Nanotechnology - Ethical and Social Issues: Results from a New Zealand Survey

Andrew Cook
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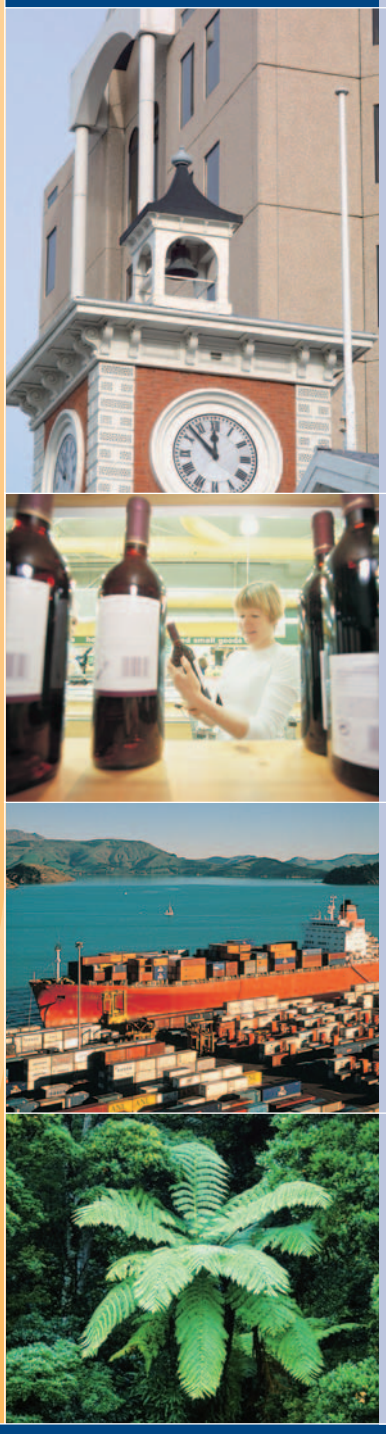

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Preface

In recent years our research unit has conducted various studies of perceptions, attitudes and economic behaviour towards new technology. These have centred mainly on explaining reactions to environmental, medical and food examples of biotechnology. During this time nanotechnology has emerged as a novel recent development that promises prosperity through the development of a wide variety of novel products and processes. This means that nanotechnology is likely to affect the lives of New Zealanders, so it is important to study social impacts and reactions. Accordingly this report presents survey research on both favourable and unfavourable reactions to a number of examples of nanotechnology. The findings are of general interest but should be particularly useful to scientists, public and private institutions, and those with a general interest in the topic area.

Professor Caroline Saunders
Director
AERU

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Summary

Rationale

- Despite the prospects for benefits, given public controversy over the use of genetic modification (GM), it cannot be entirely ruled out that nanotechnology will have problems with public acceptance. Debate about the issue of nanotechnology can be informed by an understanding of public reactions.

Research aim and objectives

- The general aim was to determine and understand New Zealand public reactions to nanotechnology.
- An objective was to assess the generalisability of focus group research in a national survey.
- A further objective was to investigate the role of values, beliefs and emotion in shaping attitudes towards nanotechnology.

Method

- A questionnaire was designed which included measurement of the following:
  - Acceptability of twelve examples of nanotechnology.
  - Beliefs about nanotechnology in general.
  - Beliefs about the use of nanotechnology in medicine, electronics and food.
  - Attitudes towards nanotechnology.
  - Values associated with post-materialism, technology, resource use and nature.
- The resulting questionnaire comprised 86 items.
- The questionnaire was randomly distributed in a national postal survey. From 2,000 potential respondents there were 387 usable responses. After accounting for those undelivered there was a 20 per cent response rate.

Representativeness

- As is common for survey research the sample over represented older age groups as well as those with higher incomes and education. There was no evidence of difference based on gender.

Main findings

Acceptability of examples of nanotechnology:

- There is a particular aversion to products of nanotechnology where people can be exposed personally to nanoparticles.
- The prospect of benefit outweighs considerations of risk in cases such as cancer treatment.
- There is a tendency to be more certain about choices over nanotechnology products, compared to statements regarding outcomes of the technology or assessments of attitude towards the technology.
- The unacceptability of a nanotechnology skin care product is similar to low levels of acceptability for examples of food biotechnology.

Beliefs about nanotechnology:

- There are concerns over control of unexpected outcomes and indecision regarding catastrophic potential.
- It is largely unknown as to whether nanotechnology would be less polluting and help clean up the environment.
- It is recognised that there is potential for a variety of useful consumer products from nanotechnology and their development is not considered disruptive to industry or the economy.
- The prospects for growth in employment and the economy are less clear and there is concern over unforeseeable social impacts.
- Nanotechnology is not far behind biotechnology in terms of general assessments of risk, while being judged as having somewhat better prospects for improving quality of life.

Nanotechnology in medicine, electronics and food:

- There was concern that various medical developments from nanotechnology would be used for self improvement or human enhancement rather than for medical treatment to alleviate suffering.
- There was more agreement than disagreement that the increased availability of affordable medical testing could lead to more people worrying about their health.
- Most disagreed with the view that tests and treatments can not replace a doctor's good judgement.
- Most agreed that medical treatments using nanotechnology were preferable to GM.
- The majority judged that medical consequences could result in harmful outcomes that can not be reversed.
- There was a strong expectation that surveillance by various means would increase and that it would be of some benefit for combating crime and terrorism.
- The use of personal information for discrimination was judged likely.
- There was a good deal of concern over food made using nanotechnology including being uncomfortable about naturalness and being concerned about long term risks.

Attitude towards nanotechnology:

- Attitude towards nanotechnology was generally favourable.
- Few disapproved of the technology and a majority disagreed that it was unacceptable.
- Some felt uneasy but more indicated there was no need to worry.
- Some felt it caused them anxiety but more indicated no anxiety.
- Most were fascinated with the new technology.
- There was more concern over biotechnology than nanotechnology.

Influences on attitude:

- Beliefs about risks and benefits were shown to be strongly linked to attitude towards nanotechnology.
- Values associated with post-materialism, technology and resource use and technology and nature were linked to attitude towards nanotechnology.

Demographics and attitude:

- Males had a more positive attitude than females.
- Younger age groups had a more positive attitude.
- Those with higher income had a more positive attitude.
- Similar relationships have been found in surveys of reactions to biotechnology.

Implications

- Addressing incorrect perceptions regarding likelihood of exposure and prospects for personal harm should have an effect on the acceptability of a target product such as food, drink or medicines.
- While judgements of outcomes are based on speculation, firmer assurance of social and economic benefits, as well as assurance of low risk to people and the environment, would likely transfer into support and attitudes would become more positive.
- Apprehension that people could become artificial and lose the natural qualities of being human is a general concern that medical nanotechnology research may wish to avoid. Alternatively it may well be productive for public debate to help clarify the boundaries for acceptance of medical use of the technology.
- Both commercial and governmental organisations are envisaged to gain the ability through new nanotechnology to track what people buy, where they go, and what they do. This suggests that there will be objections to incursions on privacy that may in turn lead to restrictions on surveillance activities and regulation of the use of information.
- Food produced using nanotechnology is likely to be more acceptable than GM food but given little advantage to the consumer it is unlikely to be widely accepted. It is also possible that, like GM food, there may be calls to provide for consumer identification of these food products. Without some form of consumer benefit, the demarcation of the new products is likely to harm sales because of concern over unknown risk and long term exposure.
- Attitude towards nanotechnology was generally favourable but many were unfamiliar with the technology or its possible effects. Many are yet to become familiar suggesting near future promotion or criticism will be particularly influential.
- At present attitude towards nanotechnology has a relationship with post-materialist values and values associated with technology, resource use and nature. The nature of values is that they are slow to change and would tend to slow any change in attitude towards nanotechnology.
- With greater familiarity, knowledge of a technology and its effects take more precedence in its appraisal and overshadow the effect of general values.
- Beliefs about nanotechnology are subject to change and lead to a change in attitude. Dealing with the various social, economic and environmental effects identified in the results would have an effect on attitude.
- As a secondary consideration, attention could be given to how the technology is being interpreted in relation to values associated with post-materialism, technology, resource use and nature. This means that nanotechnologies that assist in the sustainable use of energy and resources, and are seen not to disrupt a complex and unpredictable conception of nature, are likely to be more acceptable.

- Nanotechnology is more favoured than biotechnology in a number of overall assessments, but not by a large margin. The level of rejection of personally ingesting nanoparticles is similar to the rejection of similar products of biotechnology. Some belief statements were also similar, suggesting that nanotechnology is not far behind biotechnology in terms of general assessments of risk.
- Nanotechnology is being received with more caution than the early introduction of GM. While being somewhat more acceptable, reactions to the new technology are similar to, and comparable with, recent reactions to biotechnology. Consequently, unlike the initial general acceptance of GM, there is likely to be a good deal of public concern upon finding out more about nanotechnology.

Recommendations

- It would be prudent to deal with potential public reactions towards offsetting the potential for nanotechnology to become problematic and unacceptable.
- The public needs to be informed about key areas of their concern, including prospects for environmental and personal risk, as well as personal social and economic benefits.
- Amending research and development in response to public attitudes should be considered to avoid public controversy as well as explaining the technology in order to offset the possibility of public controversy.
- Caution should be employed in research and development in the areas of food, drink or medicines and in forms that can be inhaled or absorbed through the skin considering the high potential for public concern.
- Public reactions to each application of nanotechnology should be studied as the assessment of public reactions to general areas of the technology may differ from reactions to particular products and processes.

Chapter 1
Introduction: Nanotechnology Developments, Issues and Research Objectives

1.1 Introduction

Nanotechnology is new technology based on a new science that investigates the properties and structures of materials at an extremely small scale. The scale is called the nanoscale and is smaller than microscopic, which covers bacteria and viruses, but larger than the atomic scale containing atoms and their parts. Its standard unit of measurement is the nanometre which is an almost incomprehensible millionth of a millimetre or about one eighty thousandth the width of a human hair.

Nanotechnology is new because it has only recently become possible, through the development of new tools and techniques, to study and manipulate materials at the nanoscale. However, the novelty of this new science and technology is not merely the extremely tiny scale at which it operates. Of particular importance, materials that were formerly understood in larger form can behave very differently at the nanoscale. For example, nanosize particles of gold will rust and silver in nanoparticle form can be used to destroy bacteria. Also, carbon nanotubes, made from carbon atoms, have strength characteristics similar to diamonds and, like graphite, are good conductors of electricity. These new properties create potential for nanoscale materials to be used in the development of improved or entirely new products or processes.

The development of nanotechnology would seem to follow a trend. In recent times it has become common for new technology to emerge from scientific inquiry in places too small for everyday observation. The discovery of DNA, nuclear reactions and the development of modern biotechnology and nanotechnology are similar because they extend from scientific investigations in domains smaller than is visible to the naked eye. These technologies are the result of the progression of science into areas previously unknown and entail the development of skills and knowledge of particular environs. Accordingly nanotechnology can be considered the result of the opening of another domain for scientific investigation. These investigations can be regarded as an extension of human and cultural propensities to use and rely on technology and to encourage progress via technology so that, on these terms, nanotechnology is not unlike fire, the wheel, or even agriculture. However, nanotechnology is different because, like other modern technologies, its workings are particularly intangible and unfamiliar to lay people (Waldren, Spencer & Batt, 2006). Nanotechnology is therefore the product of a technology orientated society but is also foreign to many members of this society.

A further trend that could be a warning for nanotechnology is the level of public concern over biotechnology, in particular the use of genetic modification (GM). If nanotechnology happens to follow the trajectory that biotechnology has in New Zealand then it its introduction is likely to be difficult. There has been a good deal of public concern over risks associated with GM. Like this biotechnology, there will be benefits from nanotechnology, but it is possible that there are risks associated with some nanotechnologies. Once these become apparent, or are suspected by the public, it would be likely that a resistance to the technology would develop. For example, in the 1990s New Zealanders tended not to have been predominantly negative towards GM biotechnology. However, more people became negative about biotechnology by

the time of the holding of the Royal Commission on Genetic Modification (2001) (Cook, Fairweather & Campbell, 2000). While not solely relying on public opinion the Royal Commission nevertheless recommended caution in the development of GM biotechnology which has incurred costs for research and development.

Rather than incurring costs in the development of a new technology it would be best to find some way of avoiding problems with public acceptance. One way is to have various institutions informed by public views and values so that unnecessary costs can be avoided. This requires the use of social research that can show social concerns and aspirations and enable better informed decisions about nanotechnology developments and applications.

The research reported in the following chapters is a companion to focus group research conducted in New Zealand (Cook and Fairweather, 2005a) and is aimed at enabling a closer and mutually beneficial alignment between nanotechnology and public viewpoints. This may be achieved by pro-nanotechnology stakeholders adjusting to public response, as much as the public adjusting to the pro-stakeholders position. In the remainder of this introduction, nanotechnology is further defined and some of the increasing number of manifold topics related to the technology is presented. In closing this chapter a description is provided of the research methods, aims and objectives, the research design, as well as a summary of the remaining chapters of this report.

1.2 The emergence of nanotechnology

In hindsight, the first ideas associated with nanotechnology have been attributed to Feynman who in 1959 gave a speculative after-dinner talk about how atoms and molecules could be manipulated. As apparent by the title, this talk and subsequent transcript paper was an appeal to consider ‘There's plenty of room at the bottom’. The work outlined the way cells do not simply have information encoded in them but use information to work like tiny manufacturers. The talk suggested the miniaturisation of machines and computers to work at a small scale. To engineer these devices Feynman proposed the making of a machine engineered to replicate a smaller version of itself, so that continual replication would result in a miniature machine. This miniature machine was explained as the fabricator of miniature factories. The point of the talk was to suggest enabling manufacturing at the small scale.

Separately and much later, Taniguchi (1974; sourced from http://nanodot.org; accessed 6/6/2006) used the term ‘nano-technology’ to describe ‘... the processing of, separation, consolidation, and deformation of materials by one atom or one molecule.’ However, it was not until the 1980s that Drexler (1986) drew on Freynman’s ideas and popularised the term ‘nanotechnology’ in promotion of nanoscale machines capable of repairing cells in the human body and self-replication. Drexler’s theorising meant that nanotechnology came to be associated with engineering and manufacturing being undertaken at the nanoscale, rather than the comparatively more straight forward manufacturing of nanoscale materials.

The recent burst of activity in nanotechnology has been through interdisciplinary work involving physics, mechanical engineering, bioengineering, or chemical engineering. Largely since 2000, predominantly interdisciplinary work within and between these fields have been undertaken on the study and manipulation of materials to discern and capitalise upon their properties that are exhibited when they are isolated at the nanoscale. As Ratner and Ratner (2003) have explained, this work has been enabled by new tools and techniques. The scanning probe microscope enabled visualisation and measurement of many aspects of the nano-domain such as adhesion, energy, friction, magnetism, and surface elasticity. In addition,

some of these microscopes have been used to manipulate and arrange individual atoms. Other tools include microlithography and micro engineering systems that enable the production and etching of nanoscale layers of material. Some considerer this is an early form of nanotechnology that is merely an extension of traditional science into a new domain.

1.3 Areas of development

Areas for new developments from nanotechnology are already many and varied. According to the OECD and Allianz (2005) the following areas of development contain some of the present and near future applications of nanotechnology.

Medical applications of nanotechnology include new drug delivery systems that have been animal tested and are beginning early clinical trials. Their potential for bringing new interventions stems for their size as some on them can pass thorough cell walls. They can potentially induce biological reactions or gain access to different areas of the body. There is also potential for targeted drug delivery and for their use to enhance medical imaging and diagnostics.

Nanotechnology is also being used in the development of devices to provide hearing and eyesight. One device uses an implant of microscopic solar cells to provide simulated vision. An implant for hearing can move the fluid in the inner ear to stimulate the auditory nerve.

Nanoparticles are also being used in food production. For farming, pesticides are being developed that can more easily be absorbed by plants and it is possible to coat chemicals with nanoparticles to ensure release over time. Nanotechnology-based sensors are also being considered for monitoring farm conditions. In food production some vitamins and substances are being manufactured in nanoscale form to ensure their absorption in water. Another example provides new colour additives for food and drink. The use of nanoparticles so that the consumer can change food colour or flavour is also envisaged and there are also plans to use nanoparticles to modify the texture of some foods.

Nanotechnology can also be used to develop nanoscale sensors to detect bacteria and toxins. A handheld scanner could be used to scan food for freshness or for evidence of harmful pathogens.

Further potential advantage for agriculture is envisaged through the use of nanotechnology as a tool in genetic modification as well its general potential through manipulating food molecules. Rice DNA has already been altered to change plant colour by inserting a foreign atom through a nano-size opening in a rice cell.

The computer industry is already working on advances using nanotechnology to improve speed and capacity. In addition to improving the current design, new designs are being developed to take more advantage of the miniaturisation of components. These include computers that manipulate the spin of electrons to transfer data, the use of DNA for data storage and processing, and computers that operate within the unusual forces at the nanoscale. Improvements in speed could also prompt consideration of more direct interface by bypassing the keyboard and hooking up directly to the human nervous system.

In textiles stain and wrinkle resistant clothing are already being developed. Other features that are under experimental development are textiles that self clean or repair themselves as well as those that offer soldiers better protection, UV resistance and wound healing functions.

There is potential for development using nanotechnology in numerous areas of the energy sector. More efficient wind power, solar cells and cleaner coal burning are envisaged. Nanotechnology is being proposed to improve electric lighting, fuel cells, batteries and hydrogen storage and production. The use of nanotechnology materials could also make the transmission of electricity more efficient. Stronger, light-weight materials are also envisaged to improve the efficiency of land, sea and air transportation. Drilling technology could also be improved with nanotechnology coatings to enable deeper drilling for oil, gas and possibly geothermal resources.

1.4 Futuristic nanoscale machines

Some scientists believe that an advanced form of nanotechnology that involves manufacturing nanoscale machines can eventually be developed. This is the nanotechnology that Drexler (1986) envisaged and would involve joining molecules with specified properties to perform a particular task. This is considered to be a step beyond the current isolation and use of a nanoscale material. Hall (2005) envisaged that in the advanced form the technology would enable a number of futuristic developments. First, it was thought that much in the same way that bacteria breaks down and transforms waste into soil, a molecular machine could transform discarded material into something useful such as household objects or food. Extending on this idea it was suggested that molecular machines could improve human health by rearranging atoms or molecules with the human body. It was also thought that molecular machines could make functional connections with the human brain to enable experience of virtual realities.

1.5 Nanotechnology and science fiction

The seemingly fictional ideas of what molecular nanotechnology could lead to have given rise to some similarly unusual uses of the technology in popular media. Replicating food is common on fictional star ships and the use of ‘nanites’ for medical treatment as well as unwanted infestation has been in various storylines of Star Trek. Michael Creighton (2002) in the novel ‘Prey’ had robot like nanoparticles acting together in a swarm that acted as an intelligent foe in a Frankenstein like storyline. In Will Smith’s movie ‘I, Robot’ the swarm was used as a weapon by the hero and Terminator II had a shape shifting killer robot. Such use of nanotechnology to fit writer story lines and entertain will shape what people take nanotechnology to be. Ironically, while more dramatic, they might seem as fictional as the futuristic scenarios noted above.

1.6 Risks

An advantage of nanotechnology is that by working at the nanoscale it is discovered that materials take on new properties. This makes new nanoparticles very interesting for scientists and industry. It also makes them potentially a source of risks to people or the environment because as well as having new beneficial qualities they may have new harmful qualities.

According to Swiss Re (2004) there are a number of problems that need to be considered in assessing the risk of nanoparticles in the environment. While it is less likely that they are a risk in a composite material, in free form there is concern that some nanoparticles may be hazardous to human health or the environment. It is also expected that the small particle size will mean that they are more likely to react with other substances.

Nanoparticles can be inhaled, absorbed through the skin or the digestive system. Once in the body they are not very restricted in where they can go and may cross the blood brain barrier. Ready absorption by the body can be useful for some pharmaceuticals but may not be desirable for some nanoparticles. They can overload systems to remove foreign matter from the body, weaken natural defences and have adverse reactions with biological processes.

Nanoparticles can be useful in the environment to help clean up contaminated soil or water but some may themselves not degrade and become a pollutant. They may be released as a by-product of industry or by accident. New types of pollutants may become evident and new ways of removing them may need to be developed given difficulties of using traditional filters.

1.7 Surveys of reactions to nanotechnology

Social acceptance of nanotechnology is arguably necessary for its future development and there have been a few early studies of public opinion. However, these may have been hindered by lack of knowledge and unfamiliarity with the topic. A 2001 internet-based survey (N = 3,909) conducted in the US by Bainbridge (2002) found most of those who replied to the English language version were very positive about nanotechnology. There was 58 percent who agreed that ‘human beings would benefit greatly from nanotechnology’. Only nine percent took the negative view that nanotechnology was ‘threatening to make humans an endangered species’. The positive view was found to be linked to a positive general view of science and technology. There were high levels of interest in potential benefits and a dismissal of possible risks. Respondents who supported nanotechnology also tended to support other technologies including the space programme, nuclear power and research on cloning. The small numbers who were opposed to nanotechnology were against these three technologies.

A further survey type study was conducted by telephone in the US by Cobb & Macoubrie (2004; N = 1,536). Most were found to be unfamiliar with the technology with more than 80 per cent indicating they knew little or nothing about it. Nevertheless, many judged the risks and benefits to be about equal and forty per cent judged the benefits would exceed the risks. Only half as many judged the risks would exceed the benefits. It was also clear that level of knowledge about nanotechnology was associated with a more positive response. It was then suggested that science literature about nanotechnology tends to predict large numbers of benefits to society and only infrequently discusses the risks. The most important potential benefits were for improvements in the detection and treatment of diseases. The least important was for cheaper consumer products. The most important risks were losing personal privacy,

the arms race and breathing nanoparticles that accumulate in the body. Emotions were also shown to be associated with nanotechnology. Most were a little to very hopeful about the new technology while just under 20 per cent were a little to very worried. Fewer than five per cent indicated they trusted business leaders to minimise risk to humans.

Another survey conducted by Scheufele and Lewenstein (2005) was conducted by telephone in the US (N = 706). The purpose was to look at the role that the media played in shaping attitudes towards nanotechnology as well as the way people came to understand the new technology. The researchers found that knowledge of nanotechnology was low but respondents seemed to be able to estimate from what they had been told that economic benefits would be important and that there would be other general benefits. Those already aware tended to express support. The results indicated that these positive respondents emphasised the benefits of the technology over the risks and were more optimistic. The researchers concluded that this was evidence of the media framing news reports around potential benefits because attention to mass media was one of the strongest predictors of attitude.

Surveys reported by Gaskell et al. (2004) have looked at public reactions in both the US and Europe. They have found that studies conducted in the US show a higher level of acceptance of nanotechnology than the European studies. They have also found that in the US people are more optimistic about familiar technologies such as mobile phones, the internet and solar power. In further analysis they showed that in the US support for nanotechnology was embedded in shared values about the benefits of technological innovation. These values include interest in science, enthusiasm about progress, confidence in nature's ability to adapt and a tendency have more trust in those involved in regulating technology. Gaskell et al (2004) speculate that the tendency for optimism should ensure a smooth path for development of nanotechnology in the US. For Europe they are not so confident. On the one hand if it is associated with beneficial medical applications opinion would improve. On the other hand, if it becomes associated with the risks and uncertainties that some associate with GM food or becomes associated with negative science fiction depictions, acceptance is likely to be more difficult.

Another US (N = 1,200) and Canadian (N = 2,000) telephone survey found that there was little knowledge of nanotechnology compared to knowledge of other technology such as stem cell research (Priest, 2006). Public opinion was nevertheless positive and was linked to general attitudes towards technology. These general attitudes were themselves reflective of individual values as defined by moral, ethical or utilitarian positions. Of interest, attitudes towards nanotechnology were only found to be slightly more positive than those for GM food and less positive than those for other more well known technologies such as stem cell research. This is interpreted as showing that nanotechnology could be readily rejected if future risks and difficulties arise.

A recent national survey conducted in New Zealand as part of a series of surveys examining public reactions to a range of biotechnologies included assessment of reactions towards two biotechnologies that incorporated nanotechnology (Cook & Fairweather, 2006; N = 565). For a medical example it was proposed to use nanoparticles as a vector for gene replacement therapy. For this example it was found that there were particular concerns about using the technique for human enhancement though the use of nanotechnology was preferable to a GM technique that uses a virus to carry and insert needed genes. The new method was judged unnatural and some considered it unethical. Nevertheless, 26 per cent intended to support the use of nanoparticles in gene replacement therapy and this support was shown to be linked to respondent concerns. A second use of nanotechnology in biotechnology was the use of

nanoparticles in the genetic modification of beef or lamb that has less cholesterol causing fat. For this food example amongst other judgements most agreed with the view that it's a worry that people may not comply with the rules or regulations that govern the processes used to make product. Many indicated it would feel unnatural to eat this product and there was concern that animals used to make this product may suffer unforeseen health problems. Seventy five per cent intended to purchase the genetically modified beef or lamb produced using nanoparticles, and, like the medical example, these intentions were linked to judgements of the technology and the food product.

1.8 Research aims, rationale and objectives

The general aim of the survey research presented in this report was to determine New Zealand public reactions to nanotechnology. This survey research built upon the results of focus group investigations conducted in 2005 and reported by Cook and Fairweather (2005a). These results are reviewed in the next chapter in order to explain the development of the questionnaire. A general aim was to evaluate the relevance of the focus group findings to the wider population. A further objective was to investigate the role of values, beliefs and emotion had in shaping attitudes towards nanotechnology.

The rationale for this study was the same as the focus groups in that despite the prospects for benefits, given recent public controversy over the use of GM, it cannot be entirely ruled out that a new technology would have problems with public acceptance. Of note, these negative reactions arose only after research on public reactions to GM had made considerable progress. This suggests that the controversy could have been avoided had more attention been given to understanding public reactions and the scientific developments had been more responsive to public concerns. It would therefore seem wise to attempt to gauge and understand public reactions to nanotechnology so as to usefully inform various actors engaged with the development and implementation of nanotechnology. Therefore, the overall aim of this research was to inform the development and implementation of nanotechnology applications, through developing an understanding of public reactions.

In summary the key necessary objectives are as follows:

- Investigate and identify public reactions to possible developments of nanotechnology.
- Identify and compare reactions to particular applications as well as an overall attitude towards nanotechnology.
- Predict ethical and social reactions to, and implications arising from, nanotechnology.
- Provide guidance to educating and informing the public and scientists, and guidance for processes of interaction between scientists, policymakers and the public.

1.9 Research design

The principle source for the questionnaire was the focus groups that studied reactions to nanotechnology (Cook & Fairweather, 2005a). The research design also followed generally other questionnaires used to study public reactions to biotechnology in New Zealand (Cook, Fairweather, Satterfield, & Hunt, 2004; Cook & Fairweather, 2005b; Cook & Fairweather, 2006). These studies have used statements originally developed in focus groups to measure general values and beliefs about new technology as influences upon reactions to a biotechnology. As well as general values, emotions have also been shown to be involved in decisions regarding new biotechnologies (Cook & Fairweather, 2005b). Of note, the measurement of general values and emotions has been recommended in studies of reactions to nanotechnology in the US (Bainbridge, 2002; Cobb & Macoubrie, 2004).

Following these earlier findings and recommendations the research was in part designed to investigate the role that beliefs and values have in shaping an attitude towards nanotechnology.

1.10 Plan of the report

The following is a brief overview of the remaining chapters of this report.

Chapter 2 describes the design of the quantitative enquiry using focus groups.

Chapter 3 presents the results and their interpretation.

Chapter 4 begins with a discussion of the results and practical implications are then identified. The chapter closes with conclusions and recommendations for further research.

Chapter 2
Method

2.1 Introduction

This chapter first provides a description of the focus group method and a summary of the main findings. The second part of the chapter presents and explains the questionnaire used to measure attitudes towards nanotechnology.

2.2 Focus groups method and results

The overall aim of the focus groups conducted in 2005 was to develop an understanding of possible public reactions to nanotechnology. The research was designed with the general objective of identifying and investigating salient attitudes, beliefs, views and values arising from possible developments of nanotechnology. A further objective was to provide the grounding for the national survey presented in this report for the purpose of better gauging public reactions.

To adequately meet the earlier aims and objectives, a qualitative study was designed to explore public concerns that could arise from an unfamiliar technology. Focus groups were selected as the preferred method to investigate reactions because of the novelty of the topic. Focus groups were preferred because they encourage exploration of a topic while providing the opportunity for people to learn and jointly build on the insights and ideas of the other participants.

To adapt the method to the unfamiliar topic each group met three times. It was judged that there would be limited time for the discussion of a less than well known, diverse and technical topic if only one meeting was held. In addition, it is questionable whether respondents would have the ability to adequately consider a new technology and an array of examples in one session. Meeting three times enabled participants to be eased into the topic and allowed for sufficient time for instruction about the science behind nanotechnology as well as discussion of examples and possible future developments.

The first session took approximately one hour and comprised an introduction to the focus groups which was followed by consideration of examples of topical issues involving science and technology. Issues included aerial spraying for biocontrol in urban areas, public vaccination programmes and the use of bacteria in throat lozenges. The discussion showed that often the media was perceived to be biased and the participants often thought there was a need for information beyond what advocates might provide. Also, a number of participants considered their decisions were the result of weighing up risks or costs and benefits. In addition, once condoned it was felt licence was given to wider use of a technology so demarcating the boundaries of a particular decision could assist in acceptance. However, for some issues decisions were based on feelings, particularly where there was conflicting information. In this regard promoters and objectors to a technology might consider factors such as whether the information comes from a trusted source.

The second session began with an educational video in which scientists talked about their work on aspects of nanotechnology. This was followed by discussion of a list of examples of

everyday commercial products involving nanotechnology. The list included the following examples which are available for sale in the US:

- Improved tennis rackets and tennis balls
- Emulsion form of commercial disinfectant
- Indoor air purifier powered by light
- Shoe inserts with increased insulating properties
- Golf driver with more resistance to bending
- Sunscreens and cosmetics, and skin care products to combat the effects of aging and skin disorders

The video served the purpose of informing the group but one problem that became apparent was the realisation of the positive presentation by the scientists in the video. Discussion also included discussion of the benefits of medical advances and one group went on to discuss moral and ethical issues involving objections to eugenics. The idea of changing social views was also mentioned. Possible problems were enlarged upon by one group while linking issues that were raised in their first session to consideration of problems for nanotechnology. One group also talked about the problems of scientists focussing on the science while disregarding social outcomes. Another group choose to discuss nano-particles as pollutants and gave emphasis to the technology being driven by money. A further point was the array of varied lines of talk arising after the showing of the video and introduction of further information. This can serve to highlight the multi faceted nature of reactions and show that a planned introduction to the technology could result in unforeseen public reactions.

Session three involved discussion of examples of nanotechnology that may be developed in the next 25 years. The following six examples were provided to the participants who were asked to consider and discuss their acceptability.

- Medical investigations and self diagnosis using sensors, lab on a chip and remote diagnosis.
- Artificial body parts.
- The use of nano particles in food.
- Connecting the brain to a machine.
- Simple nano machines that could enhance the cleaning properties of toothpaste, shampoo, soap or hand wash.
- Sophisticated nano machines that could manufacture more of themselves for cleaning up toxic waste, combating viruses and disease in the human body.

The discussions of the groups ranged broadly over the topic area. The following are some of the key results:

- There was evidence of a thoughtful process of weighing up advantages and disadvantages which included consideration of personal cost and social benefit.
- Once a technology was condoned it was felt unwarranted licence was given to its wider use.
- In the face of conflicting information, decisions for some participants were based on feelings.
- The possibility of unknown harmful outcomes was an important concern.
- The possibility of medical advances from nanotechnology was praised but these raised moral and ethical concern involving objections to eugenics.
- Scientists were perceived to focus on the science while disregarding social outcomes.

- There was concern that nanoparticles could become pollutants.
- There was concern over nanotechnology being driven by commercial interests as opposed to serving social interests.
- It was considered unlikely that medical applications of nanotechnology would replace the human touch of a trusted health professional.
- The possibility of medical self diagnosis using nanotechnology was considered convenient and cost effective although the possibility of paranoia and hypochondria were also mentioned as negative consequences.
- Replacement body parts were talked about favourably, but there was ethical concern over the improvement of human abilities.
- Nanoparticles in food to add flavour were considered unusual and it was thought that consumers may not buy the products. In addition, the possibility of harmful consequences to the human body and the environment were raised in response to this example.
- The use of a direct interface between the human brain and a computer prompted concern that the human qualities of a person would be lost in the process of augmenting or transferring neural activity.
- The consideration of nanoparticles with a single moving part as a component of toothpaste was not considered particularly offensive or revolting, although concern was expressed about effects on the human body and the environment.

2.3 The questionnaire

The questionnaire items were presented on facing pages in an A5-size booklet. A copy of the questionnaire, in A4 size, is provided in Appendix 1. A letter of introduction stated the purpose of the questionnaire, introduced the aim of the research and the topics covered in the questionnaire and also invited voluntary participation. The questionnaire was designed to be short enough so as not to deter people from taking the time to complete it. Consequently only 86 separate items formed the questionnaire. Instructions were provided on the front on the questionnaire as well as a general definition of nanotechnology. At the recommendation of the Lincoln University Human Subjects Ethics Committee the definition suggested that some nanoparticles were a risk to people or the environment. The use of a definition, particularly at the start of a questionnaire, could influence the responses to the questions. However, given lack of knowledge of the technology it was considered necessary to inform respondents in this manner. Apart from demographic measures all measurements were taken on five-point Likert type scales.

Examples of nanotechnology

Measures of overall attitude to nanotechnology are useful, but do not show particular attitudes for particular applications of the new technology. Therefore, questionnaire began with 12 examples of actual products that use nanotechnology. The examples were designed to gauge reactions to a variety of the many examples of nanotechnology being used to improve common products. Given the diverse nature of examples of technology this question set gave the opportunity for responses to vary depending on the example. There were consumer products including a lunch box, computer and skin care products as well as practical items such as paint and spray for eye glasses.

The examples were drawn from a number of internet sources on current applications of nanotechnology including the international nanotechnology business directory

(www.nanovip.com; accessed 4/4/2006) and the US national nanotechnology initiative (http://www.nano.gov accessed 4/4/2006). The examples ranged from paint, sprays and cosmetics that could be purchased, to car parts and a medical treatment. Measurement was taken on five point scales anchored by very unacceptable to very acceptable.

Nanotechnology in general

The statements for the next section of the questionnaire were drawn from the focus group discussions. There were 15 statements about both positive aspects of nanotechnology, such as economic growth, and negative aspects such as pollution. The set began with the suggestion that the technology would result in cheaper longer lasting products and that it would result in more employment and economic growth. Then there was one statement which referred to unexpected outcomes that cannot be controlled and one that referred to harmful outcomes that cannot be reversed. These have been used to measure perceptions of risk (Slovic, 2000) and had also been used in previous studies of biotechnology (Cook & Fairweather, 2005b; Cook & Fairweather, 2006). These two statements enabled comparison with results from our earlier surveys of New Zealanders' reactions to biotechnology. The possibility of disruption to industry and the economy was next. Reflecting the concerns of the focus group participants, there were three statements about nanoparticles becoming pollutants. The statements continued with concern about making things that are not needed and concern that initial acceptance means more unapproved use of the technology. There was also a statement of concern about the use of limited resources and social impacts. On the positive side it was suggested nanotechnology would replace polluting technologies and help clean up the environment but it was also suggested that the technology would escalate the arms race. Measurement was taken on five point scales anchored by strongly disagree to strongly agree.

Applications of nanotechnology

Three areas of nanotechnology were then examined in detail. First, ten statements about medical uses for the technology were assessed that were drawn from the focus group discussions. A common theme from the focus group discussions was the use of nanotechnology for human improvement rather than medical repair. Also included were statements regarding the striving for beauty and perfection, artificially improving abilities and performance and loosing the natural qualities of being human. Another suggested the essence of a person was in their thoughts.

The other statements about nanotechnology in medicine began with the risk statement that harmful outcomes could not be reversed. Next it was suggested that despite new tests and treatments there would still be a need to talk about personal problems. Then there was a statement enabling direct comparison with medical treatments using cells from animals and genetic modification. A further statement from the group work suggested the technology could not replace the good judgement of a doctor and that the availability of more tests would lead to more health worries. The concern about having nanoparticles floating around in a person's body was also from the focus group discussions.

The next set of statements was used to test concern about nanotechnology in computing and electronics. In the focus groups there had been concern that improvements in computing and electronics would lead to more storage and use of personal information and more personal surveillance. Five statements were used to measure these issues. The first represented concern over the possibility of more organisations having access to personal information. Second it was suggested that use of personal identification instead of money would result in tracking by

commercial organisations. A third statement suggested that surveillance was necessary to combat crime and terrorism. A further aspect was measured using the statement indicating that eye scans and DNA would be routinely gathered by government. There was then a statement that as information becomes easier to store and use then some people will be discriminated against.

Responses to all of the statements measuring applications of nanotechnology were measured on five point scales anchored by strongly disagree to strongly agree.

Other general views and values

Other general attitude statements were sourced from a recent survey on future applications for biotechnology, some of which incorporated nanotechnology (Cook & Fairweather, 2006).

A set of 20 questions was used to measure general views and values. The first five statements were from Inglehart (1990) who had used these to survey the emergence of post-materialist values in European society. This is a reduced set that had previously been tested against attitudes towards biotechnology in earlier surveys. The set proposed two alternatives, either economic growth and a more autonomous government or emphasis on beautifying communities and making them more friendly places to live with a society where people count more than money.

The next set of six statements was included to measure values associated with the use of technology and resource use. These were derived from Seigrist (1999). These questions were designed to place preference for a technological society against preferences for a society that conserves resources.

The remaining nine statements in the set placed technology in opposition with nature. These statements had originally been developed from focus group research (Coyle, Maslin, Fairweather & Hunt, 2003). They ranged from confidence in the future of the human race through technology to the statement that interference with nature produces disastrous consequences.

Attitude towards nanotechnology

Ten questions were used to ensure attitude was measured comprehensively. They included summary assessments of approval, acceptability, safety and support as well as more emotional type measures that nanotechnology makes one uneasy or is a worry and source of anxiety. Responses were measured on five point scales anchored by strongly disagree to strongly agree.

Demographic information

Five questions gathered demographic information about the survey respondents. The questions were designed to gather data sufficient for testing for representativeness of the survey sample against New Zealand census data.

2.4 Pre-testing

Eleven people completed a draft of the questionnaire and subsequently provided comment on the content and structure of the questionnaire. Five people said they found it reasonably easy

to complete, but two commented on their lack of familiarity with topic. The assurance that there were no 'wrong or right answers' was added to the instructions to encourage completion of the questionnaire.

2.5 Survey distribution

A total of 2,000 questionnaires were distributed to randomly selected household addresses in New Zealand. The addresses were provided from a national record of listed and unlisted telephone subscribers. The questionnaire was posted with a freepost return envelope on May 24th, 2006. To encourage more replies a second copy of the questionnaire was posted on June 26th, 2006 to those who had not replied.

2.6 Response rate

Within six weeks of the second post out, 387 usable questionnaires had been returned. In addition, 80 had been returned undelivered because the address was incorrect. Also 15 were returned either uncompleted or without a sufficient number of responses. Within these 15, one considered the questions were too leading, one indicated they were too old and one had a language difficulty. There were also two phone calls from potential respondents. One did not wish to participate or receive any more surveys and one was concerned about anonymity and did not think they had the knowledge to answer the questions. The response rate for usable questionnaires was calculated as the proportion of useable questionnaires (387) over the 1920 (2000 minus 80) who had received the questionnaire. The response rate was therefore 20.2 per cent.

This response rate was lower than a survey of similar design and size that measured attitudes towards biotechnology and some examples of nanotechnology undertaken at a similar time of year (Cook & Fairweather, 1996). The biotechnology survey received a response rate of 29.6 per cent. It is likely that the differences in response rate can be attributed to lack of familiarity with nanotechnology. It is likely that few had heard of nanotechnology and so not as many felt confident to answer the questionnaire.

2.7 Representativeness

Information regarding gender, age, income and qualification were compared to 2001 census results. All comparisons were limited to people over the age of 15. Frequencies per category and percentages per category are provided in Table 1. Compared to the census, the sample had a similar proportion of males and females and it was found that there were no significant differences based on gender (Chi sq. $p < 0.05$). However, there were more respondents in older age groups and more with higher incomes and more with higher qualifications in comparison with the census results. These differences were significant (Chi sq. $p > 0.05$). Older people tend to have more time to answer a questionnaire and it is not unlikely that people with higher levels of education tended to identify with the questionnaire topic. These characteristics of the respondents sample are typical of postal surveys. Some caution is needed in extrapolating from the sample to the population. However, any relationships between variables will apply to the population.

Table 1: The sample compared to the 2001 census

Item	Sample frequency	Sample %	Population %
Gender (n = 385)			
Male	186	48.3	48.6
Female	199	51.7	51.4
Age (n = 383)			
15-24	15	3.9	13.6
25-34	33	8.6	14.1
35-44	56	14.6	15.6
45-54	84	21.9	13.1
55-64	82	21.4	9.0
65 years and over	113	29.5	12.0
Income (n = 368)			
Less than $15000	56	15.2	40.0
$15001 to $20000	45	12.2	10.0
$20001 to $40000	110	29.9	30.3
$40001 to $60000	80	21.7	14.3
$60001 to $100000	56	15.2	2.8
$100001 and above	21	5.7	2.6
Education (n = 384)			
No qualification	51	13.3	27.0
Secondary school qualifications	87	22.7	40.1
Vocational	135	35.2	20.5
Bachelors	65	16.9	8.1
Postgraduate	46	12.0	3.7

Chapter 3
Results

3.1 Introduction

This chapter presents the results of the analysis of the survey data. The results begin with an explanation of the statistical methods used in this chapter. Descriptive results are then provided. The order of item presentation follows the order of presentation in the questionnaire. Then in a separate section analysis is made of the relationship that beliefs about nanotechnology and values associated with post-materialism, technology and nature have with an overall attitude towards nanotechnology. Finally relationships between demographic information and the overall attitude are presented.

3.2 Statistical methods

Mean scores are shown for all measures taken on the five point scales and to assist in explanation the proportion of agree, neutral and disagree responses for each item is provided. Because some people did not reply to all the questions, the number of responses for each measure is also provided.

To test for relationships between attitude, beliefs and values, summary variables are formed to represent these items. This involved recoding some measures to ensure a common valence and then adding and averaging the measures to form a single variable. Reliability of this procedure is checked using Cronbach's alpha. This test is commonly used in the estimation of a common factor underlying the answers to a number of questions (Chen & Kraus, 2004). Values above 0.5 are considered acceptable as evidence of a common factor (Nunnally, 1967), while values above 0.7 are more definitive (Peterson, 1994).

Having formed the variables interrelationships are interpreted through correlation tests. The relative importance that beliefs and each of the measures of values had in explaining attitude is estimated and the proportion of attitude that these proposed determinant variables explained are shown using a standard multiple regression.

To test for relationships with demographic variables mean scores for attitude were compared using t-tests.

3.3 Acceptability of nanotechnology examples

The acceptability or unacceptability of 12 examples of commercial products made using nanotechnology are shown in Table 2. As shown in the table the highest level of acceptability was for mixing nanoparticles with other composite materials and the second highest level of acceptance was for computers that were more affordable and have better speed and capacity. Another similar example is using nanoparticles in paints and coatings which many also agreed was acceptable. Treating waste water was also judged acceptable by most respondents. In response to a different example, the next highest level of agreement for acceptability was for the use of the technology in the medical treatment of a cancer tumour. The use of sensors for chemicals was generally approved of but there was a slightly higher proportion who indicated this example was unacceptable. It is possible that this example was not adequately explained

and also possible that the mention of explosives was interpreted as a military use of nanotechnology. Cheaper and smaller communication devices with more new features and components also had a reasonably high proportion indicating acceptability. However, this example also had more respondents that were unsure or indifferent as to whether these devices were unacceptable or acceptable.

Table 2: Acceptability of nanotechnology examples

	N	Mean	Unaccep-table %	Neither %	Accep-table %
Mixing nanoparticles within other materials to increase strength or reduce weight in, for example, car or aeroplane parts.	382	4.04	5.2	13.4	81.4
Computers that are more affordable and have better speed and capacity.	385	4.08	6.0	13.8	80.3
Using nanotechnology to make improved filters for cleaning up waste water.	384	4.08	8.3	11.5	79.4
Using nanoparticles in paints and coatings to protect against corrosion and scratches.	385	3.94	9.9	11.4	78.7
Coating a drug with nanoparticles that attach to tumour cells to ensure the drug is released within a cancer tumour.	386	4.06	9.6	15.5	74.9
Using nanotechnology to manufacture improved sensors for chemicals, such as explosives or other unwanted contaminants.	384	3.80	13.0	16.1	70.8
Cheaper and smaller communication devices with more new features and components.	385	3.82	8.8	23.6	67.5
Using nanoparticles in clothing fabric to make clothing more resistant to water, stains and wrinkling.	383	3.59	15.9	25.8	58.2
Using nanoparticles in the human body to detect and neutralise viruses.	383	3.48	21.9	21.7	56.4
Nanoparticles sprayed from an aerosol can by the consumer to ensure eye glasses stay clean and clear.	383	3.29	30.3	16.2	53.5
A plastic lunch box impregnated with nano-size silver particles to keep food fresh by killing harmful microbes and bacteria.	385	3.12	35.3	20.5	44.2
Skin care products that contain nanoparticles to assist in deeper and faster penetration of nourishments.	384	2.86	38.6	30.7	30.7

Note: Range, 1 = very unacceptable, 5 = very acceptable

Approximately one quarter of the respondents were unable to make a judgement on using nanoparticles to make improvements to clothing fabric and a reasonably large proportion found this example unacceptable. Similar proportions can be seen for the example of using nanoparticles in the treatment of viruses within the human body. Unlike the example of the treatment of cancer, this example did not explain the mechanism for treatment. One further example had just over half indicating acceptability. This was use of nanoparticles in a spray can to ensure eye glasses stay clean and clear which had a relatively high proportion finding it unacceptable.

The highest proportion of those finding an example unacceptance and the lowest proportion of those finding an example acceptable was for the examples of a lunch box impregnated with nano-size silver particles to keep food fresh and skin care products that are advantaged by nanoparticles. The skin care product had the lowest proportion of agreement that it was acceptable and the highest proportion of those who judged it unacceptable. However, it is also distinguishable because it has the highest proportion who found it neither acceptable nor unacceptable.

3.4 Beliefs about nanotechnology

There were five positive beliefs about nanotechnology presented to respondents in question 2 among a list of negative and positive beliefs. The results, presented in Table 3, show there was a high proportion of neither agree nor disagree responses possibly reflecting the speculative nature of the positive belief statements. Of note, for all the measures of positive beliefs the proportion for those who apparently did not know exceeded the agreement responses and exceeded most of the disagreement responses. It is possible that lack of knowledge of nanotechnology had also contributed to uncertainty about the suggested outcomes.

Given lack of familiarity with the technology and lack of exposure to discussion of its potential it is understandably difficult for respondents to assess potential outcomes. Nevertheless, more than one third agreed that nanotechnology will result in cheaper and longer lasting products for the consumer with less than half of this proportion disagreeing. The majority of respondents did not, however, agree that the new technology would result in more employment and economic growth. While almost half were undecided, more disagreed that the technology would result in these broader outcomes.

Table 3: Positive beliefs about nanotechnology

	N	Mean	Disagree %	Neither %	Agree %
Nanotechnology will result in cheaper and longer lasting products for the consumer.	387	3.26	15.0	48.6	36.5
Nanotechnology will result in more employment and economic growth.	387	2.97	27.9	48.6	23.5
Any unexpected outcomes from nanotechnology will be controlled.	387	2.64	47.8	33.1	19.1
Nanotechnology will improve the quality of life for all New Zealanders.	387	3.11	21.7	47.8	30.4
Nanotechnology will help replace polluting technologies and be used to help clean up the environment.	386	3.25	10.4	56.7	32.4

Note: Range, 1 = strongly disagree, 5 = strongly agree

Respondents tended to be more pessimistic than confident that any unexpected outcomes from nanotechnology will be controlled. Almost one half disagreed with this statement and there was a low level of agreement that unexpected outcomes could be controlled. More agreed than disagreed that nanotechnology will improve the quality of life for all New Zealanders, although again there was a high proportion that was uncommitted. Almost one third agreed that nanotechnology will help replace polluting technologies and be used to help clean up the

environment. This proportion was three times more than those who disagreed but there was a high proportion who presumably felt they were unable to make a prediction about this outcome.

Respondents could either agree or disagree with ten negative belief statements about nanotechnology also included in question 2. The results of this enquiry are shown in Table 4. Overall, compared to the positive beliefs there was a larger number where either the agree or disagree responses exceeded the neither agree nor disagree responses. Also, the proportion of neither agree nor disagree responses tended to be lower than for the positive beliefs. This suggests the respondents tended to be more confident about assessing the negative outcomes.

The first result was nevertheless counter to the tendency for a lower neither agree nor disagree proportion. More than one half made no judgement as to whether nanotechnology will result in harmful outcomes that can not be reversed and more agreed than disagreed that this would occur. The lowest level of agreement was for the new technology disrupting industry and the economy. Most disagreed that this would occur while a still sizable proportion neither agreed nor disagreed. Most agreed that nanotechnology will result in new types of pollution. However, a sizable proportion did not appear to be confident to make a prediction and only a small proportion disagreed.

Table 4: Negative beliefs about nanotechnology

	N	Mean	Disagree %	Neither %	Agree %
No one really knows the long term social impacts from developing nanotechnology.	387	4.12	4.9	12.1	83.0
Once we accept some nanotechnology much more will follow regardless of whether we accept it or not.	387	3.73	12.9	16.8	70.3
Nanoparticles will result in new heath and safety issues in industry and the wider community.	386	3.61	10.6	30.8	58.5
Nanoparticles could become a big problem if they got into the food chain.	385	3.55	14.3	30.1	55.6
Nanotechnology will result in new types of pollution.	387	3.30	16.3	39.3	44.4
Nanotechnology will result in new weapons for war and escalate the arms race.	386	3.39	13.5	33.8	42.7
Creating a continual stream of new products using nanotechnology will increase the use of limited resources.	387	3.14	23.3	35.2	31.5
Nanotechnology will result in harmful outcomes that can't be reversed.	387	3.05	19.9	57.1	23.0
Nanotechnology will be used mostly to make things we don't really need.	387	2.82	39.5	38.5	22.0
The development of nanotechnology will disrupt industry and the economy.	386	2.60	45.3	44.0	10.6

Note: Range, 1 = strongly disagree, 5 = strongly agree

One of the highest levels of agreement was for nanotechnology becoming a big problem if nanoparticles get into the food chain. Similarly, more than one half of respondents considered the technology would result in new health and safety issues. There was one of the lowest levels of disagreement for this statement. Respondents tended to disagree that the new technology would mostly make things we do not really need and this statement had one of the lowest level of agreement. This result shows there is an expectation of useful products being made using nanotechnology.

The view that once condoned there will be more nanotechnology without consultation received the second highest level of agreement and a low level of disagreement. For the next statement respondents appeared to be somewhat unsure as to whether nanotechnology will increase the use of limited resources with a higher proportion indicating neither agree nor disagree although agreement was a higher proportion than disagreement. The highest proportion of respondents agreed that no one really knows the long term social impacts. This statement had the lowest level of disagreement and neither agree nor disagree response.

3.5 Nanotechnology in medicine

Ten statements that were generated from focus group discussions were used to investigate issues associated with the use of nanotechnology in medicine. The results are shown in Table 5. Of note, respondents were concerned that medical nanotechnology would result in harmful outcomes that cannot be reversed. Almost one half of the respondents agreed that this negative outcome would occur. However, there was a reasonably large proportion of respondents who were undecided. There was also a good deal of concern over nanotechnology becoming a new tool for striving for beauty or perfection. More than half of the respondents agreed this would occur and this statement had the lowest proportion in the set that disagreed.

In a different type of statement it was suggested that new treatments could not satisfy the need to talk about personal problems. This statement received the highest level of agreement and suggested that it was recognised that new technology had limitations in some areas. Next was a comparison between genetic modification and use of animal cells with nanotechnology. Almost one half of the respondents agreed that nanotechnology would be preferable and this proportion clearly exceeded the proportion that disagreed. The response to this statement also received the highest level of neither agree nor disagree responses. Given that the use of animal cells and genetic modification in medicine is not common and no specific nanotechnology example was given, it is likely that many did not feel sufficiently informed to respond.

More statements continued to explore the theme of using nanotechnology for human improvement rather than for medical treatment. More than one half agreed it would be wrong to use nanotechnology to artificially improve human abilities and performance but a relatively high proportion of approximately one quarter disagreed. It was then suggested that there could be a more extreme effect of the technology with the statement that people could become artificial and lose the natural qualities of being human. There was more disagreement than agreement with this statement though the level of agreement was not insubstantial. Nevertheless, most indicated that they did not think the technology would alter people to the extent that they would loose human qualities. However, a further statement had the opposite response. Most disagreed that the body could be changed because the essence of a person was in their thoughts and this was the highest level of disagreement for the set of statements. In other words it is believed that changes to the body through the new technology would alter the essence of a person. However, like the response to the previous statement there was still somewhat substantial agreement with the statement.

More respondents disagreed than agreed that more medical tests and treatments could replace a doctor's good judgement and there was more agreement than disagreement that the possible increased availability of affordable personal testing could lead to more people worrying about their health. There was a similar level of agreement and disagreement when respondents were

asked to indicate if it would feel unnatural to have nanoparticles floating around in their body but the neither agree nor disagree responses were reasonably high.

Table 5: Nanotechnology in medicine

	N	Mean	Disagree %	Neither %	Agree %
Medical nanotechnology could result in harmful outcomes that can't be reversed.	386	3.38	15.8	36.5	47.7
Nanotechnology would eventually become a new tool for striving for beauty and perfection.	387	3.54	9.8	34.6	55.6
New medical tests and treatments cannot satisfy the need to talk about personal problems.	383	3.64	11.5	24.0	64.5
Treatments using nanotechnology would be preferable to those using genetic modification or cells from animals.	385	3.44	10.6	42.3	47.0
It would be wrong to use nanotechnology to artificially improve human abilities and performance.	387	3.44	24.5	21.7	53.7
Eventually people could become artificial and lose the natural qualities of being human.	386	2.82	43.0	27.7	29.3
It doesn't matter how the human body is changed because the essence of a person is in their thoughts.	385	2.84	43.6	25.7	30.6
More medical tests and treatments cannot replace a doctor's good judgement.	387	2.85	42.9	28.4	28.7
The possible increased availability of affordable personal testing could lead to more people worrying about their health.	385	3.10	32.7	25.5	41.8
It would feel unnatural to have nanoparticles floating around in my body.	387	3.03	32.8	34.1	33.1

Note: Range, 1 = strongly disagree, 5 = strongly agree

3.6 Nanotechnology in computing and electronics

The results of the investigation of some aspects of nanotechnology in computing and electronics are shown in Table 6. In response to the first statement more than half agreed that the ability to store more information will result in more organisations having access to personal information. There was also some disagreement with this statement with more than one quarter choosing to disagree. The highest level of disagreement for the set of statements was for the idea that new electronic devices would result in more time for leisure. The highest level of agreement was for commercial organisations being able to track the activities of individuals. More than three quarters of respondents considered this would occur and relatively few disagreed or were unsure.

Table 6: Nanotechnology in computing and electronics

	N	Mean	Disagree %	Neither %	Agree %
The ability to store more information will result in more organisations having access to personal information.	387	3.31	26.4	22.0	51.7
New electronic devices would result in more time for	386	2.80	43.0	29.5	27.5

leisure.					
Using personal identification instead of money will result in commercial organisations tracking what we buy, where we go and what we do.	384	3.87	7.8	15.6	76.6
Making surveillance cheaper and more readily available is necessary to combat crime and terrorism.	386	3.39	20.7	28.0	51.3
As information becomes easier to store and use, eye scans and DNA will be routinely gathered and stored by government authorities.	383	3.69	9.7	23.0	67.4
As information becomes easier to store and use personal information will be used to discriminate against some people.	383	3.40	17.8	31.6	50.7

Note: Range, 1 = strongly disagree, 5 = strongly agree

Just over one half of the respondents considered surveillance necessary to combat crime and terrorism. More clear agreement was given to the statement that eye scans and DNA will be routinely gathered and stored by government authorities. This statement had one of the highest levels of agreement and relatively few disagreed. The final statement of the set referred to the storage and use of personal information making it easier to discriminate against some people. Approximately one half agreed, although a substantial proportion were unsure at present, as is shown by the high proportion of agree nor disagree responses.

3.7 Nanotechnology in food production

Table 7 provides the results for agreement or disagreement with statements regarding the use of nanotechnology in food production. Starting at the top of the table, just over one half of the respondents agreed that they would feel uncomfortable knowing they were eating nanoparticles. Similarly, just over one half judged that the use of nanoparticles in food would benefit the producer rather than the consumer, but a smaller proportion disagreed and a greater proportion are likely unsure at the time of the survey. The respondents were more sure that there is a lack of knowledge about widespread or long-term harmful effects. Proportionately few disagreed with this proposal and only a small proportion did not know or were undecided.

More disagreed than agreed that nanotechnology would result in food savings for consumers, but the largest proportion of just over one half did not make a judgement. It was more generally agreed than disagreed that people on limited budgets could not avoid buying cheaper food made using nanotechnology. The response to the next two statements was dominated by a high number of neither agree nor disagree responses. Respondents would have been logically unsure as to whether nanotechnology would improve the nutrition of convenience foods. Similarly, it is likely that as they had not heard much about the use of nanotechnology in food so it could not be judged if it was preferable to GM food. Finally, more agreed than disagreed that food produced using nanotechnology would be unnatural.

Table 7: Nanotechnology in food production

	N	Mean	Disagree %	Neither %	Agree %
It would feel uncomfortable knowing I was eating nanoparticles.	385	3.45	22.3	23.9	53.8
The use of nanoparticles in food production will	386	3.53	12.4	34.7	52.8

benefit the producer more than the consumer.					
Nobody really knows whether widespread, long term exposure to nanoparticles in food will be harmful.	386	4.09	4.4	13.0	82.6
Nanotechnology will result in savings for food consumers.	386	2.74	33.4	51.6	15.0
Because of a limited budget many people could not avoid buying cheaper food produced using nanotechnology.	385	3.60	10.1	27.8	62.1
Nanotechnology will result in convenience foods being more nutritious.	384	2.75	32.3	52.9	12.8
Food produced using nanotechnology will be more acceptable than food produced using genetic modification.	384	3.10	16.5	55.2	27.9
Food produced using nanotechnology would be unnatural.	385	3.40	18.2	34.5	47.3

Note: Range, 1 = strongly disagree, 5 = strongly agree

3.8 Post-materialism

The results of the measure of post-materialism are shown in Table 8. As can be seen in the table, the first result and the fourth and fifth results were similar. The first of these called for a more democratic government through more public involvement. The next of the three encouraged a friendlier, less impersonal society and the third advocated a society where people count more than money. The agreement percentage for each of these three exceeded three quarters of the respondents. The second statement of the set advocated a different emphasis from those just mentioned as it called for a higher rate of economic growth. The response was different from the others as more respondents disagreed with this suggestion of materialism. The remaining statement that called for the making cities and countryside more beautiful had a level of agreement or disagreement that was in keeping with responses to the post-materialist statements but with a higher proportion of those who were unsure or indifferent.

Table 8: Post-materialism

	N	Mean	Disagree %	Neither %	Agree %
People should have more say in the decisions of government.	386	3.98	8.3	13.7	78.0
The priority of government should be to maintain a high rate of economic growth.	386	3.42	21.0	27.2	51.8
More effort should be given to making our cities and countryside more beautiful.	386	3.64	7.5	31.9	60.6
Efforts should be made to encourage a friendlier, less impersonal society.	385	3.91	2.6	18.7	78.7
We need to develop a society where people count more than money.	387	4.09	2.8	12.7	84.5

Note: Range, 1 = strongly disagree, 5 = strongly agree

3.9 Technology and resource use

Table 9 shows the results of the measurement of reactions to five statements that were related to technology and resource use. In general the statements that advocated technology had mixed responses whereas the statements that advocated conservation of resources tended to gain a more positive response.

The first statement that a technological society has the best chance of eliminating poverty had a similar proportion of agree and disagree responses. Larger than these responses was the neither agree nor disagree response suggesting a good deal of indecision about this possible benefit from technology. The next statement advocating technology had a similar response to the first with reasonably even proportions of agree and disagree responses and a large proportion of undecided respondents. In contrast, the next two measurements clearly favoured alternatives to a technological approach through the tighter management of resources by adopting a simpler lifestyle or limiting resource use by wealthy nations. Most agreed with these statements, only small proportions disagreed and only a reasonably small proportion had no opinion. For the last statement most were unsure about the less direct approach through supporting groups that oppose materialism. Overall, the general public appear to favour some limits on the use of technology.

Table 9: Technology and resource use

	N	Mean	Disagree %	Neither %	Agree %
A technological society has the best chance of eliminating poverty.	385	3.03	29.4	39.7	30.9
Advances in technology mean that the goals of society can be realised.	387	3.01	28.9	43.4	27.6
Living a simpler lifestyle is the best way to conserve energy and resources.	387	3.63	14.0	22.0	64.1
Wealthy nations should consume less and limit their use of resources.	386	3.69	13.0	23.3	63.7
Groups that oppose materialistic values deserve support.	386	3.06	24.6	44.8	30.6

Note: Range, 1 = strongly disagree, 5 = strongly agree

3.10 Technology and nature

Results of the ten measures of technology and nature statements are provided in Table 10. First, most respondents agreed that it was natural for people to improve their lives using technology. Comparatively few disagreed with this statement and reasonably few had no opinion. Despite support for technology through responses to this first question, technology was not as favoured in the subsequent results. There was more disagreement than agreement that technology will eventually replace reliance on finite resources with most respondents being uncertain. A similar response though weighted in favour of technology was found for the view that sustainable use of resources will be achieved through technology. Less in favour of technology was the high level of disagreement with the view that science and technology will lead eventually to no need to worry about the future of the human race. Also more disagreed than agreed that nature has a tremendous capacity to adapt to the effects of human progress. Almost one half then agreed that people need to start thinking about how much to change the world and themselves. There was a low level of disagreement for this proposal but a high level of neither agree nor disagree responses. It is possible that the prompt to consider changing both the world and ourselves was confusing for respondents.

Table 10: Technology and nature

	N	Mean	Disagree %	Neither %	Agree %
It is natural for people to improve their lives by using technology.	386	3.72	10.1	18.4	71.5
Technology is progressing so that in the future there will be no need to rely on finite natural resources.	385	2.89	33.8	40.3	26.0
New technology will eventually enable sustainable use of the planets natural resources.	386	3.12	22.0	43.8	34.2
Through science and technology there will eventually be no need to worry about the future of the human race.	385	2.15	69.4	22.1	8.6
Nature has tremendous capacity to adapt to the effects of human progress.	386	2.80	47.9	18.4	33.7
Rather than considering more technology, we need start thinking about how much we should change the world and ourselves.	382	3.45	14.7	36.1	49.2
Scientists will eventually know enough about nature to be able to control it.	383	2.14	71.8	18.0	10.2
Technology will eventually repair most of the environmental damage that has been done.	385	2.16	69.9	20.3	9.9
Interference with nature often produces disastrous consequences.	384	3.91	9.9	13.3	76.8
When we interfere with the nature the consequences are unpredictable.	383	3.95	9.7	9.7	80.7

Note: Range, 1 = strongly disagree, 5 = strongly agree

The last four statements in Table 10 were about nature. The highest level of disagreement was for the idea that scientists may eventually know enough about nature to be able to control it and the second highest level of disagreement was for the proposal that technology will eventually repair most of the damage that has been done to the environment. The results of the final two measurements had the highest levels of agreement and the lowest levels of disagreement and no opinion responses. More than three quarters of the respondents agreed that interference with nature produces disastrous consequences and the view that consequences are unpredictable was supported in agreement with the next statement. Again,

these results are suggesting that the general public are sceptical about the benefits from technology.

3.11 Attitude towards nanotechnology

To measure attitude towards nanotechnology a number of emotional statements were included as well as summary assessments. As shown in table 11, the first summary assessment measured approval of the use of nanotechnology. Almost one half of the respondents agreed that they would approve of the use of the new technology and only a small proportion disagreed. However, there was a large proportion that, at the time of the survey, did not know whether they approved or disapproved. In response to the next statement, comparatively more respondents disagreed that they found it unacceptable and relatively few agreed it was unacceptable. While most respondents were able to make a summary assessment of nanotechnology the majority were unable to decide whether it was safe or not. In another summary assessment of attitude more respondents agreed they would support the use of nanotechnology than disagreed. Again a large proportion was undecided.

Some emotional measurements were also used for the purpose of getting a more complete estimate of attitude. Slightly more respondents agreed it made them feel uneasy than disagreed. However, fewer indicated it caused them to worry and more disagreed that it caused them to worry. In another emotional measure it was apparent that the new technology caused some anxiety.

Table 11: Attitude towards nanotechnology

	N	Mean	Disagree %	Neither %	Agree %
I approve of the use of nanotechnology.	385	3.41	9.9	42.0	48.1
I consider that the use of nanotechnology is unacceptable.	385	2.48	55.1	34.0	10.9
I consider the use of nanotechnology to be safe.	384	2.87	25.3	59.9	14.8
I support the use of nanotechnology.	384	3.32	13.5	41.4	45.1
The use of nanotechnology makes me uneasy.	386	3.10	32.4	28.8	38.9
The use of nanotechnology causes me to worry.	384	2.86	39.8	33.6	26.6
The use of nanotechnology causes me no anxiety.	384	2.86	39.8	30.7	29.4
I am fascinated by the use of nanotechnology.	384	3.47	15.9	28.4	55.7
I am indifferent to the use of nanotechnology.	383	2.43	58.5	28.5	13.1
I am the type of person who would support the use of nanotechnology.	383	3.29	16.7	38.4	44.9

Note: Range, 1 = strongly disagree, 5 = strongly agree

The highest level of agreement from Table 11 was for being fascinated with nanotechnology. More than half agreed they were fascinated and those undecided and disagreeing were of low proportions. The highest level of disagreement was for being indifferent about the technology. Also the type of person who would support nanotechnology was found to be similar to the earlier measurement of support (I support the use of nanotechnology).

3.12 Relationships between beliefs, values and attitude

The results in this section test for evidence that supports the proposition that beliefs and values are involved in shaping attitude towards nanotechnology.

Descriptive results for the variables after their items had been formed is provided in Table 12. The first variable representing attitude towards nanotechnology was formed using four summary assessments and four emotional type measures. Whether the respondent was indifferent to nanotechnology and whether they were the type of person to support its use did not align well with the other measurements. The resulting eight measures were highly interrelated as indicated by a very high alpha score. This suggests the summary measures of approval, acceptability, safety and support were partly based upon or were strongly aligned to the measures of emotional reactions including worry and anxiety. The mean score for the measure of attitude showed that respondents were generally slightly positive about the new technology.

Table 12: Description of variables

	N	Mean	Std. Dev.	Cronbach's Alpha
Attitude towards nanotechnology	383	3.19	0.728	0.91
Post-materialism	382	3.81	0.503	0.55
Technology and resource use	383	2.73	0.585	0.58
Technology and nature	377	2.65	0.487	0.66
Beliefs	382	2.79	0.539	0 .81

The respondents were most positive about post-materialist values which meant they generally approved of a friendlier more democratic society with only some emphasis on economic growth. As a measure of a common theme, the alpha score shows the items were less aligned than the other items that had been combined, but were still an acceptable measure of post-materialism. The five items proposed as measures of technology and resource use were only marginally more aligned than post-materialism. The mean score for this variable shows that the respondents were slightly negative about technology and tended to favour the conservation of resources over the use of technology. The technology and nature measures tended to place concern over ability of nature to absorb change over the advantages of technology. The alpha score for this variable was higher than the previous ones and suggested a better capturing of the subject matter.

The beliefs variable combined the measurement of responses to 15 statements about good or bad possible outcomes of nanotechnology. In other words the measurement was of beliefs about the possible outcomes or consequences of nanotechnology. As the mean score shows the beliefs about the consequences of nanotechnology were generally slightly negative. Their good alignment indicated by the high Cronbach's alpha score indicates they were interrelated. For example, the score shows that a respondent who was positive about the outcomes of nanotechnology would have tended to agree with positive statements and not agree with negative statements.

The correlation table provided in Table 13 shows evidence of links between attitude towards nanotechnology and values related to post-materialism and general values associated with aspects of the use of technology. There was evidence of a weak link between post-materialism and attitude and moderate links between the technology variables and attitude. A strong link is shown between beliefs and attitude. The results also show that there was a tendency for

those who ranked the belief statements more positively to favour technology over concerns about resource use and conservation and believe that progress through technology would not overly damage nature.

Table 13: Correlation table

		Post-materialism	Technology and resource use	Technology and nature	Beliefs
Attitude	r n	-0.10* 379	0.43** 380	0.36** 374	0.68** 378
Post-materialism	r n		-0.04 380	0.07 373	0.04 377
Technology and resource use	r n			0.32** 375	0.46** 378
Technology and nature	r n				0.40** 372

Note: * = $p < 0.05$, ** = $p < 0.01$

The results of the regression analysis on attitudes towards nanotechnology are shown in Table 14. The R^2 shows that together the four variables provided a good explanation of attitude by explaining half of its variance. All of the variables were significant in their relationship with attitude and the beta scores show the relative importance of the four variables. Beliefs about the outcomes of nanotechnology had the strongest relationship with attitude towards nanotechnology followed by post-materialism, attitude and resource use, and attitude and nature. The results also show that the general values associated with post-materialism including those for a less commercial, more friendly society were in contrast with a positive attitude towards nanotechnology. The negative sign shows that an increase in adherence to this value is related to attitudes towards nanotechnology becoming more negative. Nevertheless, the results show that those who hold post-materialist values only had a weak tendency to be against nanotechnology compared to beliefs. An even weaker influence is indicated for technology and resource use which indicates that nanotechnology is favoured by those who believe society can be advanced using technology with little need to be concerned about resource use. There was also evidence of a link between attitude and technology and nature that was less strong than the relationship between technology and resource use.

Table 14: Regression of values and beliefs onto attitude towards nanotechnology

$R^2 = 0.50$, N = 363		
Variable	**Beta**	**Significance**
Post-materialism	-0.14	0.000
Technology and resource use	0.13	0.002
Technology and nature	0.11	0.006
Beliefs	0.57	0.000

3.13 Demographic information and attitude

An investigation was made for differences in attitude towards nanotechnology based on demographic information. The results of these tests for differences are shown in Table 15. There were differences in attitude between males and females with males in general having a more positive attitude. In terms of differences in age based on attitude the youngest respondents (15 to 24 years) were more positive than those in three groups from 45 years upwards. For income groups, except for those earning less than $15,000, those in lower income groups tended to hold less positive attitudes. Those earning more than $100,000 had a very positive attitude towards nanotechnology. There were few differences based on level of education with those holding a trade certificate or similar qualification having a slightly more positive attitude than those of two other levels.

Table 15: Demographic variables and attitude towards nanotechnology

Item	Frequency	Attitude mean	Significant differences (t-tests, $p < 0.05$)
Gender (n =381)			
Male (1)	186	3.39	1-2
Female (2)	199	3.00	
Age (n = 379)			
15-24 (1)	15	3.63	1-4, 1-5, 1-6
25-34 (2)	33	3.36	
35-44 (3)	56	3.23	
45-54 (4)	84	3.11	
55-64 (5)	82	3.14	
65 years and over (6)	113	3.15	
Income (n = 365)			
Less than $15000 (1)	56	3.34	1-2, 1-4, 2-5,
$15001 to $20000 (2)	45	3.08	2-6, 3-5, 3-6,
$20001 to $40000 (3)	110	3.13	4-5, 4-6
$40001 to $60000 (4)	80	3.09	
$60001 to $100000 (5)	56	3.42	
$100001 and above (6)	21	3.52	
Education (n = 380)			
Primary school (1)	3	2.83	
Secondary - no qualifications (2)	48	3.02	
Secondary - with qualifications (3)	87	3.15	2-4, 4-5
Trade tech or similar (4)	76	3.31	
Undergraduate (5)	59	3.07	
Bachelors (6)	65	3.30	
Postgraduate (7)	46	3.29	
Religion (n = 368)			
Agnostic (1)	43	3.08	
Christian (2)	174	3.23	
Atheist (3)	41	3.37	
Spiritual - not religious (4)	101	3.09	
Other (5)	12	3.28	

Chapter 4
Discussion and Conclusion

4.1 Introduction

The general aim of this research was to determine the reactions that New Zealanders have towards nanotechnology. Within the confines of the method a number of different approaches have been used to measure aspects of the topic. Reactions to a number of current examples of commercial products, as well as positive and negative beliefs about the outcomes of the technology, have been measured. Attention has also been given to use of nanotechnology in medicine, computing and electronics as well as food. Attitude towards nanotechnology has been measured including emotional based assessments and a good proportion of this attitude has been shown to be explained by beliefs about outcomes of nanotechnology and general values held by New Zealanders.

In this chapter the research findings are discussed as well as related implications for the development and implementation of nanotechnology in New Zealand. First, issues associated with representativeness are discussed. The main findings are then reviewed and discussed. The findings are drawn on further for a discussion of implications with attention given to relationships that attitude towards nanotechnology has with beliefs and values.

4.2 Representativeness and response rate

There was evidence of response bias in tests of represenativeness with the survey sample. Although there was a similar proportion of males to females compared to census information, more respondents in older age groups, more with higher incomes and more with higher qualifications had replied. It is not unusual for there to be differences between those who reply and the population as older people may have more time and those with more knowledge or interest in the survey topic tend to reply. An investigation of those who failed to respond to a biotechnology survey found that those who replied had more knowledge of, or interest in, biotechnology (Cook, Fairweather, Satterfield & Hunt, 2004). Given the recent development of nanotechnology it would be likely that a good proportion of those who had not replied had not heard of the new technology.

Lack of familiarity with nanotechnology is also likely to have affected the response rate. The 20 per cent response rate was low compared to surveys of biotechnology that were similar in design and layout to this nanotechnology survey. For comparison, a recent biotechnology survey that incorporated examples of nanotechnology had a response rate of 30 per cent (Cook & Fairweather, 2006) and the previous year a biotechnology survey had a response rate of 36 per cent (Cook & Fairweather, 2005b). Given the lower response rate and the earlier work on investigating those who failed to respond to a similar biotechnology survey, it is likely that the survey sample contains proportionately more people who are familiar with, or have heard of, nanotechnology than exist in the population. It is also then very likely that the sample gives slightly greater representation to those in the population that currently have a view about nanotechnology.

4.3 Discussion of results

The use of examples of commercial products made using nanotechnology suggested a number of influences on the acceptability or unacceptability of the products. First there were higher levels of acceptance for products that contained nanomaterials in a composite form. Using nanoparticles to reduce weight or increase strength in car or aeroplane parts may seem unlikely to be the most desirable consumer product. However, this was ranked the most acceptable use of nanotechnology and had the lowest proportion who indicated it was unacceptable. Given the mention of the risk of some nanoparticles being poisonous or toxic in the description at the start of the questionnaire, it is likely that some may have considered this example as safer because the nanoparticles would be trapped in a composite material. This suggests its consideration as an example of low risk is substantial in making it the most acceptable item ahead of other items that are more personally useful but which may be perceived as potentially involving personal risk.

High personal risk appears to be having more weight than personal benefit in a number of examples. The use of nano-sized silver particles impregnated in a lunch box to keep food fresh and skin care products that have deeper and faster penetration of nourishments were generally not acceptable. In these examples, high risk is associated with the potential for personal contact with nanoparticles in food or by absorption through the skin. Others with low levels of acceptance have the same characteristic with an aerosol spray for eye glasses and using the particles to detect and neutralise viruses in the human body. These examples suggest strongly that there is a particular aversion to products of nanotechnology where people can be exposed personally to nanoparticles. It is presumably the result of a perception of an increase in personal risk that results from the perceived increase in potential for personal exposure.

One example that seems to be an exception to the risk of personal exposure resulting in rejection of the example is the treatment of cancer tumour cells by coating a drug with nanoparticles. However, given that cancer is a serious disease that can be incurable and fatal, there is great potential for benefits from a successful treatment. Also, compared to the medical example of using nanoparticles in the human body to combat viruses, cancer is generally recognised as a serious and often intractable condition. This suggests that in the case of cancer, unusual treatments that may for some seem radical and risky are more readily considered. In this case it is suggested that the prospect of benefit outweighs considerations of risk.

A further point is the lack of neither acceptable nor unacceptable responses that were measured for the examples of nanotechnology. There appeared to be more confidence in assessing the acceptability of examples of products made using nanotechnology compared to some other measures. At an average of 18 per cent the neither acceptable nor unacceptable responses were less than averages of the neutral responses for nanotechnology in medicine (30 per cent), computing and electronics (25 per cent) and in food production (37 per cent). The neither acceptable nor unacceptable responses were also less than averages of neutral responses for positive beliefs (47 per cent), negative beliefs (34 per cent) and overall assessments of attitude (37 per cent). It is apparent that there is a tendency to be more certain about choices over nanotechnology products compared to statements regarding outcomes of the technology or assessments of attitude towards the technology. This could further support the suggestion that some people use the heuristic or simple rule of the degree of personal risk believed to be involved in using the product. The heuristic, the effect of which is apparent in the examples, is unlike the presumed deliberative process reflecting the situation that nanotechnology is not well-known and some may not be prepared to consider its broader consequences.

To compare acceptability of examples of nanotechnology with examples from biotechnology it would seem that the level of personal risk also affects assessment of biotechnology examples. Of the examples presented to the respondents, food and farm animal treatments were identified as the least acceptable examples using the same measurement scale as used for the examples of nanotechnology (Cook & Fairweather, 2006). These had levels of acceptability ranging from 27 per cent to 30 per cent and were examples where food had been genetically modified or animals had been treated with growth hormone. For each example, ingestion of a food product involved personal exposure to biotechnology. Both surveys therefore show that low proportions of acceptability are associated with prospects for personal exposure. Of further interest, the low score for the acceptability of the nanotechnology skin care product (31 per cent) is similar to these low biotechnology levels of acceptability. This suggests that while it can be presumed that nanotechnology lacks the stigma of biotechnology certain examples can nevertheless be seen as similarly unacceptable.

There were both positive and negative belief statements. There were fewer positive belief statements but these were balanced as each statement could be either positively or negatively assessed by agreement or disagreement. Another aspect of the belief statements was their speculative nature. The statements proposed consequences of the development and use of nanotechnology before it has been more fully developed. Consequently many indicated they neither agreed nor disagreed with the statements presumably because they did not know enough about the technology to make a judgement. This presumes that agreement or disagreement with the belief statements about consequences of nanotechnology is made with knowledge of the consequences. At this stage in the development of nanotechnology such knowledge is likely to be limited suggesting a possible contributor to the assessment of consequences is apprehension of the risks of harmful consequences with some people being more positive and optimistic.

In the set of belief statements that were assessed there was a number of statements involving risk or harm to the environment or risks to the public. The results for these enquiries showed there was concern that unexpected outcomes would be controlled and that some were concerned that harmful outcomes could not be reversed. The issue of control and prospect of catastrophe from irreversible outcomes have for some time been known to be key public concerns over technology (Slovic, 2000). Nuclear power has often been closely associated with these concerns while in general, vaccines and common medications have not. The descriptive results indicate that at present, people tend not to envisage or rule out the potential for catastrophe from nanotechnology but the issue of control is presently a concern for the public. More specifically, targeted enquiries about risk showed more certainty in agreement regarding whether the technology would result in new types of pollution, problems in the food chain and health and safety issues. It was less clear whether nanotechnology was judged to increase the use of limited resources and largely unknown as to whether it would be less polluting and help clean up the environment. In summary, regarding risks to people or the environment there are concerns over control of unexpected outcomes and present indecision regarding catastrophic potential.

A further topic in the belief statements concerned the characteristics of the products of nanotechnology. While for many it was unknown, there was a tendency to believe that the technology would result in cheaper and longer lasting consumer products. There was also a tendency to believe that the products of nanotechnology would be useful and would tend to make things that people would need. This indicates that it is recognised that there is commercial potential for the technology. There was nevertheless an indication that once established and accepted it was felt that it would be difficult to then raise objections to more

nanotechnology, and more broadly people were less sure of economic outcomes. In general, lay people are not able to forecast whether or not there will be more employment and economic growth although more are positive than negative about this outcome. Similarly, there is indecision that nanotechnology will improve the quality of life for all New Zealanders but in this case those who made a judgement tended not think this would occur. There was more clear disagreement that the technology would be disruptive to employment and the economy but it was judged that there was a good deal of uncertainty regarding the forecasting of social impacts from nanotechnology. In summary, it is recognised that there is potential for a variety of useful consumer products from nanotechnology and their development is not considered disruptive to industry or the economy. The prospects for growth in employment and the economy are less clear and there is concern over unforeseeable social impacts.

To compare the results of the belief statements about nanotechnology, the results of similar questions used in a nationwide biotechnology survey (Cook & Fairweather, 2005b) are shown in Table 16. As can be seen, the wording of the statements in the biotechnology survey is not exactly the same but nevertheless varies little from the nanotechnology survey. First, regarding the control of unexpected outcomes it can be seen that in terms of mean score and agreement percentage more agreed that they would be controlled for nanotechnology compared to biotechnology. Similarly more agreed the new technology would improve the quality of life and less considered nanotechnology would result in irreversible consequences. These differences were significant (Chi Sq. $p < 0.001$). However, the percentage of agreement with control of unexpected outcomes of nanotechnology was less than one per cent higher than agreement for biotechnology, although the mean score shows a wider difference overall. There was more agreement that nanotechnology would improve the quality of life for all New Zealanders and less agreement that the new technology would result in irreversible outcomes but the scores can still be judged as similar. This suggests that nanotechnology is not that far behind biotechnology in terms of general assessments of risk, while being judged as having somewhat better prospects for improving quality of life.

Table 16: Nanotechnology and biotechnology belief results.

Nanotechnology	**Mean**	**Agreement %**
Any unexpected outcomes from nanotechnology will be controlled.	2.64	19.1
Nanotechnology will improve the quality of life for all New Zealanders.	3.11	30.4
Nanotechnology will result in harmful outcomes that can't be reversed.	3.05	23.0
Biotechnology – 2005	**Mean**	**Agreement %**
I am confident that any unexpected outcomes from biotechnology can be controlled.	2.41	18.4
Biotechnology will improve the quality of life for all New Zealanders.	2.85	25.0
The use of biotechnology will result in irreversible harmful outcomes.	3.10	29.2

The belief statements about medical uses for nanotechnology reflected closely concerns raised in focus groups reported by Cook and Fairweather (2005a). One theme of these discussions was the concern that various medical developments from nanotechnology would be used for self improvement or human enhancement rather than for medical treatment to alleviate suffering. There was a good deal of concern as this was likened to the beginnings of the philosophy of Hitler for a perfect race of human beings and the persecution of ordinary

people. As an initial indicator of concern, in the survey results it was generally agreed that medical nanotechnology would eventually become a new tool for striving for beauty and perfection. More directly addressing the issue, it was also judged wrong to use the technology to artificially improve human abilities and performance. These responses indicate that the basis for the concerns of focus group respondents for an undesirable use of medical nanotechnology also exists in the wider community.

Another aspect of concern for some focus group participants was that social relations and human thinking and behaviour would be undesirably changed through medical interventions or enhancements. However, while it was generally judged wrong to artificially improve human abilities and performance it was not generally agreed that people could become artificial and lose the natural qualities of being human. This difference between the focus group and survey response can nevertheless be attributed to differences in context. The groups had discussed the implications of thought controlled prosthetic limbs and brain to computer connections. Given the necessary brevity of the survey these examples were not included. Consequently it can be presumed that medical interventions that were brought to mind were comparatively less radical with coating a cancer drug, combating viruses and enhancing skin care had been mentioned in the survey.

A more abstract extension of consideration of change to the body through nanotechnology was the suggestion that change to the body does not matter because the essence of a person is in their thoughts. In the focus groups there had been concern that neural activity alone did not constitute the human qualities of a person. While the results show that some agreed with this proposal more had disagreed. Again the context of minor medical interventions may have moderated these responses.

Some of the other medical results pertained to possible differences in interaction with health professionals. While some focus group participants would rather have reduced health care costs than a talk with their doctor, many thought it important to talk to their doctor. This importance can also be seen in the high proportion that agreed in the survey that new tests and treatments would not satisfy the need to talk. The human element is nevertheless considered to be less important because most disagreed with the view that tests and treatments can not replace a doctor's good judgement. As an explanation, saving money and convenience were important to many focus group participants, particularly where the technology replaced the need to visit the doctor.

An expectation from the focus groups was that the increased availability of tests and treatments would lead to an increase in hypochondria. This expectation was supported in the survey as there was more agreement than disagreement that the increased availability of affordable testing could lead to more people worrying about their health.

A further statement from the survey sought to compare the use of GM with the use of nanotechnology in medical treatments. Most agreed that treatments using nanotechnology were acceptable. To understand why, one result for comparison is the perceived naturalness of nanotechnology compared to biotechnology. From Cook and Fairweather (2005b), biotechnology, of which GM is a sub group, was judged unnatural by almost the majority of respondents (50 per cent). Also in the same survey the transfer of animal cells to treat diabetes was agreed to be unnatural by many respondents (49 per cent). In comparison, agreement that nanoparticles floating around in the body were unnatural was much lower (33 per cent) and only exceeded disagreement by a small margin.

Finally, almost the majority had judged that medical consequences could result in harmful outcomes that can not be reversed. This suggests a higher level of concern over medical technology with a lower level of agreement for nanotechnology in general for a similar statement.

There were six statements in the survey regarding computing and electronics. One statement concerned leisure time and the remainder were aspects of surveillance and the gathering and use of personal information. Concerning leisure time, more had disagreed than had agreed that new electronic devices resulted in more leisure time. Concerning surveillance, in the focus groups it was recognised that greater use of personal identification could be a problem because it could be used to monitor the activities of an individual. It was felt that while the police could use such a form of surveillance it would nevertheless be available for misuse. One aspect of this topic was the use of personal identification instead of money resulting in the collection of information about an individual's activity. The survey showed that a large majority judged that this would occur with commercial organisations judged to gain the ability to track what people buy, where they go, and what they do. Another aspect of the gathering of information was the collecting of eye scans and DNA by government authorities. A large majority also judged that this would occur. There was also general agreement that greater ability to store information would result in more organisations having access. A benefit of easier personal identification and surveillance from the focus groups was the combating of crime and terrorism. This benefit was generally recognised in the survey but by not as large a proportion as the expectation of an increase in the gathering of personal information. An expected negative result of similar proportions to combating crime or terrorism was that personal information would be used to discriminate against some people. Overall, there was a strong expectation that surveillance by various means would increase and that it would be of some benefit for combating crime and terrorism. A negative outcome is using personal information for discrimination which appeared to be judged as likely as combating crime or terrorism.

In the focus groups some participants indicated that they would be uncomfortable eating food produced using nanotechnology and also indicated that they felt it would be unnatural. In the survey these suggested reactions were supported as about half indicated they would feel uncomfortable and a similar result was found for it being regarded as unnatural. It was also found in the focus groups that the use of nanotechnology in food production was associated with convenience foods that were believed to be unhealthy. This was supported because in the survey there was a tendency to disagree that altered food would be more nutritious. A further point in the focus groups was the possibility of the development of food using nanotechnology being driven by commercial interests. A number of statements about this aspect in the survey showed this was a worthwhile line of enquiry. The results showed concern over benefits to the producer rather than the consumer and some concern of no food savings to the consumer. There was also agreement that poorer people may not be able to avoid buying the food. An important result was that while more agreed than disagreed most did not know weather the new food would be more acceptable than genetically modified food and there was general agreement that the long term risks were largely unknown. Overall, it is generally indicated that there is likely to be a good deal of concern over food developed using nanotechnology and likely that there are a number of reasons for this concern. These reasons would include concern about the results of commercial interests, being uncomfortable about the food products and about naturalness and being concerned about long term risks.

The inquiry into post-materialism was directed towards determining whether these modern values would resist the development and introduction of a new technology. The results for post-materialism showed that while it was agreed that there should be an emphasis on

economic growth more liberal values were being promoted. These included the development of a society where ideas count more than money, where friendliness should be supported and calls for a more open form of democracy.

Other value-oriented measures were taken of technology and resource use. These results showed that conservation of energy and resources was favoured. On the other hand, technological fixes for the problem of poverty and meeting social goals were not well supported.

Further questions about technology and nature found that while it was regarded as natural for people to improve themselves using technology, the use of technology was not well supported. The results showed only some were confident that technology was a means of enabling sustained use of finite natural resources and the majority did not envisage science and technology would ease concern over the future of the human race. In further results against technology it was judged that scientists would not be able to control nature and that technology would not be able to repair most environmental damage. Interference with nature was seen to invite disaster and the results of such interference were judged to be unpredictable. Of interest, the broader alternative of considering how much the world and people should be changed was supported ahead of considering more technology.

Measures of attitude towards nanotechnology were generally favourable. While many people were undecided, few disapproved of the technology and a majority disagreed that it was unacceptable. Most were undecided about the safety of nanotechnology and only a small proportion indicated it was safe. Nevertheless, there was support for the use of nanotechnology. In measures of emotional reactions some felt uneasy but more indicated there was no need to worry. Some felt it caused them anxiety but more indicated no anxiety. Most were fascinated with the new technology, few were indifferent and the majority were the type of person who would support nanotechnology.

In Table 17 the results for the nanotechnology measures for attitude are compared to the same measures for biotechnology taken by Cook and Fairweather (2005b). The differences between responses to each survey were significant (Chi Sq. $p < 0.05$). As a general context from which to assess the nanotechnology results, the table shows that there was more concern over biotechnology than nanotechnology. For the judgement of safety, both technologies only had a small proportion judge them as safe while nanotechnology was perceived to be safer. The agreement percentage for feeling uneasy was similar for both technologies but with less unease about nanotechnology. There was less similarity for worry and no anxiety with more worry and concern over biotechnology. A large difference can be seen for being fascinated. Clearly there was a good deal of interest in nanotechnology which biotechnology fails to similarly generate. Nevertheless, there was an indication of slightly more indifference to nanotechnology in terms of percentage agreement and mean score.

Table 17: Nanotechnology and biotechnology – measures of attitude

Item measured	Nanotechnology		Biotechnology - 2005	
	Mean	Agree %	Mean	Agree %
Safe	2.87	14.8	2.55	10.0
Uneasy	3.10	38.9	3.25	39.2
Worry	2.86	26.6	3.02	36.7
No anxiety	2.86	29.4	2.55	20.9
Fascinated	3.47	55.7	3.09	36.9
Indifferent	2.43	13.1	2.32	8.2

Finally, a proposal was tested as an explanation for variations in attitude towards nanotechnology. This attitude was formed using measures of emotional reactions as well as summary evaluations because it was assumed that such reactions are prominent when a new technology is unfamiliar. Attitude towards nanotechnology was then held to be influenced by general views and values related to technology as well as beliefs about the outcomes of nanotechnology. Again this arrangement has the assumption of the technology being unfamiliar with general views about materialism, progress and technology posed as influencing attitude directly. It is also proposed that a range of initial beliefs about possible outcomes of nanotechnology are being assessed and summarised and that these also influence attitude.

Subsequently the proposed variables and their arrangement were supported with beliefs and values in combination explaining a reasonably large proportion of attitude towards nanotechnology. It was shown that beliefs were of particular importance in influencing attitude. This indicates that a change in beliefs will have a requisite effect on attitude. Beliefs would become more positive if positive outcomes, such as cheaper and longer lasting products, were realised. Similarly if negative outcomes, such as new types of pollution, did not occur then beliefs and attitudes would also improve. On the other hand if expected good outcomes fail to eventuate or there is evidence of negative outcomes attitudes towards nanotechnology can be expected to become more negative. In these ways beliefs can change and affect attitude.

Unlike beliefs, which can be changed with more information, values are understood to be less subject to change over time. They are also likely to be more involved in the assessment of a technology at an early stage in its introduction to society when the details of the technology are not well known. Some influence was attributed to variables representing post-materialist values, technology as opposed to conservation of resources and technology as opposed to defending nature. This suggests that, at least during the early years of introducing nanotechnology, that values representing post-materialism are likely to impede the development of a positive attitude towards nanotechnology. Rather than encouraging technological development it is likely that adherence to post-materialism would encourage social processes ranging from more democracy to more friendly communities. Some influence is attributed to technology in relation to resource use with those who favour technology over living a simpler lifestyle and conserving resources having a more positive attitude. Also some minor positive influence is attributed to the general view that technology is natural, is the key to sustainability and is not against nature. On the other hand those who advocate conserving resources, question weather technology can lead to sustainability and see nature as hostile to technology, tend to have a negative attitude towards nanotechnology. The results show that these general views and values involve pessimism about technology in general and these general views and values have an effect on attitude towards nanotechnology.

Males had a more positive attitude than females which unlike beliefs and values are attributes that cannot be changed. Similar differences have been found for attitudes towards biotechnology (e.g. Cook & Fairweather, 2005b) and suggest a general tendency for females to be less positive about new technology. Attitude towards nanotechnology also varied with age with younger age groups being more positive. Age has been similarly related to attitudes towards biotechnology. This suggests younger New Zealanders are more comfortable with new technology in general. However, there could also be a positive reaction to improved younger age group consumer goods such as mobile phones and computers that were mentioned in the questionnaire. There were also differences in attitude based on income with those with higher incomes being more positive. This is another tendency that has been found

for attitude towards biotechnology. These relationships and those for biotechnology indicate that attitudes towards new technology are biased depending upon gender, age and income.

4.5 Implications

A key finding was that reactions to products of nanotechnology vary depending on the perceived level of personal exposure to nanoparticles. The increase in the possibility of ingestion indicates that use of nanotechnology in food, drink or medicines and in forms that can be inhaled or absorbed through the skin will be less acceptable than other types of nanotechnology products. On the other hand, situations of low exposure where nanoparticles are presumed to be fused in a composite material will generally be perceived as more acceptable. For this area of public concern addressing incorrect perceptions regarding likelihood of exposure and prospects for personal harm should have an effect on the acceptability of a target product.

Further implications stem from beliefs about nanotechnology in general. First, the lack of familiarity with nanotechnology means that judgements about the new technology would likely be based on conjecture or incomplete information. Consequently there is a high proportion of the public that are uncommitted about most of the outcomes of the technology and it is likely that many judgements of outcomes are based on speculation. This is understandable because many of the outcomes are generally difficult to predict and could merely reflect confidence that the technology will succeed or fail. Nevertheless, given firmer assurance of social and economic benefits as well as assurance of low risk to people and the environment, conjecture would likely transfer into support and attitudes would become more positive. Such assurance can be effective in two ways; first it may influence judgements of likelihood of occurrence of an outcome and its expected magnitude. For example, a pollution scenario would receive fewer objections if it were more unlikely and fewer objections if it was localised and non toxic. Second, because uncertainty tends to make outcomes appear more likely, reducing uncertainty would make negative outcomes seem less likely.

Our research suggests that for the use of nanotechnology for medical purposes a number of associated difficulties might arise. The prospect of using the technology to artificially improve human abilities and performance was not condoned and there was apprehension that people could become artificial and lose the natural qualities of being human. This is not necessarily a criticism of specific medical interventions but is more likely a general concern that a raft of new interventions would mean some are amenable for used in artificial improvement. The basic concern is that this would be ethically wrong and might provide the means that lead to a new class of people which could generate prejudice and discrimination. This finding serves to highlight an area of public concern that those involved in medical nanotechnology research may wish to avoid. Unless such research can be distanced from the objection it will be considered controversial. Alternatively, it may well be productive for facilitated public debate to help clarify the boundaries for acceptance of the technology. Those developing and implementing the technology would then have the opportunity to be responsive to the public and provide products and services for enhancement that are not against the ethical position.

In a view of the possibility of nanotechnology changing the role of the medical doctor it was shown that there was resistance to reducing a doctor's involvement with a patient. New medical tests and treatments would generally not satisfy the need to talk about personal problems. However, the judgement of a doctor is seen to be replaced by new medical tests and treatments with medical professionals becoming less involved in diagnosis and more involved

in patient counselling. A further element in tests and treatments is the view that affordable personal testing would lead to hypochondria. Although assumed to lead to better tests and treatment, the presumed increase in availability of diagnostic tools is expected to cause unnecessary introspection and concern. It is possible that this negative outcome would be countered by the expected trend for more professional counselling.

It was recognised that increased surveillance of individuals would become a problem as improvements were made in electronics and computing. Both commercial and governmental organisation involvement was envisaged with commercial or private organisations gaining the ability to track what people buy, where they go, and what they do. Rights to privacy would be threatened by government agencies taking eye scans or collecting DNA and more organisations are expected to gain access to this kind of information. There was an expectation that surveillance would be useful against crime and terrorism but it was similarly expected to lead to discrimination. This suggests that there will be objections to incursions on privacy. These may not necessarily lead to restrictions on surveillance activities but would likely be met with regulation of the use of information.

There is particular concern about the use of nanotechnology in food production. Its use is seen to be driven by commercial interests, there is discomfort at the thought of the products and they tend to be regarded as unnatural. Its use is also associated with food of lower nutritional value and price, but without a consumer saving. There is also some risk attributed to this use of the technology and, while it may be more acceptable than GM food, given little advantage to the consumer it is unlikely to be widely accepted. It is also possible that, like GM food, there may be calls to provide for consumer identification of products incorporating nanotechnology. In this situation, without some form of consumer benefit, the demarcation of the new products is likely to harm sales because of concern over unknown risk and long term exposure.

General values held by New Zealanders suggest some resistance to technology in general. However, friendliness, more say in government, an emphasis on ideas over money and beautifying the landscape, are objectives that are not immediately associated with technological development. More immediately opposed to technology is the recognised need to live a simple lifestyle and the call for wealthy nations to consume less. Also a minority believe that technology can eliminate poverty or for realise social goals. While human use of technology is judged natural there is a good deal of pessimism over the ability of technology to address sustainability issues involving resources and nature. This view includes the judgement that nature cannot be easily controlled or repaired, is not readily understood and tends to react unpredictably and catastrophically to interference. These general values against technology mean there is likely to be some resistance of nanotechnology by New Zealanders.

Despite the scepticism about technology in general, attitude towards nanotechnology was generally favourable. The technology received a good deal of approval and was generally judged acceptable, although safety was an issue. Unease, worry and anxiety were not excessive and many found it fascinating. There were, however, many who were unable to make a judgement about the technology presumably because they were unfamiliar with the technology or its possible effects. This indicates that many are yet to become familiar with nanotechnology suggesting that as people become familiar with nanotechnology their judgement will become firmer and more robust. This means that near future promotion or criticism will be particularly influential.

At present attitude towards nanotechnology has a relationship with post-materialist values and values associated with technology, resource use and nature. The nature of values is that they

are slow to change and would tend to guide the appraisal of a technology when it is largely unfamiliar. With greater familiarity, knowledge of a technology and its effects take more precedence in its appraisal and overshadow the effect of general values. Beliefs about nanotechnology are presumed to be subject to change and lead to a change in attitude whereas values tend to be invariant over time and have an anchoring effect on attitude. This means that because beliefs are the dominant influence, dealing with the various social, economic and environmental effects identified in the results would have an effect on attitude. As a secondary consideration, attention could be given to how the technology is being interpreted in relation to values associated with post-materialism, technology, resource use and nature. This means that nanotechnologies that assist in the sustainable use of energy and resources, and are seen not to disrupt a complex and unpredictable conception of nature, are likely to be more acceptable.

Finally, comparisons between biotechnology and nanotechnology also have implications for the new technology. The acceptability of GM food and animals treated with growth hormone was of a similar level to the low score for the acceptability of the nanotechnology skin care product. This suggests that the level of rejection of personally ingesting nanoparticles is similar to the rejection of some products of biotechnology. However, differences between the two technologies were found in comparing responses to belief statements. While significantly different at present, it could nevertheless be seen that nanotechnology is not far behind biotechnology in terms of general assessments of risk. Nanotechnology was also more favoured than biotechnology in a number of overall assessments, but not by a large margin.

It would seem from comparisons with biotechnology that nanotechnology is being similarly assessed by the public. Level of personal contact is a factor in this assessment and there are some similar reactions in terms of assessment of risks and benefits, emotional reactions and overall summary assessments. These findings suggest that nanotechnology is being received with caution which is unlike the early introduction of GM to the New Zealand public. For example, an early survey of New Zealanders found general acceptance for GM plants (86 per cent) and GM animals (57 per cent) (Couchman & Fink-Jensen, 1990), but by 2000 surveys reported predominantly negative attitudes towards GM food (Cook, Fairweather & Campbell, 2000; Gamble et al., 2000). There had been a marked increase in aversion to GM which has been shown to have only slowly decreased in recent years (Cook & Fairweather, 2006). The measured reaction to nanotechnology and comparison with biotechnology shows that there is no early period of general acceptance as had occurred for GM. Instead, the reaction to nanotechnology indicates that, while being somewhat more acceptable, reactions to the new technology are similar to, and comparable with, recent reactions to biotechnology. Consequently, unlike the initial general acceptance and increase over time in public concern over GM, there is likely to be a good deal of public concern upon finding out about nanotechnology.

4.6 Recommendations

The research implications indicate that it would be prudent to deal with potential public reactions towards offsetting the potential for nanotechnology to become problematic and unacceptable. This would involve informing the public about key areas of their concern including prospects for environmental and personal risk, as well as personal social and economic benefits. There are two immediate dimensions to this response. One is to adapt the technology to better suit public attitudes and the other is to explain nanotechnology to the public in order to offset the possibility of public controversy. The first could be seen as unfairly influencing science and limiting the development of technology. Nevertheless,

amending research and development in response to public attitudes is an important strategy for avoiding public controversy. The latter response is relevant to situations where the public lack information or are misinformed, as it may be possible to initiate discussions to nullify public concern. Ideally, such discussion should be initiated prior to the development and implementation of a nanotechnology. While ensuring nanotechnology developments do not conflict with social attitudes and values, public involvement would also moderate, or ideally offset, the possible shock of an unexpected discovery by the public of the technology.

In addition to a focus on risks and benefits of a nanotechnology, a further relevant recommendation is for consideration of the area of application of a particular product or process. In general, caution should be employed in research and development in the area of food and food production considering the high potential for consumer rejection. More generally, the degree of personal contact with the product or process should also be considered. Further, the reaction of the public to each application of nanotechnology should be studied because the assessment of public reactions to general areas of the technology may differ from particular products and processes. It would be preferable for proponents of nanotechnology to have a targeted understanding of public reactions to nanotechnology in order to better inform their research programmes and divert attention to technologies that will receive strongest support. It would be useful to inform and involve the public in this process.

4.7 Conclusion

New Zealand public reactions to nanotechnology can be readily framed in terms of the controversy over the introduction of GM. Proponents and promoters of nanotechnology would clearly be wise to avoid such controversy and there is now an additional imperative for action. It should be of particular concern that the level of public apprehension over nanotechnology is already high. Nevertheless, it has been shown that public responses vary depending upon the particular example of nanotechnology and it has been shown that beliefs about risks and benefits, and social values, shape attitudes towards nanotechnology.

Ultimately, the findings provide a guide for programmes and projects that involve public consideration of nanotechnology. Ideally, these would involve the timely consideration of public concerns and aspirations and incorporate these in their planning for research development and implementation. It is from this detailed understanding that effective steps can be taken to prompt people to consider issues arising from new science and technology that are important to them. This could lead to new technologies that are more acceptable, given that those involved in science and technology take the opportunity to make effective use of the process.

References

Bainbridge, W.S. (2002). Public attitudes toward nanotechnology. *Journal of Nanoparticle Research*, 4, 561-570.

Chen, P. Y. & Kraus, A. D. (2004). Cronbach's alpha. In M. S. Lewis-Beck, A. Bryman, T. Futing Liao (Eds.). *The Sage encyclopaedia of social science research methods* (Volume one) (pp. 225- 226). Thousand Oaks, Calif.: Sage.

Cobb, M. D. & Macoubrie, J. (2004). Public perceptions about nanotechnology: Risk, benefits and trust. *Journal of Nanoparticle Research*, 6, 395-495.

Cook, A. J. & Fairweather, J. R. (2005a). *Nanotechnology – ethical and social issues: Results from New Zealand focus groups.* Research Report, Agribusiness and Economics Research Unit, Lincoln University.

Cook, A. J. & Fairweather, J. R. (2005b). *New Zealanders and biotechnology: Attitudes, perceptions and affective responses.* Research Report, Agribusiness and Economics Research Unit, Lincoln University.

Cook, A. J. & Fairweather, J. (2006). *New Zealanders and biotechnology: Reactions to novel developments in medicine, farming and food.* Agribusiness and Economics Research Unit, Research Report, Lincoln University.

Cook, A. J, Fairweather, J. R., Satterfield, T. & Hunt, L. M. (2004). *New Zealand public acceptance of biotechnology.* Agribusiness and Economics Research Unit, Research Report, Lincoln University.

Cook, A. J., Fairweather, J. & Campbell, H. (2000). *New Zealand farmer and grower intentions to use genetic engineering technology and organic methods.* Agribusiness and Economics Research Unit, Research Report, Lincoln University.

Couchman, P. K. & Fink-Jensen, K. (1990). *Public attitudes to genetic engineering in New Zealand.* DSIR Crop Research Report No 138.

Coyle, F. J., Maslin, C., Fairweather. J. R. & Hunt, L. M. (2003). *Public understandings of biotechnology in New Zealand: Nature, clean green image and spirituality.* Agribusiness and Economics Research Unit, Research Report, Lincoln University.

Crichton, M. (2002). *Prey*. New York: Harper Collins.

Drexler, E. D. (1986). *Engines of creation: The coming era of nanotechnology*. New York: Anchor Books.

Gamble, J., Muggleston, S., Hedderly, D., Parminter, T. & Richardson-Harman, N. (2000). *Genetic engineering - the publics' point of view*. Mount Albert Research Centre. Horticulture and Food Research Institute of New Zealand Limited.

Gaskill, G. Ten Eyek, T. Jackson, J. & Veltri, G. (2004). Public attitudes to nanotechnology in Europe and the United States. *Nature Materials* 3, 8, 496.

Hall, J. S. (1995). *Nanofuture: What's next for nanotechnology.* New York: Prometheus Books

Inglehart, R. (1990). *Culture shift in advanced industrial society*. Princeton, N.J.: Princeton University Press.

Nunnally, J.C. (1967). *Psychometric Theory*. New York: McGraw-Hill.

OECD & Allianz (2005). Opportunities and risks of nanotechnologies (www.oecd.org).

Peterson, R.A. (1994). A meta-analysis of Cronbach's coefficient alpha. *Journal of Consumer Research* 21, 381–391.

Priest, S. (2006). The North American opinion climate for nanotechnology and its products: Opportunities and challenges. *Journal of Nanoparticle Research* (http://springerlink.metapress.com).

Ratner, M. & Ratner, D. (2003). *Nanotechnology: A Gentle Introduction to the Next Big Idea*. NJ: Prentice Hall

Scheufele, D. A. & Lewenstein, B. A. (2005). The public and nanotechnology: How citizens make sense of emerging technologies. *Journal of Nanoparticle Research*, 7, 659-667.

Siegrist, M. (1999). A causal model explaining the perception and acceptance of gene technology. *Journal of Applied Social Psychology*, 29, 10, 2093-2106.

Slovic, P. (2000). *The perception of risk*. London: Earthscan publications.

Swiss Re (2004). *Nanotechnology: Small matter, many unknowns* (www.swissre.com).

Waldren, A. M., Spencer, D. & Batt, C. A. (2006). The current state of public understanding of nanotechnology. *Journal of Nanoparticle Research* (http://springerlink.metapress.com).

Appendix

Public Attitudes towards New Technology

A Nationwide Survey

Lincoln University

Te Whare Wānaka o Aoraki

What is Nanotechnology?

You may not have heard of nanotechnology. Nanotechnology is a new development in science that involves the use of materials of an extremely small size, often less than a billionth of a metre. At this scale specialised instruments are being used to construct new materials often called nanoparticles. Overseas, nanoparticles have been used to develop clothing with stain-resistant fibres and formulate more effective sun-screen lotions. Nanoparticles are also helping to deliver drugs to targeted tissues within the body affected by cancer. Nanoparticles are also being used the automotive industry, and in electronics, computers and communication. As these examples show nanoparticles can be useful. However, scientists have also found that some particles can be poisonous or toxic. This has led to calls to avoid the possibility of nanoparticles becoming hazardous to people or the environment.

Instructions

For <u>each</u> question, please select the number for the option that best indicates your response and write it in the box provided on the right hand side of the page. Please note that we are interested in your personal opinion and that there are no wrong or right answers.

1. Examples of nanotechnology

The following are overseas examples of actual products currently being developed using nanotechnology. Based on your current knowledge, please indicate your opinion about the acceptability of each example.

Very acceptable **1**	Acceptable **2**	Neither acceptable nor unacceptable **3**	Unacceptable **4**	Very unacceptable **5**

Nanoparticles sprayed from an aerosol can by the consumer to ensure eye glasses stay clean and clear.	
Using nanoparticles in paints and coatings to protect against corrosion and scratches.	
A plastic lunch box impregnated with nano-size silver particles to keep food fresh by killing harmful microbes and bacteria.	
Skin care products that contain nanoparticles to assist in deeper and faster penetration of nourishments.	
Using nanotechnology to manufacture improved sensors for chemicals, such as explosives or other unwanted contaminants.	
Using nanotechnology to make improved filters for cleaning up waste water.	
Mixing nanoparticles within other materials to increase strength or reduce weight in, for example, car or aeroplane parts.	
Using nanoparticles in the human body to detect and neutralise viruses.	
Using nanoparticles in clothing fabric to make clothing more resistant to water, stains and wrinkling.	
Computers that are more affordable and have better speed and capacity.	
Cheaper and smaller communication devices with more new features and components.	
Coating a drug with nanoparticles that attach to tumour cells to ensure the drug is released within a cancer tumour.	

2. Nanotechnology in general

The following statements about nanotechnology were drawn from interviews with everyday New Zealanders. Please indicate your level of agreement or disagreement with each of them.

Strongly disagree **1**	Disagree **2**	Neither agree nor disagree **3**	Agree **4**	Strongly agree **5**

Nanotechnology will result in cheaper and longer lasting products for the consumer.	
Nanotechnology will result in more employment and economic growth.	
Any unexpected outcomes from nanotechnology will be controlled.	
Nanotechnology will result in harmful outcomes that can't be reversed.	
Nanotechnology will improve the quality of life for all New Zealanders.	
The development of nanotechnology will disrupt industry and the economy.	
Nanotechnology will result in new types of pollution.	
Nanoparticles could become a big problem if they got into the food chain.	
Nanoparticles will result in new heath and safety issues in industry and the wider community.	
Nanotechnology will be used mostly to make things we don't really need.	
Once we accept some nanotechnology much more will follow regardless of whether we accept it or not.	
Creating a continual stream of new products using nanotechnology will increase the use of limited resources.	
No one really knows the long term social impacts from developing nanotechnology.	
Nanotechnology will help replace polluting technologies and be used to help clean up the environment.	
Nanotechnology will result in new weapons for war and escalate the arms race.	

3. Applications of nanotechnology

Please indicate your level of agreement or disagreement with each of the following statements.

Strongly disagree **1**	Disagree **2**	Neither agree nor disagree **3**	Agree **4**	Strongly agree **5**

Nanotechnology in medicine

Medical nanotechnology could result in harmful outcomes that can't be reversed.	
Nanotechnology would eventually become a new tool for striving for beauty and perfection.	
New medical tests and treatments cannot satisfy the need to talk about personal problems.	
Treatments using nanotechnology would be preferable to those using genetic modification or cells from animals.	
It would be wrong to use nanotechnology to artificially improve human abilities and performance.	
Eventually people could become artificial and lose the natural qualities of being human.	
It doesn't matter how the human body is changed because the essence of a person is in their thoughts.	
More medical tests and treatments cannot replace a doctor's good judgement.	
The possible increased availability of affordable personal testing could lead to more people worrying about their health.	
It would feel unnatural to have nanoparticles floating around in my body.	

Nanotechnology in computing and electronics

The ability to store more information will result in more organisations having access to personal information.	
New electronic devices would result in more time for leisure.	
Using personal identification instead of money will result in commercial organisations tracking what we buy, where we go and what we do.	
Making surveillance cheaper and more readily available is necessary to combat crime and terrorism.	
As information becomes easier to store and use, eye scans and DNA will be routinely gathered and stored by government authorities.	

As information becomes easier to store and use personal information will be used to discriminate against some people.	

Nanotechnology in food production

It would feel uncomfortable knowing I was eating nanoparticles.	
The use of nanoparticles in food production will benefit the producer more than the consumer.	
Nobody really knows whether widespread, long term exposure to nanoparticles in food will be harmful.	
Nanotechnology will result in savings for food consumers.	
Because of a limited budget many people could not avoid buying cheaper food produced using nanotechnology.	
Nanotechnology will result in convenience foods being more nutritious.	
Food produced using nanotechnology will be more acceptable than food produced using genetic modification.	
Food produced using nanotechnology would be unnatural.	

4. Other general attitudes

Please indicate your level of agreement or disagreement with <u>each</u> of the following statements about society and technology

Strongly disagree **1**	Disagree **2**	Neither agree nor disagree **3**	Agree **4**	Strongly agree **5**

People should have more say in the decisions of government.	
The priority of government should be to maintain a high rate of economic growth.	
More effort should be given to making our cities and countryside more beautiful.	

Other general attitudes continued

Efforts should be made to encourage a friendlier, less impersonal society.	

We need to develop a society where people count more than money.	
A technological society has the best chance of eliminating poverty.	
Advances in technology mean that the goals of society can be realised.	
Living a simpler lifestyle is the best way to conserve energy and resources.	
Wealthy nations should consume less and limit their use of resources.	
Groups that oppose materialistic values deserve support.	
It is natural for people to improve their lives by using technology.	
Technology is progressing so that in the future there will be no need to rely on finite natural resources.	
New technology will eventually enable sustainable use of the planets natural resources.	
Through science and technology there will eventually be no need to worry about the future of the human race.	
Nature has tremendous capacity to adapt to the effects of human progress.	
Rather than considering more technology, we need start thinking about how much we should change the world and ourselves.	
Scientists will eventually know enough about nature to be able to control it.	
Technology will eventually repair most of the environmental damage that has been done.	
Interference with nature often produces disastrous consequences.	
When we interfere with the nature the consequences are unpredictable.	

5. Overall attitude towards nanotechnology

While considering nanotechnology in general, please indicate your level of agreement or disagreement with each of the following statements.

Strongly disagree **1**	Disagree **2**	Neither agree nor disagree **3**	Agree **4**	Strongly agree **5**

I approve of the use of nanotechnology.	
I consider that the use of nanotechnology is unacceptable.	
I consider the use of nanotechnology to be safe.	
I support the use of nanotechnology.	
The use of nanotechnology makes me uneasy.	
The use of nanotechnology causes me to worry.	
The use of nanotechnology causes me no anxiety.	
I am fascinated by the use of nanotechnology.	
I am indifferent to the use of nanotechnology.	
I am the type of person who would support the use of nanotechnology.	

Please turn over

Please provide some information about yourself. We need this information to check whether our sample is representative.

1. Please provide your age (Years) ☐

2. Please indicate your gender (1) Male (2) Female ☐

3. What was your personal income over the past 12 months? ☐

(1) Less than $15,000 (2) $15,001 - $20,000 (3) $20,001 - $40,000
(4) $40,001 - $60,000 (5) $60,001 - $100,000 (6) $100,001 and above

4. What is your highest level of education completed? ☐

(1) Attended primary school
(2) Attended secondary school, without qualifications
(3) Attended secondary school, with qualifications
(4) Trade technical qualification or similar
(5) Undergraduate diploma or certificate
(6) Bachelors degree
(7) Postgraduate or similar

5. Which of the following best describes your religious beliefs? ☐

(1) Agnostic
(2) Christian
(3) Atheist
(4) Spiritual but not religious
(5) Other - Please specify

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Thank you for completing our questionnaire. Please return your questionnaire using the freepost envelope.