. The questions regarding the measurement of positive affect were about the following 5 kinds of positive feelings: joy, hope, satisfaction, calmness and pride. Also for the measurements of negative affect 5 kinds of feelings were addressed: stress, fear, anger, powerlessness and worry.

Subjective knowledge and objective knowledge were measured at the end of the questionnaire to make sure that no information bias is introduced when measuring the other variables [6], [13]. For the same reason subjective knowledge is measured prior to objective knowledge. Subjective knowledge was measured with 5 items which asked how much knowledge the respondent had on: (a) nanotechnology, (b) how nanotechnology is used in products, (c) the disadvantages of nanotechnology, (d) nanotechnology as a waste, (e) the potential benefits of nanotechnology for medical applications. The measurement were done using a scale that went from 1 very little – 5 very much.

The objective knowledge level was determined with 8 true/false statements (‘1’ = correct answer, ‘0’ = incorrect answer or do not know), see Table 1. The statements were partially based on the research of Cacciatore et al. [50] who also measured the knowledge of nanotechnology, but did not focus on the risks of nanotechnology. The objective knowledge level was calculated by dividing the correctly answered questions by the total number of questions, as a result the obtained scores run from 0 (everything incorrect) to 1 (everything correct).

The Dutch questionnaire that was distributed to the respondents can be found in Appendix B and Appendix C provides an English version.

Question	True or False?
Nanotechnology involves materials that are not visible to the naked eye	True
Nanotechnology is used in clothing to kill disease-causing bacteria	True
Nanoparticles are being used in food packaging	True
Different nanoparticles generally behave in the same way	False
Nanoparticles are too small to have a health effect	False
Nanoparticles are used in sunscreen	True
1 nanometer is equal to 1 x 10^{-6} meter	False
Nanoparticles can penetrate your skin	True

Table 1. The questions used to measure the objective knowledge level.

3.2.4 Pre-test

Before the survey can be used to collect data from the target group, a pre-test is required. The pre-test was implemented on 4 people from the target group to verify the validity, the comprehensibility and the duration of the survey. The feedback, which was provided by the participants of the pre-test, was used to improve the draft questionnaire and subsequently the data could be collected from the subgroup − Dutch students of the TU Delft.

4 Results

This chapter will answer the third subquestion of this thesis by discussing the collected data and the results of the analyses that were executed with SPSS and AMOS.

4.1 Collected data

The online questionnaire was developed and distributed with Collector, the online survey tool of the TU Delft, and the data was gathered in March 2017. TU Delft students were approached on campus and the questionnaire was distributed via several Facebook pages as well. The final database contains 204 useful responses of which 140 completed questionnaires were collected on campus and the other 64 completed questionnaires were obtained via Facebook, with an estimated response rate of 40% on campus and 3% on Facebook.

Women were oversampled to be able to obtain reliable analyses of differences between men and women; 59% of the respondents are male and 41% are female, where the actual distribution of male and female students at the TU Delft is approximately 75% and 25%, respectively [52]. The average age is 23 years and the sample contains a bit more master students than bachelor students (56% - 44%). Figure 4 provides an overview of the other demographic characteristics of the respondents. The first bar chart shows that a relatively large number of students of the faculties of Applied Sciences and Industrial design have participated. This is probably caused by the fact that the questionnaire was distributed among students of the Facebook pages of Applied Sciences. The large number of Industrial design students that have participated is most likely a direct result of the many questionnaires that they themselves have to distribute, which made them more willing to participate.

The second bar chart in Figure 4 shows the percentage of participants that have come across nanotechnology during their study (25%) and from the first and the third chart it can be deduced that most of these students are from the faculty of Applied Sciences. The third chart also shows that a relatively large amount of students at the faculty of Mechanical, Maritime and Materials Engineering (3ME) have come across nanotechnology during their study (40%). These are predictable outcomes because most courses concerning nanotechnology are given at the faculty of Applied Sciences and 3ME offers a bachelor ‘Clinical Technology’ which includes the study of bodily systems [51]. Due to the fact that the target population of this thesis consists of Dutch students of the TU Delft with a similar scientific education, the variable ‘faculty’ will not be taken into account since the level of scientific education per faculty is assumed to be similar and the variable ‘coverage of nanotechnology’ is a good indication of difference in knowledge of nanotechnology.

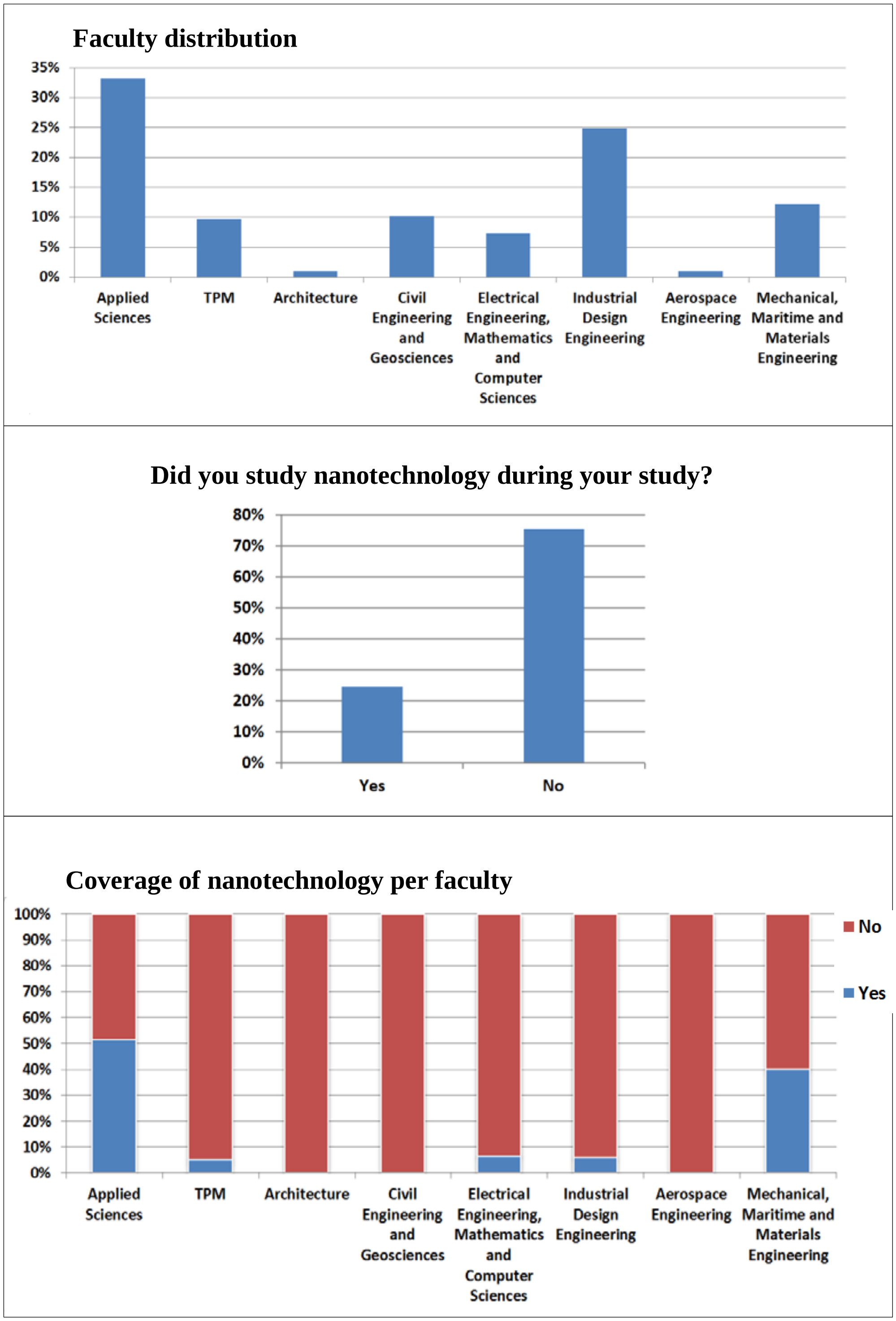

Figure 3. Three bar charts, the top one displays the distribution of the respondents per faculty, the chart in the middle displays the percentage of students that have studied nanotechnology during their study and the third chart provides the distribution of the coverage of nanotechnology among the faculties.

4.2 Data analysis

To find out if the hypotheses of this thesis are supported, the collected data will be analysed with the use of factor analyses and SEM. This section discusses the different analyses that have to be implemented to answer the third subquestion of this thesis.

First factor analyses need to be executed to confirm if the items indeed load on the psychological variables as expected (validity). Subsequently Cronbach's alpha's have to be calculated to determine if each set of items that belong to one psychological variable, actually reflect the same latent variable (reliability). The next step is to check whether variables are correlated, this can be done with the Pearson correlation coefficient because the ordinal scales that are used can be approximated as interval scales. It should be noted that this correlation coefficient does not provide information on which variable 'causes' which [46].

To eventually determine the direct and indirect effects of the different independent variables on the dependent variable (evaluation of nanotechnology), a structural equation model can be estimated and by retaining the significant paths the model will help understanding the underlying effects [46]. Structural equation modeling (SEM) is a multivariate technique that is often used in the behavioural sciences because it permits complex theories to be statistically modelled, it can however not provide information on the direction of a causality. It is a confirmatory technique as it compares a model to the empirical data, so it is necessary to develop a model in advance. The advantages of SEM over multiple linear regression are that it deals with a system of regression equations, it allows for more complicated modeling of causal effects as it can estimate indirect paths and SEM also corrects for measurement errors which results in less biased estimations [6], [52], [53]. The latter is done by fixing the measurement error of each indicator variable at a value of: (1 - Cronbach's alpha) times the variance of the average of the respective summated items [56].

In this thesis research the initial model that is developed in AMOS will include all conceivable causal paths and then backward elimination is used to stepwise delete the paths that are representing insignificant effects. This method will be used to develop three models; one model for the whole sample (including both men and women), one model that only includes the data of the men and one model that only includes the data of the women. The separate models for men and women will provide an insight into the moderating effects of gender. To reduce the complexity of the models the average of the summated items per construct is taken as the indicator variable for the latent variable.

Chi-square difference tests will eventually be executed to be able to compare the model for men with the model for women. The chi-square difference test includes comparing the chi-square value of two nested models with the chi-square value of the models when a similar path of both models is constraint. The constraint path is then found to be significantly different if the difference between the chi-square scores is above a certain value which depends on the difference in degrees of freedom. This critical chi-square difference value can be found in a chi-square table [55].

4.3 Results

4.3.1 Factor analyses

Separate factor analyses were performed for the groups of items which were expected to load on one factor with the exception of the expected effects and expected costs items. On those items a factor analysis (direct Oblimin rotation) is performed because literature on the evaluation of technologies mostly distinguishes the two factors benefits and risks, this thesis however suggests the three factors: safety, health and environmental risks, economical benefits and costs. The factor analysis of items measuring expected effects and costs is shown in Table 2 and the items do indeed load on three factors. Three items load on the factor expected costs with a loading higher than 0.5. Four items have a loading of more than 0.5 on the second factor and these items represent the expected health and environmental risks. Three other items which represent the economical benefits have a loading higher than 0.5 on the third factor (the fourth item has a factor loading below 0.5).

The outcomes of this factor analysis and the other factor analyses confirmed the expected factors and underlying measures, except for the items that were meant to measure the trust in industry and the items that were meant to measure health, safety and environmental effects. The items that were expected to measure the trust in industry did not load on one factor as was expected but on two, but this could possibly be explained by the fact that two questions on the trust in the industry's concern with the environment were added to 4 questions on the trust in the industry's concern with the safety of the technology, which were based on measurements by Huijts et al. [6]. In addition only four out of five items that were expected to measure the factor ´health, safety and environmental effects´ loaded on one factor. The safety item did not load significantly on the health, safety and environmental factor, indicating that there may be a fourth factor 'safety' and the factor that was measured was actually only about the health and environment effects.

To further examine the items on trust in industry a factor analysis with direct Oblimin rotation was performed over all the items measuring the trust in industry. Table 3 presents the outcomes of the factor analysis and it shows that two factors were found. Four items have a factor loading higher than 0.5 on the first factor and these items measure the trust in the industry's concern with the safety of nanotechnology. The other 2 items have a loading of more than 0.5 on the second factor, which is about the trust in the industry's concern with the environment. The first factor is in agreement with literature but the second factor has not been discussed in literature up till now. These findings suggest that respondents make a distinction between different types of trust in the industry depending on the subject. As was discussed in section 2.3.3, it is expected that women find the environment more important than men and because the aim of this research is to examine gender differences in the judgement of nanotechnology, this second factor on the trust in the industry's concern with the environment is expected to be relevant and will be inserted in the model.

Almost all the constructs displayed acceptable construct reliability (Cronbach's alpha > 0.7). As can be seen in Table 4, the Cronbach's alpha of the items that should represent the factor expected costs has a rounded value of 0.7 but it is a bit low, meaning that the factor should have been measured more thoroughly (e.g. more items). This factor is found to be of importance for the evaluation of a risky technology and will therefore be included in the model [55], [56]. The Cronbach's alpha of the factor expected economical benefits is unfortunately far below 0.7 which theoretically means that the items do not represent the same underlying construct and as a consequence the factor should not be used in the model. The factor will however be included in the structural model due to the fact that it is found in literature that the expected economical benefits play an important role in the evaluation of risky technologies and because the factor analysis shows that it is an individual factor and we would like to test the hypothesis [6], [26], [38], [39].

Table 2. Factor analysis with direct Oblimin rotation over the items measuring the (expected) effects of nanotechnology.

	1	2	3
The expected costs of the development of nanotechnology applications for society	**0.82**	-0.10	-0.01
The expected costs of the use of nanoproducts	**0.74**	-0.18	0.14
The expected costs of the recycling or disposal of nanoproducts	**0.74**	0.27	-0.13
The effect of nanotechnology on the health of citizens	-0.12	**0.83**	-0.12
The effect of nanotechnology on the health of people that use products that contain nanotechnology	-0.12	**0.78**	0.07
The effect of nanotechnology on the environment	0.14	**0.59**	-0.05
The effect of nanotechnology on future generations	-0.07	**0.53**	0.40
The effect of nanotechnology on the safety of citizens	0.07	0.421	0.38
The effect of nanotechnology on the economy	-0.03	0.03	**0.75**
The effect of nanotechnology on the number of jobs	-0.03	-0.20	**0.73**
The effect of nanotechnology on welfare	0.07	0.12	**0.67**
The effect of nanotechnology on the usefulness of products	0.02	0.34	0.36

Table 3. Factor analysis with direct Oblimin rotation over the items measuring the trust in industry.		
	1	2
Trust that the industry has enough knowledge on nanotechnology to safely manufacture nanoproducts	**0.82**	-0.14
Trust that the industry has the intention to be certain that the developed nanoproducts are safe	**0.64**	0.28
Trust the industry to pay attention and perform safety checks to be certain that the production processes stays safe	**0.54**	0.36
Trust that the industry has enough knowledge on nanotechnology to safely develop nanoproducts	**0.82**	-0.11
Trust in the industry to develop nanoproducts that do not harm the environment once they are disposed as waste	-0.09	**0.88**
Trust in the industry to develop nanoproducts that are environmental friendly when being used	0.06	**0.82**

Table 4. Summary of all the constructs						
	Nr. of items	Cronbach's alpha	Scale of factor	Mean[a]	Standard deviation	Error
Evaluation of nanotechnology	4	0.79	1 – 5	4.14	0.62	0.08
Positive affect	5	0.84	0 – 5	2.40	1.12	0.20
Negative affect	5	0.84	0 – 5	3.86	0.98	0.15
Trust in Government	3	0.70	1 – 5	2.96	0.77	0.18
Trust in industry's concern with safety	4	0.72	1 – 5	3.41	0.64	0.12
Trust in industry's concern with the environment	2	0.71	1 – 5	2.63	0.78	0.18
Expected economical benefits	3	0.56	1 – 5	3.74	0.57	0.14
Expected health and environmental effects	4	0.71	1 – 5	3.44	0.60	0.11
Expected costs	3	0.65	1 – 5	2.27	0.72	0.18
Subjective knowledge	5	0.89	1 – 5	2.21	0.85	0.08
Objective knowledge	8	0.51	0 – 1	0.56	0.21	0.21

[a]The factor is calculated by taking the average of the corresponding items

4.3.2 Correlations

The correlation of all the variables with gender and evaluation are shown in Table 5. The independent variable ‘gender’ and ‘people who have come across nanotechnology during their study’ are the only two demographic variables that significantly correlate with the evaluation of nanotechnology. Men are more positive about nanotechnology than women and people who have discussed nanotechnology during their studies are more positive than people who have not.

The psychological variables that significantly correlate with the evaluation of nanotechnology are positive affect, trust in industry’s concern with safety, economical benefits, health and environmental effects, subjective and objective knowledge. People that have more positive feelings towards nanotechnology are more positive about nanotechnology, which is logical. The other significant correlations suggest that people are more positive about nanotechnology if they: have more trust in the industry’s concern with safety, perceive more economical benefits from nanotechnology, and if they expect a good influence of nanotechnology on health and environment. Higher levels of both subjective and objective knowledge on nanotechnology also have a positive influence on the evaluation of nanotechnology. It is interesting to notice that subjective knowledge correlates more strongly with the evaluation of nanotechnology than objective knowledge. Overall the influence of nanotechnology on health and environment has the highest correlation coefficient with the evaluation of nanotechnology, followed by positive affect and subjective knowledge.

Fewer factors correlate with gender, namely: evaluation of nanotechnology, health and environmental effects, subjective knowledge, objective knowledge and age. The correlation with the demographic factor age indicates that the older respondents are more likely to be men. The significant psychological variables are all negatively correlated with gender, meaning that men ‘score’ higher on the variables than men. This can also be concluded from the mean values for men and women and the t-tests.

The discussed correlations with gender and the evaluation of nanotechnology are most interesting for this thesis. It can be expected that the variables that do not correlate with the evaluation of nanotechnology will also be deleted in the SEM. However, to obtain a better idea of all the interrelations one can view the correlations of all variables in Table 6. The variables that stand out are the variables negative affect and costs, since they significantly correlate with only two variables. Negative affect significantly correlates with positive affect and with the type of education. It can be deduced that the more positive people are the less negative they are, and BSc. students have more negative than positive feelings towards nanotechnology than MSc. students. The cost variable significantly correlates with subjective knowledge and whether students had nanotechnology in their curriculum, the values indicate that the costs are expected to be higher if people have a higher level of subjective knowledge and if people did not come across nanotechnology in their study.

Psychological Factors	Mean men	Mean women	t-test (sig. 2-tailed)	Correlation with gender	Correlation with the evaluation of nanotechnology
Evaluation of nanotechnology	4.27	3.96	**0.00048**	-0.24***	1
Positive affect	2.48	2.27	0.19	-0.09	0.35***
Negative affect	3.84	3.90	0.68	0.03	0.03
Trust in government	3.03	2.86	0.13	-0.11	0.09
Trust in industry's concern with safety	3.48	3.31	0.070	-0.13	0.20**
Trust in industry's concern with the environment	2.67	2.57	0.35	-0.07	0.10
Economical benefits	3.78	3.69	0.24	-0.08	0.28***
Health & environmental effects	3.55	3.28	**0.0014**	-0.22**	0.43***
Costs (1 = low costs, 5 = high costs)	2.33	2.18	0.13	-0.11	-0.01
Subjective knowledge	2.40	1.94	**0.00017**	-0.26***	0.35***
Objective knowledge (0 = false, 1 = correct)	0.60	0.50	**0.00081**	-0.23***	0.20**

Demographic Factors	Mean men	Mean women	t-test (sig. 2-tailed)	Correlation with gender	Correlation with the evaluation of nanotechnology
Gender (0 = men, 1 = women)	/	/	/	1	-0.24**
Nanotechnology in curriculum (0 = yes, 1 = no)	0.28	0.19	0.14	0.10	-0.28***
BSc. or MSc. (0 = BSc., 1 = MSc.)	0.48	0.37	0.13	-0.11	0.13
Age	22.94	22.20	**0.021**	-0.16*	0.05

Table 5. The factors and the corresponding mean values for men and women, the t-test's significance and the correlations with gender and the evaluation of nanotechnology. The light blue highlighted rows indicate factors with a significant mean difference between men and women. *, **, *** Correlation is significant at the 0.05, 0.01, 0.001 level (2-tailed) respectively.

Factors	E	PA	NA	TG	TIS	TIE	B	H&E	C	SK	OK	G	N	ED
Evaluation of nanotechnology (E)														
Positive affect (PA)	**.35****													
Negative affect (NA)	.026	**-.39****												
Trust in government (TG)	.09	.06	.13											
Trust in industry's concern with safety (TIS)	**.20****	**.21****	.07	**.30****										
Trust in industry's concern with the environment (TIE)	.10	**.19****	-.007	**.16***	**.32****									
Economical benefits (B)	**.28****	**.26****	.006	.02	**.18****	**.21****								
Health & environmental effects (H&E)	**.43****	**.33****	.01	**.18***	**.37****	**.35****	**.30****							
Costs (C)	-.01	.07	.10	.03	.01	.02	.01	-.04						
Subjective knowledge (SK)	**.35****	**.39****	-.98	.05	**.24****	**.20****	**.25****	**.28****	**.16***					
Objective knowledge (OK)	**.20****	**.26****	-.04	-.08	.04	**.14***	**.17***	**.15***	-.07	**.41****				
Gender (G)	**-.24****	-.09	.03	-.11	-.13	-.07	-.08	**-.22****	-.11	**-.26****	**-.23****			
Nanotechnology in curriculum (N)	**-.28****	**-.23****	-.08	-.09	-.07	-.11	**-.23****	-.10	**-.16***	**-.50****	**-.27****	.10		
BSc. or MSc. (ED)	.13	-.02	**-.16***	**-.18****	-.11	-.11	.11	-.04	.05	.12	-.08	-.11	**-.14***	
Age	.05	-.08	-.10	**-.31****	**-.21****	-.04	**.14***	-.08	.08	.02	-.08	**-.16***	-.08	**.68****

Table 6. Correlations between all the variables used in the initial structural equation model, with the used abbreviations.

4.3.3 Structural equation model

SEM of the complete sample

The structural equation model is first estimated for the entire sample, including men and women, to obtain a model which provides insights into the mediation effects. The final model is shown in Figure 5 and it only includes the paths that have a significant direct or an indirect effect on the evaluation of nanotechnology. The standardized direct effects and the standardized total effect are depicted in Table 7 and Table 8, respectively. The squared multiple correlation (SMC or R^2) of each dependent variable in the final model can be found in Table 8 as well.

The SMC is the relative amount of the variance of a dependent variable which is explained by the explanatory variables. The SMC's in Table 8 indicate that the variables in the final model 'explain' 49.9% of the variance of the variable evaluation of nanotechnology. The evaluation of nanotechnology has the highest SMC, followed by effects on health and environment (40.5%) and subjective knowledge (38.6%). The variables economical benefits, positive affect and trust in government all have a SMC around 20% and the others are around 10% or lower.

In the same table of the SMC values the standardized total effects are also depicted; standardized coefficients make it easier to compare the effects of variables that are measured on different scales than unstandardized coefficients. The directions of these standardized total effects, of the variables in the final model, can be compared with the significant correlation coefficients that were found between these variables and the evaluation of nanotechnology with SPSS. The sign of the standardized total effects are equal to the correlation, except for both determinants of knowledge. The objective knowledge and subjective knowledge both have a significant correlation with the evaluation of nanotechnology but they do not have a standardized total effect on the evaluation since there are no significant paths from these determinants to the evaluation, meaning these determinants are not present in the model.

The total effects of the demographic variables in the final model indicate that students that have studied nanotechnology, Msc. students, men and younger people are more positive about nanotechnology then students that have not studied nanotechnology, Bsc. students, women and older people. The latent variables that have a significant effect on the evaluation of nanotechnology are: trust in industry's concern with the environment, trust in the industry's concern with safety and the effects of nanotechnology on health and environment. The signs indicate that students that have more trust in the industry's concern with safety, less trust in the industry's concern with the environment and expect nanotechnology to have a good influence on health and environment are more positive about nanotechnology then students who do not trust the industry's concern with safety, have more trust in the industry's concern with the environment and expect a bad influence of nanotechnology on health and environment. These relations are in line with the expectations, except for the trust in the industry's concern with the environment which was expected to have a positive relation with the evaluation of nanotechnology.

The values of the total effects indicate that the expected effect of nanotechnology on health and environment is the strongest predictor of the evaluation of nanotechnology followed by studying nanotechnology, trust in industry's concern with safety and gender, respectively. The determinants that are weak predictors of the evaluation of nanotechnology are age, trust in industry's concern with the environment and level of education. The model also provides insights on mediation effects since significant paths were found between variables in the model. These significant paths and the corresponding effects are as follows:

- Men have a higher level of trust in the industry's concern with safety then women and this higher level of trust results in more positive expectations for the effects of nanotechnology on health and environment.
- Men have more positive expectations for the effect of nanotechnology on health and environment (direct path) than women and a more positive attitude towards H&E leads to a more positive evaluation of nanotechnology.
- The older students have less trust in the industry's concern with safety than younger students and this leads to less positive expectations for the effects of nanotechnology on health and environment.
- BSc. students have more trust in the industry's concern with the environment than MSc. students, this results in the two effects that these students are less positive about nanotechnology and experience a more positive evaluation of the effects of nanotechnology on health and environment.

It was not expected that any of the observed variables would have a direct effect on the evaluation of nanotechnology, but the final model shows that studying nanotechnology does have a direct effect which indicates that there may be other mediating variables that were not included in this research. It is important to note that many other variables who were, on the other hand, expected to have a direct effect on the evaluation of nanotechnology do not have a significant effect on the evaluation at all (subjective knowledge, trust in the government, positive affect, negative affect, costs, economical benefits). A model with all the initially included variables and the significant paths, including the ones that do not influence the evaluation of nanotechnology, can be found in Appendix D.

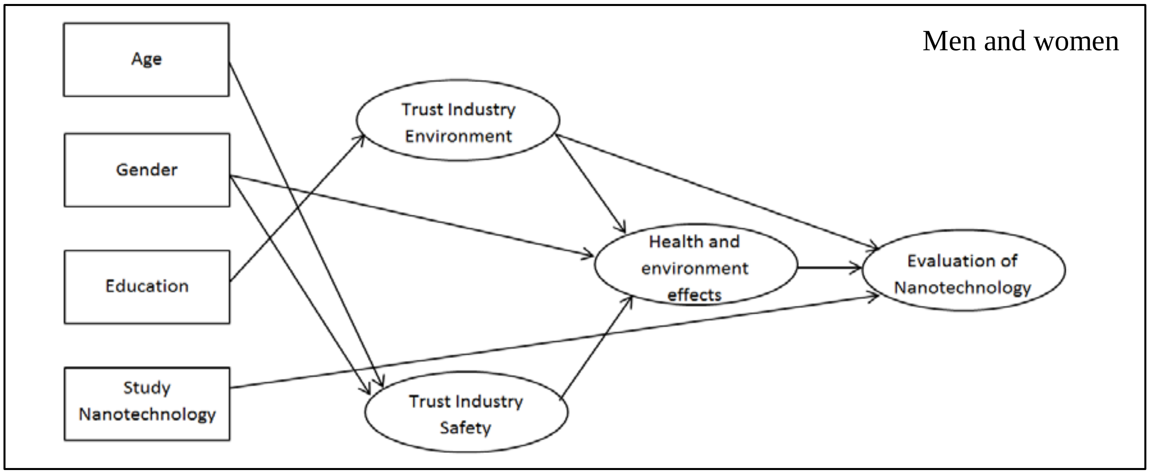

Figure 4. A final model for the whole sample.

	TIS	TIE	OK	H&E	SK	B	C	NA	PA	TG	E
N			-.25		-.43	-.25		-.24			-.27
ED		-.17						-.21			
G	-.17		-.20	-.24	-.16					-.22	
Age	-.29					.28				-.42	
TIS				.36		.36			.23		
TIE				.31							-.29
OK					.28		-.23			-.19	
H&E											.73
SK							.34	-.21	.34		

Table 7. standardized direct effect of the variables in SEM of the entire sample. The abbreviations of the variables can be found in Table 6.

	TIS	TIE	OK	H&E	SK	B	C	NA	PA	TG	E
N			-.25		-.50	-.25	-.11	-.13	-.17	.05	-.27
ED		-.17		-.05				-.21			.01
G	-.17		-.21	-.30	-.22	-.06	-.03	.05	-.11	-.18	-.22
Age	-.29			-.10		.17			-.07	-.42	-.08
TIS				.36		.36			.23		.26
TIE				.31							-.07
OK					.28		-.13	-.06	.10	-.19	
H&E											.73
SK							.34	-.21	.34		
SMC	.10	.03	.11	.41	.39	.23	.10	.09	.21	.22	.50

Table 8. Standardized total effects of variables in SEM of the entire sample and the squared multiple correlations of the dependent variables. The abbreviations of the variables can be found in Table 6.

Separate SEMs for men and women

The structural equation models are calculated for the separate data of men and women to determine if gender functions a moderator in the model. The final models for the separate groups are shown in Figure 6, only the paths that have a significant direct or indirect effect on the evaluation of nanotechnology are depicted.

Paths that are present in one of the models and not in the other, are paths that are significantly different. The chi-square difference test is used to determine if paths that are present in both models are similar or significantly different. The chi-square value of the model was calculated in the final model and compared to the chi-square value of the model after a path was constraint to have the same value in both models. Due to the fact that only on path is constraint, only one degree of freedom is added and the chi-square difference needs to be above 3.84 for the path to be significantly different ($\alpha \leq 0.05$) in the model for men compared to the model for women. Subsequently the path was unconstraint again and another path was constraint and the chi-square difference test is done all over again and this is repeated for each path that was found in both models. The coloured arrows in Figure 6 depict the paths that are found to be significantly different in the two models.

The squared multiple correlations (SMC) of the dependent variables of a model are measures for how ‘complete’ the model is. The SMC’s of the model for men can be found in Table 9. These SMC’s indicate that the evaluation of nanotechnology is ‘explained’ for 66.1% by the variables in the model. The evaluation of nanotechnology has the highest SMC and is followed by effects on health and environment (38%) and subjective knowledge (27.5%), other SMC’s are all around 10%. In the final model for women 57.1% of the variance of the evaluation is accounted for by the variables in the model. The other variables with a relatively high SMC score are subjective knowledge (41%) and health and environment effects (35.5%), the remaining variables have a score of approximately 10%.

In the same tables of the SMC values the standardized total effects are also depicted. The total effects of the observed variables in the final model for men suggest that MSC. students, respondents that have studied nanotechnology and men with less objective knowledge are more positive about nanotechnology then BSc. students, men with more objective knowledge and those who have not studied nanotechnology. The standardized total effect of the demographic variable in the final model for women (Table 11) also suggests that students who have studied nanotechnology evaluate the technology more positively then student who have not studied nanotechnology. The only difference between men and women and the total effect of having studied nanotechnology on the evaluation of nanotechnology, is that the effect is stronger for women. The total effect of the variable objective knowledge on the evaluation of nanotechnology is not similar to the model for men since it has a different sign.

Continuing with the total effects of the latent variables on the evaluation of nanotechnology, the total effects of the final model for men indicate that an increase in the trust in industry’s concern with the environment leads to a more negative evaluation of nanotechnology. The evaluation of nanotechnology however increases if men score higher on subjective knowledge, expect lower costs and if the expected effects on health and environment are more positive. The total effects for the final model for women suggests that the evaluation is more positive if the trust in the industry’s concern with the environment increases, if people expect higher costs and if the expected effects on health and environment are more positive. This means that for men and women opposite relations consist between trust in industry’s concern with the environment and the evaluation of nanotechnology and between expected costs and the evaluation.

The actual values of the total effects for men indicate that the variable health and environment has the biggest effect on the evaluation of nanotechnology. The other variables that have a relatively big total effect on the evaluation are: costs, subjective knowledge and having studied nanotechnology. The largest total effect for women is also the variable health and environment, but it is not as big as it is for men. Similar as the model for men, the next largest total effect for women is the variable cost.

Besides the SMC’s and the standardized total effects, the standardized direct effects also provide valuable information. The standardized direct effects in a final model reveal the mediation effects. Therefore the mediation effects for men can be deduced from the standardized total effects in Table 10 and they are as follows:

- BSc. students have a higher amount of objective knowledge than MSc. students and a higher amount of objective knowledge induces a higher level of subjective knowledge, worse expectations for the effects on health and environment and an increase in the trust in industry’s concern with the environment.
- Respondents who study nanotechnology have more objective knowledge and an increase in objective knowledge has the same effects as described in the previous mediation effect.
- Men who have studied nanotechnology expect lower costs than people who have not studied nanotechnology. The expected lower costs result in a more positive evaluation of nanotechnology.
- Men who have studied nanotechnology have a higher level of subjective knowledge and this leads to more positive expectations for health and environmental effects.

- Respondents with a high level of trust in the industry's concern with the environment also have a higher level of positively expected effects on health and environment and this induces a more positive evaluation of nanotechnology.

Such mediation effects can be formulated for the model for women as well (see Table 12):

- Women who have studied nanotechnology have a higher level of objective knowledge and this leads to higher expected costs and more positive expected health and environment effects.
- Women with a high amount of objective knowledge expect high costs and as a result they have a higher score on the evaluation of nanotechnology.
- Women with more objective knowledge or more trust in the industry's concern with the environment have more positive expectations for health and environmental effects and as a consequence they evaluate nanotechnology more positively.

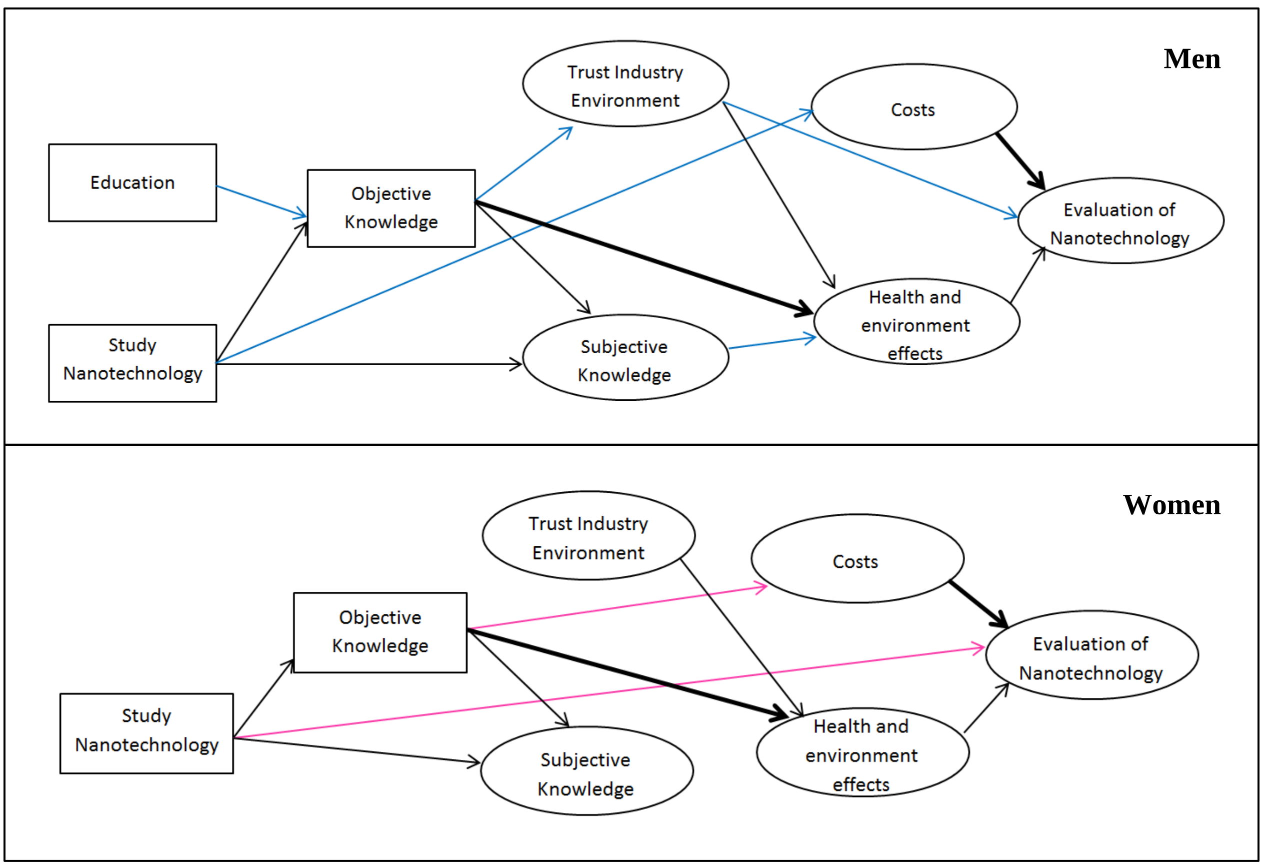

Figure 5. Two final models; a model calculated for the men in the sample and a model calculated for the women in the sample. The rectangles indicate observed variables and the ovals indicate latent variables. Blue and pink arrows indicate paths that are only significant for the model for men and the model for women, respectively. The thickened arrows are paths that are found to be significantly different for men and women.

	TIS	TIE	OK	H&E	SK	B	C	NA	PA	TG	E
N		-.06	-.23	-.15	-.45	-.17	-.26	-.18	-.23		-.23
ED		-.06	-.23	.001	-.07	-.03		-.21	-.03		.03
Age	-.32									-.46	
TIE				.43							-.04
OK		.26		-.006	.29	.11		-.07	.15		-.13
H&E											1.00
SK				.39		.38		-.25	.51		.39
C											.44
SMC	.11	.07	.08	.38	.28	.14	.07	.11	.26	.22	.66

Table 9. Standardized total effects of variables in the SEM of the data on men and the squared multiple correlations of the dependent variables. The abbreviations of the variables can be found in Table 6.

	TIS	TIE	OK	H&E	SK	B	C	NA	PA	TG	E
N			-.23		-.39		-.26	-.30			
ED			-.23					-.23			
Age	-.32									-.46	
TIE				.43							-.47
OK		.26		-.23	.29						
H&E											1.00
SK				.39		.38		-.25	.51		
C											.44

Table 10. Standardized direct effect of the variables in the SEM of the data on men. The abbreviations of the variables can be found in Table 6.

	TIS	TIE	OK	H&E	SK	B	C	NA	PA	TG	E
N			-.36	-.09	-.60	-.12	.10		-.29		-.35
ED								-.23		-.25	
Age						.40					
TIE				.55		.55			.38		.30
OK				.24	.25	.33	-.29		.22		.26
H&E											.55
SK											
C											-.44
SMC	.00	.00	.13	.36	.41	.58	.09	.06	.27	.06	.57

Table 11. Standardized total effects of variables in the SEM of the data on women and the squared multiple correlations of the dependent variables. The abbreviations of the variables can be found in Table 6.

	TIS	TIE	OK	H&E	SK	B	C	NA	PA	TG	E
N			-.36		-.51				-.21		-.26
ED								-.23		-.25	
Age						.40					
TIE				.55		.55			.38		
OK				.24	.25	.33	-.29		.22		
H&E											.55
SK											
C											-.44

Table 12. Standardized direct effect of the variables in the SEM of the data on women. The abbreviations of the variables can be found in Table 6.

5 Discussion of the results

The overall model for the evaluation of nanotechnology is depicted in Figure 7 and is obtained by combining the 3 final models that were developed in AMOS. The overall model is very similar to the final model for the whole sample, but gender is added as a moderator for the paths that were found to be significantly different in the separate models for men and women. When comparing this model to the conceptual model that was proposed in chapter 2, it can be concluded that there are differences and the main difference is that a lot of expected interrelations are not found. The hypothesis of this thesis and the outcomes will now be discussed to obtain a better understanding of the underlying effects.

5.1 Direct effects

This thesis focused on the influence of gender on the evaluation of nanotechnology and was partly motivated by the statement of Prof Macdonald in which she suggests that women have lower levels of acceptance because they lack scientific understanding of the topic. The model suggests that the observed variable ‘study nanotechnology’ has a direct effect on the evaluation of nanotechnology and that gender is the moderating variable. This direct effect was only significant in the model for women, meaning that the size of the effect is smaller for men than for women. The significant direct effect for women is negative which indicates that women who have studied nanotechnology evaluate nanotechnology more positively than women who have not studied nanotechnology. Gender is also a moderating variable for the relation between level of education and objective knowledge in the model for men, but no significant path between these variables was found for the final model for women. The conclusion that can be drawn from this is that gender works as a moderator variable between level of education and objective knowledge and that the variable level of education is a stronger predictor of knowledge for men than for women.

Comparing the average values of the evaluation of nanotechnology for men and women it can however be concluded that men do have a higher average score on the evaluation of nanotechnology than women: 4.27 and 3.96, respectively. This difference is in agreement with what was expected. It was also expected that higher educated people more positively evaluate nanotechnology and the model is in agreement with this hypothesis but the standardized total effect of education on the evaluation of nanotechnology is very small; 0.01.

The subjective knowledge was expected to be a better predictor of the evaluation of nanotechnology than objective knowledge but both variables are not present in the final model for the whole sample. Both knowledge variables are however found in the model for men and the standardized total effect of subjective knowledge on the evaluation of nanotechnology is indeed larger than the standardized total effect of objective knowledge (.39 vs. -.13). The negative effect of objective knowledge on the evaluation of nanotechnology was however not expected but can be explained by the fact that men with an increased level of objective knowledge are more aware of the dangers of nanotechnology which therefore results in a more negative evaluation of nanotechnology. This effect is seen in the direct effect of objective knowledge on health and environmental effects (-.23 for men). This explanation is however not applicable on the model for women since the effect of objective knowledge on health and environment has a positive value of .24. This difference in sign between men and women can be an indication that women with more objective knowledge on nanotechnology have paid less attention to the facts about the dangers of nanotechnology or they can be more aware of how to avoid bad effects of nanotechnology on health and environment. The variable subjective knowledge is however not significant for women which may be due to the fact that women have answered more neutrally due to a lower self-esteem, causing the size of the effect to be smaller than the size of the effect for men [58].

In this thesis a positive relation was expected between the two trust factors and the evaluation of nanotechnology but this not the case according to the overall model. There exists a standardized negative direct effect between the trust in industry's concern with the environment and the evaluation of nanotechnology (-.29). It is difficult to explain this relation so maybe the measured factor actually represents a different factor than the trust in industry's concern with the environment. The variable trust in the industry's concern with safety does have a positive indirect effect on the evaluation of nanotechnology, which is as expected.

The two factors 'costs' and 'health and environmental effects' are present in the overall model but the factor 'economical benefits' is not. This means that the variable 'economical benefits' did not have a significant influence on the evaluation of nanotechnology. The variable on the health and environment effects follows up to the expectations and has a big positive effect on evaluation of nanotechnology, meaning that more positive expectations for the effects of nanotechnology on health and environment result in a more positive evaluation of nanotechnology. The cost variable falls out of the final model for the whole sample because the effect on the evaluation of nanotechnology for men is opposite to the effect on the evaluation for women (0.44 vs. -0.44) and they therefore cancel each other. The difference in sign could be due to differences in interpretation, men may for example be more positive if something is cheaper but women may think that the products will be of a bad quality if they are cheap. This is only a speculative and would require further research.

The last variables that are left from the conceptual model are positive and negative affect. Neither of the two variables significantly contributed to any of the models, although it was expected that at least one of the two could have been a good predictor of the evaluation of nanotechnology. This could be an indication that both factors do not have a significant effect on the evaluation of nanotechnology, but it could also indicate that people had trouble answering questions about their feelings on a technology. Positive affect did however correlate significantly with the evaluation of nanotechnology which could mean that the influence of positive affect is already contained in the other variables.

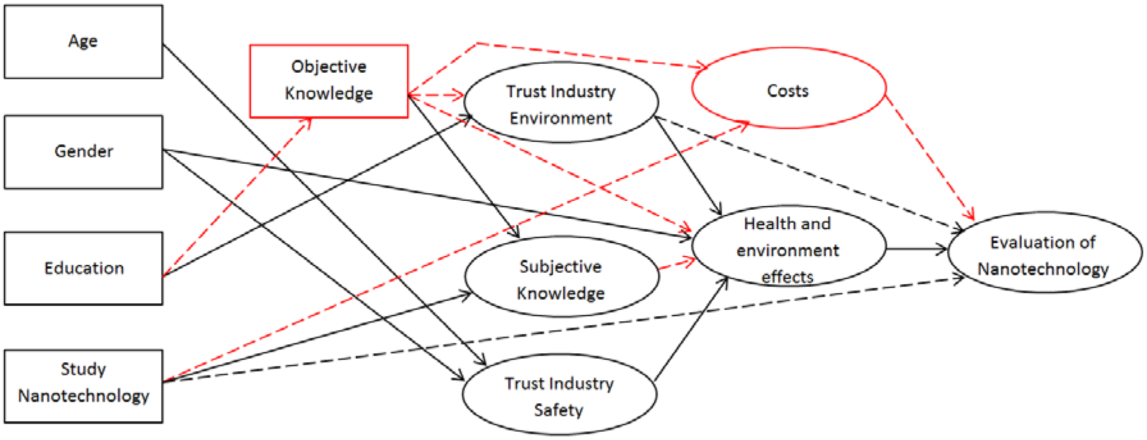

Figure 6. The overall model: the final model for the whole sample including the paths on which gender has a moderating effect. Dashed arrows indicate paths on which gender has a moderating effect and red arrows indicate paths that are only found in the separate models for men and women.

5.2 Indirect effects

The indirect effects of demographic variables will first be discussed, followed by the other variables. It was expected that the level of scientific education has a direct positive effect on the objective knowledge but this effect is not included in the model. The effect was only significant in the model for men and the direction was negative instead of positive. It may be that no significant effect is found in the final model of the whole sample because the difference in level of scientific education is too small. The variable gender does not have an effect on objective knowledge as well, which indicates that the men and women at the TU Delft have a similar amount of objective knowledge.

The model does not support the expectation that men have more trust in industry's concern with the environment since no significant direct effect of gender is found, but it does support the expectation that men have more trust in the industry's concern with safety. It was furthermore expected that women find health and environment more important than men, but the effect between the variable health and environment and the variable evaluation of nanotechnology, has an almost twice as big value for the model for men than for the model for women (.998 vs. .549). These values suggest that a change in the expected health and environmental effects of nanotechnology results in a bigger change in the evaluation of nanotechnology for men than for women.

Objective knowledge was expected to have an effect on all the other psychological variables, but objective knowledge is not present in the model of the whole sample. The variable objective knowledge is however present in the separate models for men and women, meaning that the combined effects cancel each other and that there is a significant gender difference. Finally both types of trust in the industry were expected to influence the expected effects and they indeed influence the variable 'health and environment' positively.

5.3 The moderating variable gender

The red paths in Figure 7 are paths that differ significantly for men and women, but which are not significant in the final model of the whole sample. A reason for being insignificant in the final model of the whole sample may be due to the fact that the significant paths for men and women have an opposite sign and this is indeed the case for the direct path between objective knowledge and health and environment effects and for the direct path between study nanotechnology and costs.

6 Conclusion

This thesis has found that there is a significant gender difference in the evaluation of nanotechnology which is in agreement with most research in literature. One of the contributions of this study to literature is that the gender difference is found among TU Delft students who all have a similar level of education. In addition, the objective knowledge level does not explain the gender difference in the evaluation of nanotechnology, meaning that the outcomes of this research are not in agreement with the statement of Prof Macdonald who suggested that women had lower levels of acceptance of a risky technology (fracking) because they lacked scientific understanding of the topic.

This study also adds to literature since the underlying reasons for the gender difference in the evaluation of risky technologies were estimated with structural equation models and this was not examined in literature before. It can be concluded that there is a significant gender difference in the evaluation of nanotechnology because men have more positive expectations for the effects of nanotechnology on health and environment than women and a more positive attitude towards effects on health and environment leads to a more positive evaluation of nanotechnology. It was already found in literature that men perceive less risks then women, so the outcome is in agreement with the expectation that men would have more positive expectations for the effect of nanotechnology on health and environment [22]. It was however also expected that women would be more negative about nanotechnology than men if it had bad effects on the environment and health [9], but the estimated SEMs suggest that variations in the expected effects on health and environment have a greater effect on the evaluation of nanotechnology for men than for women. This means that men find the effects on health and environment more important than women. In addition men have a higher level of trust in the industry's concern with safety than women and this also results in a higher level of positive expectations for the effects of nanotechnology on health and environment, which again induces a more positive evaluation of nanotechnology.

These outcomes support the notion that it is essential to include women in the boards of the development of risky technologies. The research shows that women are less positive about the effects of nanotechnology on the health and environment, suggesting that women pay more attention to the negative effects of the technology which makes them essential for responsible innovation.

Other variables that are of importance for the overall model on the evaluation of nanotechnology are: age, education, if the respondent has studied nanotechnology, objective knowledge, subjective knowledge, trust in the industry's concern with the environment, costs. The variable gender also affects the direct relations of the three variables 'having studied nanotechnology', 'trust in the industry's concern with the environment' and 'costs' to the variable 'the evaluation of nanotechnology'. This means that the direct relation between these variables is different for men and women. The direct effect of the variable 'having studied nanotechnology' on the 'evaluation of nanotechnology' was not expected which could mean that a mediating variable is missing in the estimated model. This direct effect is only significant in the model for women and the overall model, meaning that the size of the effect is smaller for men than for women. The significant direct effect for women suggests that women who have studied nanotechnology evaluate nanotechnology more positively than women who have not studied nanotechnology. This outcome seems to be in conflict with survey research that was executed by Smith et al. [13], who found that women were likely to be less positive about nanotechnology after receiving information about the benefits and the risks of nanotechnology.

The direct effect of trust in the industry's concern with the environment on the evaluation of nanotechnology is, on the other hand, not significant for women but it is for men and it suggest that the more trust men have in the industry's concern with the environment, the more negative they evaluate nanotechnology. This outcome is not in line with Prof Macdonald's statement that women do not take issues on trust, because it seems that men are the ones that do not take issues on trust and that the effect of women is unknown but smaller [1], [2]. The direct effect of the cost variable on the evaluation of nanotechnology for men is opposite to the direct effect on the evaluation for women and they therefore cancel each other in the model of the whole sample. The result that the variable costs is not found to be significant in the model of the whole sample is in agreement with literature, since no research examined the influence of gender on the effects between variables. The difference in sign could be due to differences in interpretation, men may for example be more positive if something is cheaper but women may think that the products will be of a bad quality if they are cheap and will therefore be less positive.

Gender also influences other relations in the model, namely the relations between: objective knowledge and costs, subjective knowledge and health and environment effects, objective knowledge and health and environment effects and between studying nanotechnology and costs. To conclude, the strongest mediator of the effect of gender on the evaluation of nanotechnology is the variable of the effects of nanotechnology on health and the environment and this variable also has the biggest effect on the evaluation of nanotechnology.

7 Recommendations for further research

Due to the fact that this research suggest that gender can influence the relations between the variables, resulting in different SEM's for men and women, it is recommended to take these underlying relations and variables into account in future research on the evaluation of risky technologies. Certain relations of men and women can even cancel each other in the model for both men and women due to opposite signs, making it necessary to examine the two groups separately. It is also recommended to investigate whether placing the positive and negative affect variables prior to the variables 'costs', 'effects on health and environment' and 'economical benefits' does provide additional significant paths, since research on the evaluation of hydrogen fuel stations did provide extra relations [6].

To be able to obtain a model that is better explained by all the variables, variables concerning values could be added to the model on a similar position as objective knowledge. The values can be used to connect people's evaluation with the values that they find more important than others. Studies on values and gender differences have for example found that there are gender differences in environmental concern and pro-environmental behaviour, where the values altruism, self-interest, traditionalism and openness were important correlates [61]. This example clearly shows how the values may provide a better model, since gender differences were indeed found in this thesis for the variable on health and environmental effects.

It is expected that similar SEMs would be estimated for research on specific applications of nanotechnology, but it can be expected that the knowledge of applications will differ and that certain relations will be stronger if the respondents have to deal with applications in daily life e.g. between costs and the evaluation of the application. It is therefore necessary to separately examine each application of a risky technology for men and women. Finally it would be relevant from a management point of view to examine if the gender differences in the evaluation of nanotechnology actually result in gender differences in buying and voting behaviour.

More research should also be done on the effect of both knowledge and received information on the evaluation of nanotechnology or any other technology, since the effect of studying nanotechnology had a different effect on the evaluation of nanotechnology than what was expected from literature. Research could provide insights in how knowledge and information can result in bigger or smaller differences between men and women.

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Appendix A
Applications and safety concerns of nanotechnology

Nanotechnology is an innovation from recent years and it is therefore quickly developing and the applications are growing. There are different contexts in which nanotechnology is used or can be used in the near future and these contexts will now be discussed.

9.1 Healthcare and Industry

Nanotechnology is employed for the development of new applications to improve diagnostics and treatment of sick people. A good example of nanotechnology in medicine is the targeted control drug release nanosystems which are undergoing clinical evaluation [57]. Another example are implantable nanosensors that are being developed for long-term monitoring of tissue concentrations [58].

In industry the employment of nanotechnology can save a lot of time and money since production processes become more efficient and cheaper. Nanocapsules can for example be used in agriculture to deliver growth hormones, pesticides or fertilizers more efficiently but they can also be introduced within the food as flavour enhancers [59], [60]. Nanoparticles are used in food packaging as well since they support the production of sustainable packages and they improve the preservation of fresh food [61].

In the electronics industry, nanotechnology has also lead to great advances as the electric components, such as transistors, have become smaller, faster and cheaper [62], [63]. Another application of nanotechnology are nanoscale materials/films, which are being used in a diverse set of industries. These films can make surfaces for example water-repellent or it can be used as an anti-bacterial application for clothing, medical equipment and paints [64], [65].

9.2 Safety concerns

Although nanotechnology provides unique possibilities, it also introduces safety concerns with respect to people and the environment. These concerns are mainly induced by the fact that the properties of nanomaterials and their interaction with the environment are unknown since they differ from the ‘same’ large-sized particles [66]. It should be noted that there are two types of nanostructures: ‘fixed’ nanoparticles and ‘free’ nanoparticles. ‘Fixed’ nanoparticles are particles that are incorporated within a substance or device and ‘free’ nanoparticles are individual nanoparticles which are not bound to another substance.

The main concern is with the ‘free’ nanoparticles as it is unknown what the effect of these particles is on the environment and on people. Moreover, it is uncertain what the amount of exposure is of people and the environment to the free nanoparticles. The research that has been done up till now has established that each nanoparticle has to be investigated and no outcomes can be extrapolated for other nanoparticles as the potential risks depend on the particle’s toxicity, size, morphology and the rates of migration and ingestion [67], [68]. An example of the effects that a free nanoparticle can have on humans is given by Poland et al. They showed that carbon nanotubes gave rise to asbestos-like, length dependent, toxic behaviour within mice [69]. This result is a good indication of the harmful effects that nanotechnology can have if we are exposed to it.

In total there are four ways for nanoparticles to enter our body: inhalation, ingestion, skin absorption, injection. As the preceding section discussed, nanoparticle are already being used in food packaging and this could be a significant source of exposure through oral ingestion. Although, the legislation in Europe currently applies an overall migration limit for all substances that can migrate from the package to the food, the possible health risks of the consumption of a certain amount and type of nanoparticle is still not fully understood. This means that there is a severe need for further research to avoid long-term damage. Companies should, therefore, be careful when introducing new products that contain nanotechnology [70]. An example of a product that has been investigated more thoroughly is sunscreen. Sunscreens can contain nanoparticles and research by Cross et al. [71] fortunately suggests that minimal nanoparticle penetration occurs through the outer layer of the skin.

Unfortunately not enough data is available on the effects that nanoparticles can have on the environment. It should, however, be noted that the free nanoparticles can be released in air or water during production and these particles can eventually accumulate in the water, soil or plant life. The fixed nanoparticles are on the other hand incorporated within a product and these products will be recycled or disposed as waste at some point in time. For both the free and the fixed nanoparticle it is unclear how big the negative consequences are for the environment [68], [72].

Appendix B – Questionnaire (Dutch)

A	Algemene informatie over de respondant

Eerst volgen er 5 algemene vragen, wilt u het juiste antwoord aankruisen?

A1 .
Bent u man of vrouw?
- o man
- o vrouw

A2.
Wat is uw geboortejaar?
.. ..

A3.
Wat voor soort opleiding doet u?
- o Bachelor
- o Master

A4.
Aan welke faculteit studeert u?
- o Technische Natuurwetenschappen
- o Techniek, Bestuur en Management
- o Bouwkunde
- o Civiele Techniek & Geowetenschappen
- o Elektrotechniek, Wiskunde & Informatica
- o Industrieel Ontwerpen
- o Luchtvaart- & Ruimtevaarttechniek
- o Werktuigbouwkunde, Maritieme Techniek & Materiaalwetenschappen

A5.
Heeft u zich tijdens uw studie verdiept in nanotechnologie?
- o Ja
- o Nee

B Evaluatie nanotechnologie

B1.
Kunt u aangeven wat u van het gebruik van nanotechnologie vindt?

Ik vind het gebruik van nanotechnologie ....

a. Een erg slecht idee	1	2	3	4	5	een erg goed idee
b. Nutteloos	1	2	3	4	5	erg nuttig
c. Totaal niet belangrijk	1	2	3	4	5	erg belangrijk
d. Een sterke achteruitgang	1	2	3	4	5	een sterke vooruitgang

C Affect

C1.
Kunt u aangeven in welke mate de volgende gevoelens bij u worden opgeroepen als u aan nanotechnologie denkt.

Als een bepaald gevoel voor u helemaal niet van toepassing is in deze situatie, kiest u dan voor 0 'helemaal niet'.

Helemaal niet	0	1	2	3	4	5	heel veel
a. vreugde:	0	1	2	3	4	5	
b. machteloosheid:	0	1	2	3	4	5	
c. kalmte:	0	1	2	3	4	5	
d. bezorgdheid:	0	1	2	3	4	5	
e. trots:	0	1	2	3	4	5	
f. angst:	0	1	2	3	4	5	
g. tevredenheid	0	1	2	3	4	5	
h. stress:	0	1	2	3	4	5	
i. hoop:	0	1	2	3	4	5	
j. boosheid:	0	1	2	3	4	5	

D	Vertrouwen

D1.
De overheid maakt onder andere wetgeving over het gebruik van technologiën.
Geef aan hoeveel vertrouwen u erin heeft dat de overheid ...

a. verantwoordelijke beslissingen neemt met betrekking tot het gebruik van nanotechnologie?
Erg weinig vertrouwen 1 2 3 4 5 erg veel vertrouwen

b. genoeg rekening houdt met het welzijn van de burgers bij het toestaan van het gebruik van nanotechnologie?
Erg weinig vertrouwen 1 2 3 4 5 erg veel vertrouwen

c. in de wetgeving ook voldoende aandacht besteedt aan de veilige afvalverwerking van producten die nanotechnologie bevatten?
Erg weinig vertrouwen 1 2 3 4 5 erg veel vertrouwen

D2.
De volgende vragen gaan over uw vertrouwen in de industrie.

Vertrouwt u erop dat de industrie ...

a. genoeg kennis heeft over nanotechnologie om op een veilige manier nanoproducten te fabriceren?
helemaal niet 1 2 3 4 5 heel erg

b. de intentie heeft om er zeker van te zijn dat de ontwikkelde nanoproducten veilig zijn?
helemaal niet 1 2 3 4 5 heel erg

c. oplettend is en veiligheidscontroles uitvoert om er zeker van te zijn dat de productie van nanoproducten veilig blijft verlopen?
helemaal niet 1 2 3 4 5 heel erg

d. genoeg kennis heeft over nanotechnologie om op een veilige manier nanoproducten te ontwikkelen?
helemaal niet 1 2 3 4 5 heel erg

e. nanoproducten zal ontwikkelen die veilig zijn voor het milieu tijdens het gebruik?
helemaal geen vertrouwen 1 2 3 4 5 erg veel vertrouwen

f. nanoproducten zal ontwikkelen die niet schadelijk zijn voor het milieu nadat ze gebruikt zijn en worden weggegooid ?

helemaal geen vertrouwen 1 2 3 4 5 erg veel vertrouwen

E Invloed van nanotechnologie

E1.
Wat voor invloed heeft nanotechnologie volgens u op ...

	erg slechte invloed	1	2	3	4	5	erg goede invloed
a.	het mileu	1	2	3	4	5	
b.	de economie	1	2	3	4	5	
c.	de gezondheid van burgers	1	2	3	4	5	
d.	het aantal banen	1	2	3	4	5	
e.	toekomstige generaties	1	2	3	4	5	
f.	de welvaart van Nederland	1	2	3	4	5	
g.	de veiligheid van burgers	1	2	3	4	5	
h.	de bruikbaarheid van producten	1	2	3	4	5	
i.	de gezondheid van gebruikers van producten die nanotechnologie bevatten	1	2	3	4	5	

E2.
Welke verwachting heeft u voor de kosten van ...

	erg lage kosten	1	2	3	4	5	erg hoge kosten
a.	het gebruik van nanoproducten	1	2	3	4	5	
b.	de ontwikkeling van toepassingen van nanotechnologie	1	2	3	4	5	
c.	het recyclen of de afvalverwerking van nanoproducten	1	2	3	4	5	

F Kennis test

F1.
Geef aan hoeveel kennis u heeft over de volgende 5 items:

a.	nanotechnologie	Erg weinig	1	2	3	4	5	erg veel
b.	het gebruik van nanotechnologie in producten	Erg weinig	1	2	3	4	5	erg veel
c.	de nadelen van nanotechnologie	Erg weinig	1	2	3	4	5	erg veel
d.	nanotechnologie als afval	Erg weinig	1	2	3	4	5	erg veel
e.	de potentiele voordelen van nanotechnologie voor medische toepassingen	Erg weinig	1	2	3	4	5	erg veel

F2.
Geef bij de volgende stellingen aan of ze waar of niet waar zijn, als u het niet weet kunt u

'*Weet ik niet'* aanvinken.

a. Nanotechnologie heeft betrekking op materialen die <u>niet</u> zichtbaar zijn met het blote oog
   o Waar o Niet waar o Weet ik niet

b. Verschillende nanodeeltjes gedragen zich over het algemeen allemaal het zelfde
   o Waar o Niet waar o Weet ik niet

c. Nanotechnologie wordt gebruikt in kleding om ziekteverwekkers te doden
   o Waar o Niet waar o Weet ik niet

d. Nanodeeltjes worden gebruikt in zonnebrand
   o Waar o Niet waar o Weet ik niet

e. Nanodeeltjes worden gebruikt in de verpakkingen van levensmiddelen
   o Waar o Niet waar o Weet ik niet

f. Nanodeeltjes zijn te klein om gevolgen te hebben op de gezondheid
   o Waar o Niet waar o Weet ik niet

g. 1 nanometer is gelijk aan 1×10^{-6} meter
   o Waar o Niet waar o Weet ik niet

h. Nanodeeltjes kunnen via de huid het lichaam binnendringen
   o Waar o Niet waar o Weet ik niet

H Einde enquête

Heel erg bedankt voor het invullen van de enquête.

Ter extra informatie:
Bij de analyse van de data zal vooral worden gekeken naar verschillen in antwoorden tussen verschillende groepen mensen, waarbij de focus ligt op verschillen tussen mannen en vrouwen. Bij deze verzoek ik u om deze invalshoek van het onderzoek niet te delen met andere personen die de enquête eventueel nog zouden kunnen invullen.

Als u geïnformeerd wilt worden over de resultaten van het onderzoek dan kunt u hieronder uw e-mailadres invullen. Uw e-mailadres zal alleen voor dit doeleinde gebruikt worden en als respondent blijft u verder anoniem.

E-mailadres: ....

Als u eventueel een opmerking heeft over de enquête dan kunt u dat hier later weten: ....

Appendix C – Questionnaire (English)

A	**General information on the respondent**

First
Eerst volgen er 5 algemene vragen, wilt u het juiste antwoord aankruisen?

A1 .
Are you male or female?

- o Male
- o Female

A2.
What is your date of birth?
.. ..

A3.
What kind of education are you following?

- o Bachelor
- o Master

A4.
At which faculty are you studying?

- o Applied Sciences
- o Technology, Policy & Management (TPM)
- o Architecture and the Built Environment
- o Civil Engineering and Geosciences (CEG)
- o Electrical Engineering, Mathematics & Computer Science (EEMCS)
- o Industrial Design Engineering (IDE)
- o Aerospace Engineering (AE)
- o Mechanical, Maritime and Materials Engineering (3mE)

A5.
Did you cover/come across the topic ‘nanotechnology’ during your study?

- o Yes
- o No

B Evaluation Nanotechnology

B1.
Can you indicate what you think of the use of nanotechnology?

I find the use of nanotechnology ....

e.	A very bad idea	1	2	3	4	5	a very good idea
f.	Useless	1	2	3	4	5	very useful
g.	Not at all important	1	2	3	4	5	very important
h.	A strong deterioration	1	2	3	4	5	a strong progression

C Affect

C1.
Please indicate to what extent thinking of nanotechnology evokes the following feelings.

If a certain feeling does not apply to you in this situation, then please choose 0 'not at all'..

		Not at all	0	1	2	3	4	5	very much
k.	joy:		0	1	2	3	4	5	
l.	powerlessness:		0	1	2	3	4	5	
m.	calmness:		0	1	2	3	4	5	
n.	worry:		0	1	2	3	4	5	
o.	pride:		0	1	2	3	4	5	
p.	fear:		0	1	2	3	4	5	
q.	satisfaction:		0	1	2	3	4	5	
r.	stress:		0	1	2	3	4	5	
s.	hope:		0	1	2	3	4	5	
t.	anger:		0	1	2	3	4	5	

D Trust

D1.
The government makes laws on the use of technologies.
Please indicate how much you trust the government to...

d. take responsible descisions regarding the use of nanotechnologyverantwoordelijke?
Very little trust 1 2 3 4 5 a lot of trust

e. take the well-being of the citizens sufficiently into account when allowing the use of nanotechnology?
Very little trust 1 2 3 4 5 a lot of trust

f. pay enough attention in the legislation on safe waste processing of products that contain nanotechnology?
Very little trust 1 2 3 4 5 a lot of trust

D2.
The next questions will be about your trust in the industry.

Do you trust the industry to ...

g. has enough knowledge to produce nanoproducts in a safe manner?
not at all 1 2 3 4 5 very much

h. has the intention to make sure that the developed nanoproducts are safe?
not at all 1 2 3 4 5 very much

i. pays attention and performs safety checks to be certain that the production processes of nanoproducts stay safe?
not at all 1 2 3 4 5 very much

j. has enough knowledge to develop nanoproducts in a safe manner?
not at all 1 2 3 4 5 very much

k. develop nanoproducts that are environmental friendly when being used?
not at all 1 2 3 4 5 very much

l. develop nanoproducts that do not harm the environment once they are disposed as waste?
not at all 1 2 3 4 5 very much

E Effects of nanotechnology

E1.
What kind of effect do you think nanotechnology has on ...

	very negative effect	1	2	3	4	5	very positive effect
j.	the environment	1	2	3	4	5	
k.	the economie	1	2	3	4	5	
l.	the health of citizens	1	2	3	4	5	
m.	the number of jobs	1	2	3	4	5	
n.	future generations	1	2	3	4	5	
o.	welfare of The Netherlands	1	2	3	4	5	
p.	safety of citizens	1	2	3	4	5	
q.	the usefulness of products	1	2	3	4	5	
r.	the health of people that use products that contain nanotechnology	1	2	3	4	5	

E2.
What expectations do you have for the costs of ...

	very low costs	1	2	3	4	5	very high costs
d.	the use of nanoproducts	1	2	3	4	5	
e.	the development of nanotechnology applications	1	2	3	4	5	
f.	the recycling or disposal of nanoproducts	1	2	3	4	5	

F Knowledge tests

F1.
Please indicate how much knowledge you have on the following 5 items:

	very little	1	2	3	4	5	very much
a.	nanotechnology	1	2	3	4	5	
b.	how nanotechnology is used in products	1	2	3	4	5	
c.	the disadvantages of nanotechnology	1	2	3	4	5	
d.	nanotechnology as a waste	1	2	3	4	5	
e.	the potential benefits of nanotechnology for medical applications	1	2	3	4	5	

F2.
Please indicate if the following statements are true or false, if you don’t know the answer you can check the box ‘*don’t know*’.

i. Nanotechnology involves materials that are not visible to the naked eye o True o False o Don't know

j. Different nanoparticles generally behave in the same way
   o True o False o Don't know

k. Nanotechnology is used in clothing to kill disease-causing bacteria
   o True o False o Don't know

l. Nanoparticles are used in sunscreen
   o True o False o Don't know

m. Nanoparticles are being used in food packaging
   o Waar o Niet waar o Weet ik niet

n. Nanoparticles are too small to have a health effect
   o True o False o Don't know

o. 1 nanometer is equal to 1×10^{-6} meter
   o True o False o Don't know

p. Nanoparticles can penetrate your skin
   o True o False o Don't know

H	End of the questionnaire

Thank you very much for finishing the questionnaire.

Extra information:

In the analysis of the data I will mainly look at differences in answers between different groups of people, where the focus will be on differences between men and women. I would like to ask you to not share this information with people who still may take part in this questionnaire.

If you would like to be informed on the results of the research, you can fill in your e-mail address below. Your e-mail address will only be used for this purpose and as a respondent you will remain anonymous.

E-mail address: ....

If you have any remarks on the questionnaire, please leave a comment:

....

Appendix D – Final SEM for the entire dataset

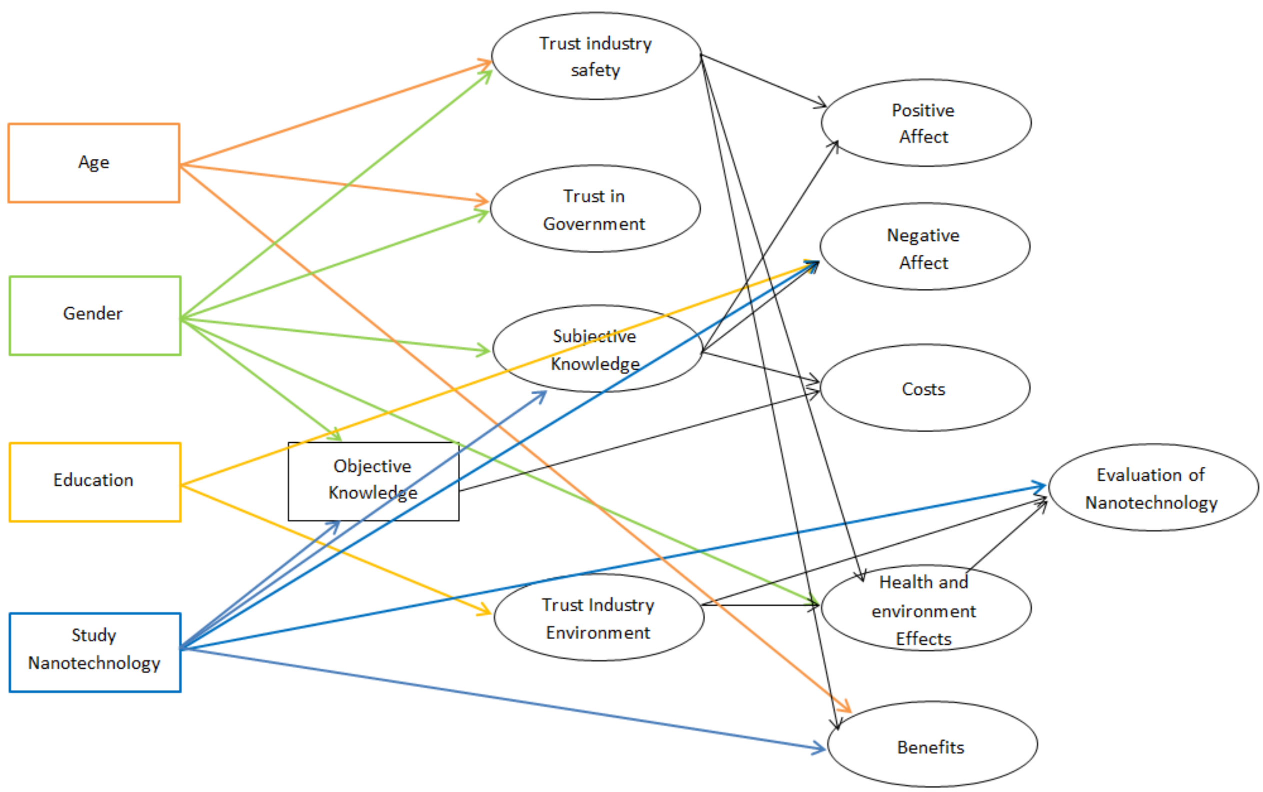

Figure 7. The final SEM for the whole sample, including significant relations with variables that do not have an impact on the acceptance of nanotechnology**.**