A CONCEPTUAL FRAMEWORK EXPLAINING PUBLIC PERCEPTION OF NANOTECHNOLOGY TOWARDS SUSTAINABLE DEVELOPMENT

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ABSTRACT

From tiny assembling atoms to nano-enabled application, nanotechnology has opened a new realm to science and technology to assist sustainable development. Its benefits are widely spread all over the world from environmental remediation to food security. However, nanotechnology is also touted to uncertain risks from laboratories to consumer products. Public perception is matters to know whether nanotechnology is beneficial or risky to them. Thus, this paper aims to explain public perception towards nanotechnology through a conceptual framework. This paper contains literature review of public risk and benefit perceptions of nanotechnology from 2002 to 2015 and a conceptual framework of factors influencing public perception towards nanotechnology. The conceptual framework consists of (1) public perception towards nanotechnology (dependent variables) (2) psychology and sociology approaches (independent variables), and (3), intervened by other variables such as media, technology development, economy status, application of nanotechnology and risk information. Public perceptions will be instrumental for good governance of nanotechnology to facilitate sustainable development by considering the relevant factors in the conceptual framework, it can benefit companies, academics, and policy makers to further develop nanotechnology that suits and secures public interests.

Keywords: Benefit perception, conceptual framework, nanotechnology, risk perception, sustainable development.

INTRODUCTION

From assembling atoms and processing them into imagining, fabricating, manipulating and controlling; to nano-enabled applications, nanotechnology has opened a new realm in science and technology to assist sustainable development. Environmental degradation caused by the over consumption of natural resources and poverty gives an warning to the world to take better actions in development which meet the needs of the world population today in these finite and limited resources without compromising the needs of future generation. Development of economy, improvement of social well-being and conservation of the natural resources are the keys in achieving sustainable development and we shall take into account when developing nanotechnology for our nation. National Nanotechnology Initiatives (NNI) defines nanotechnology as;

"research and technology development at the atomic, molecular or macromolecular levels, in the length scale of approximately 1–100 nm range, to provide a fundamental understanding of phenomena and materials at the nanoscale and to create and use structures, devices and systems that have novel properties and functions because of their small and/or intermediate size small and/or intermediate size [1]."

Nanotechnology is applied in cosmetics, electrical appliances, sports equipment, and etc. to improve products' functionality, strength and prolong the life span. Nanotechnology is also applied widely in healthcare for nano-diagnostics using magnetic resonance imaging and nano-therapies by drug delivery which will boost disease diagnosis and treatment [2]. Nanotechnology is also applied in treating surface water, ground water and wastewater by removing heavy metals, organic and inorganic compound, and microorganisms [3]. The costs for water treatment using nanomaterials are lower compared to conventional way. For example, magnetic nanoparticles are widely used for water treatment because they are found abundance in the nature and this will assure adequate water supplies and sanitation for the increasing world population. The recent application of nanotechnology in food by smart nutrient delivery and nano-encapsulation of nutraceuticlas has the ability to enhance food production and avoid food scarcity. These applications of nanotechnology will improve human well being and revolutionize the society.

However, there are concerns touted to nanotechnology. 1) The size of nanoparticles. Nanoparticles are in at the size from 1 nm to 100 nm which execute different physical, chemical and biological properties compared to larger size of the same particles. With that size, it may enter and travel through human body and harm the cell. Even using nanoparticles to deliver drugs to targeted cell, the release of it in the body may be hazardous. 2) The other concerning issue is the new potential contaminants produced from manufacturing and combustion. The release of nano-contaminants to the environment may be due to leakages from the landfill and enter reclaimed water which later flow into the water bodies. The risks of nanomaterials are not only focusing on its potential hazards for example its toxicity, but also considering how long living cells are exposed to the materials. People may also expose to manufactured nanomaterials when they are working with them and the exposure can happen through airborne and dermal contact. The degree of exposure from aquatic environment is another path for the particle to come into contact with living cells. Metal oxide nanoparticles such as TiO_2, ZnO and Fe_2O_3, can to be toxic and cause inflammatory reaction and cell membrane leakage [3].

As much as the benefits of nanotechnology are promising for sustainable development, the potential risks of nanomaterials are also debated among researchers and the public. Nanotechnology has progressed from laboratory research to

applications and will continue to evolve. Public are the ones who will gain the benefits and get affected by the risks from nanotechnology. Public perception, acceptance, rejection, opinion and satisfaction matters in creating informed public and getting the public to participate in nanotechnology development [4]. It is vital to deliberate the development of nanotechnology to inform, exchange knowledge, receive feedback from the public. Hence, public perceptions will affect the decision makers for good governance of nanotechnology for sustainable development. Public is dynamic with no one answer to fit all. Everyone would perceive risk and benefit of the development of nanotechnology in a different way depending on their educational background and worldview. Public perception is defined as;

"A social phenomenon on how public sees the risk and benefit in a situation which can be based on facts or fiction shaped by the knowledge, culture and/or media. Public constructs risks in their mind as a concept for them to deal with uncertainties and dangers in life [5]. While, they perceive benefit through belief of positive consequences by specific actions [6]. Public and experts have a very different way of seeing risks. To experts, risk is seen as annual mortality rates while public see it as the sum of hazards and outrage"

Our mind constructs the uncertainty because of the lack of knowledge. Complete knowledge will put us in certain position with no fear and only confidence. Be in control in a situation lowers the perceived risk of an individual. This subjective assessment of the probability of an event occurrence creates individual risk and benefit perceptions. However, not all risks are intolerable. Risks are found to be acceptable if they are associated with benefits [7] and it is called voluntary risk. Individual perception is beyond predicting danger in the future but also influenced by social, cultural, and ideology [5]. Figure 1 shows the number of publications for public perception of nanotechnology research from 2002 to 2015 whereby this subject matter is attracting researchers to know further about public perception for good governance of nanotechnology.

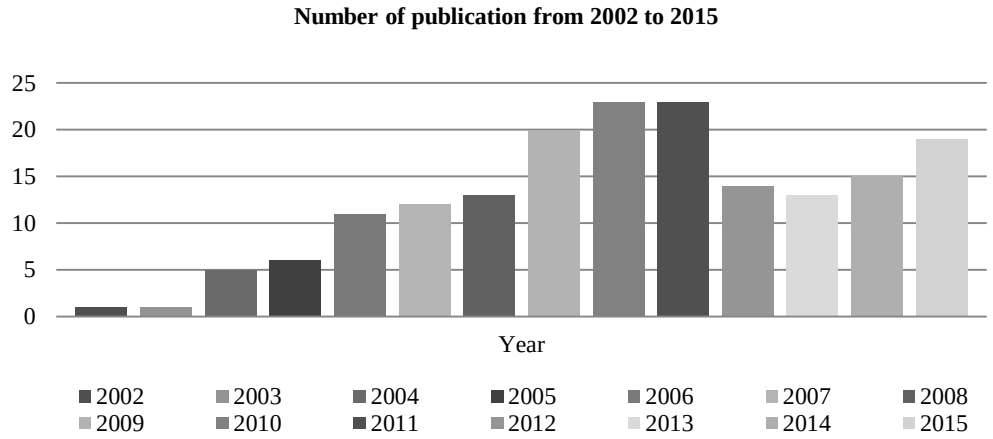

Figure 1. Number of research papers of public perception of nanotechnology published from 2002 to 2015

BUILDING A CONCEPTUAL FRAMEWORK

Figure 2 explains the public perception of nanotechnology from the factors influencing the risk and benefit perceptions. Risk and benefit perceptions are influenced by psychological approach – knowledge, trust and attitude, sociological approach – culture, social and religion. Beyond psychological and sociological approach, risk and benefit perceptions are also intervened by other influencing factors – media coverage, technology development, economy status, different application of nanotechnology, and risk information. This conceptual framework attempts to develop an understanding on how risk and benefit perceptions are shaped by the factors influencing them and the impact of perceptions to the development of nanotechnology for sustainable development.

The following sections will further discuss the components in the risk-benefit perceptions of nanotechnology conceptual framework. The first section will discuss on the public perception of nanotechnology followed by psychological, sociological and intervening factors in shaping public perception.

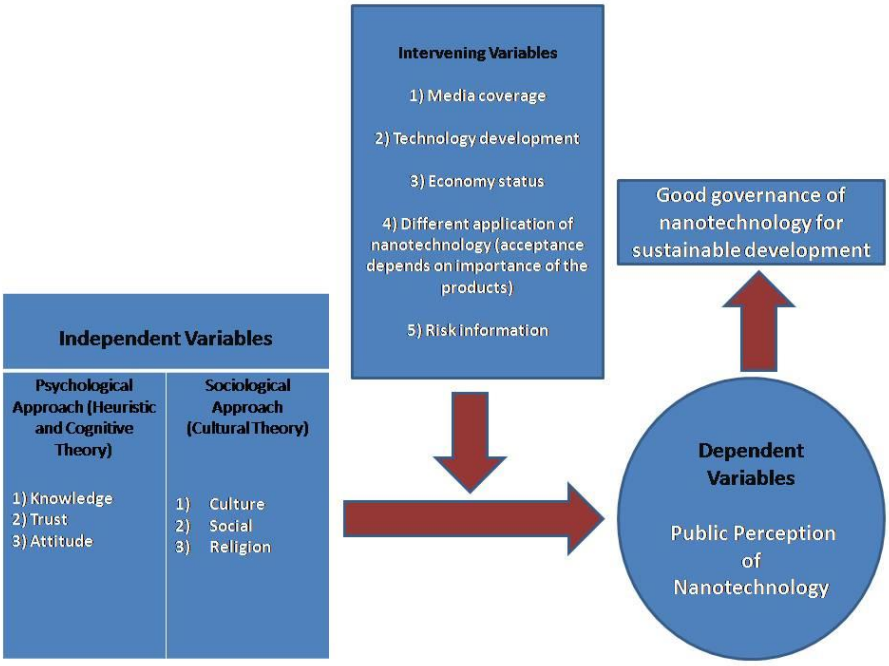

Figure 2. Public risk-benefit perception of nanotechnology conceptual framework

Public perception of nanotechnology

Researches were made to make sense of public perception. The most common cognitive strategy adapted by most people to make quick choices and judgment is heuristic. Individual will employ heuristic by adapting the available information presented to them to help them in decision making. Information stating low risk in a technology will affect someone to judge the technology to be safe or vice versa [8]. People not only will judge based on the information given, they will also make judgment based on what they feel, whether they like or dislike a particular technology [9]. The ability to feel is important in making a rational decision where the lost of the sense due to brain damage can cause someone to unable to decide and socialize [10]. It is argued by Panglossian theorists that heuristic can be biased and will contribute to mistakes or performance errors [11]. However, in this technological day we must make our rapid decision based on what is presented to us [12] and able to critically judge a situation or an event. Hence, with different levels of intelligence, world view and way of thinking will yield different outcome.

During the initial stage of understanding public perception of nanotechnology, people with scientific background perceived benefits in the technology, while some were worried of the inequality of its benefit in the future [13]. The concern of risks in nanotechnology development was at rise in 2003. Researches were conducted discussing over the societal impact of nanotechnology such as new contaminants produced at nanoscale [14] and the concern in misuse of nanotechnology to manufacture weapon which can be more powerful than non-nanotechnology weapon [15]. The same public concern were also shown in other studies[16–19]. Not only was the weapon the major concern of the public but also devices that can jeopardize public privacy such as the miniature surveillance devices and computers in clothes and goods [18]. “Fear of the unknown”, “going against nature” and “environmental destruction” were the public concerns.

Apart from those concerns, nanotechnology has been proven to become the solution to many problems, for example medicine for early detection and treatment of diseases, improve the utilization of non-renewable resources, effective pollution remediation and many other benefits. Studies shows that public are positive about nanotechnology rather than worry [13,16,19–26] even when they are not knowledgeable enough about nanotechnology. Even with the lack of knowledge, public are able to make judgment based on what are being conveyed to them by the media and employ other familiar social aspects as preferences to make sense and evaluate the risk of this emerging technology [27,28]. Therefore, media coverage plays an important role to the public risk and benefit perceptions by framing either positive of negative information to the public.

Perceiving risk and benefit in nanotechnology will lead to acceptance and rejection of the technology. Their acceptance and rejection matters to further develop nanotechnology for the nation to be able to utilize the technology to attain sustainable development. Knowing the factors influencing the perception will serve as guidance for decision makers, industries and researchers to understand the public needs and develop nanotechnology accordingly.

Factors influencing public risk-benefit perception

Factors influencing public perception of nanotechnology were determined from the 2002 to 2015 literature. The risk-benefit perceptions on nanotechnology conceptual framework explain perception influenced by psychological approach (knowledge, trust and attitude) and sociological approach (culture, social and religion). These two approaches impact the ability of a person to think, reason, and process information to decide and judge. However, there are also other intervening factors that influence individual’s perception, such as media coverage, technology development, economy status, different application of nanotechnology, and risk information.

Psychological approach (knowledge, trust and attitude)

Experts such as scientists and researchers with factual knowledge of nanotechnology show different perception of nanotechnology compared to laypeople [19,29]. Both groups agree on benefits of nanotechnology outweighing the risks, however, laypeople tend to perceive higher risk of nanotechnology than experts. Only by complete knowledge of a technology, where benefit is perceived higher than risk, a person is willingly to accept the technology [27,30–32]. Therefore, scientists are less concern of the risks compared to laypeople because of the knowledge and experience regarding the hazardous of nanotechnology which are less likely to affect the public directly [29]. Nevertheless, experts are concerned about "new pollution" and "new health problems" which may caused by nanotechnology in the future [19].

According to Siegrist (2007), experts have more trust for the government in handling nanotechnology and protecting the public from the risks while laypeople depend on how the industries, government agencies and NGOs in managing the new emerging technology. Although with limited knowledge, public are still able to judge risks and benefits of nanotechnology and generally show positive attitude towards it, but the concerns and trusts between the experts and laypeople are different. Trust for government, business leaders and researchers influence public risk and benefit perceptions. With limited knowledge of nanotechnology among the public, trust is employed by the public to willingly accept nanotechnology by relying on information given by researcher, government, industries and other sources [24]. Trust is an important indicator for risk and benefit perceptions where it reduces the complexity in decision making for the public to either accept or reject new emerging technology based on their risk and benefit perceptions and also ease the formation of public policy of nanotechnology for the regulators [33].

Positive or negative attitudes towards nanotechnology is depended on the benefit and risk perceived by an individual [24,34]. Perceiving benefit will increase positive attitude, while perceiving risk will lead to negative attitude and might lead to rejection of the technology. Positive attitude for nanotechnology is shown by people who are positive about science and technology whereby no controversy regarding the science and technology experienced by a country will boost public trust and their positive attitude for science and technology as well as nanotechnology [26].

Sociological approach (culture, social, religion)

Culture is the way of living with shared values and beliefs established by older generation and then pass onto the younger generation. It is also someone's view shaped by the social groups such as organizations and peers which they are a part of [35]. High support for nanotechnology can be observed in China. In the study in 2015 by Zhang et al, Chinese have high expectation on nanotechnology to increase their living standards and for them to be able to compete globally. It is the culture of the Chinese to support technology since the establishment of the Reform and Opening Up policy in 1978 that engage science and technology as the main force for economic development and industries.

In social context as for social interaction, public perception of nanotechnology not only embed to the toxicology risks but it goes beyond the benefit and risk of nano-enabled production, distribution, use and disposal to the unequal social groups [36]. Thus, social acceptance of this new ubiquitous technology relies on the information provided and also trusts for government, scientists, and industries [37–39]. Religious people however on the other hand are not supportive for the funding of nanotechnology [32]. The 'play God' term where science interfere with natural system is the reason for highly religious people to oppose man-made technologies.

Intervening factors (Media coverage, technology development, economy status, application of nanotechnology, risk information)

With incomplete knowledge about nanotechnology, heuristic approach is a commonly applied by the public to judge. Being exposed to media coverage of nanotechnology will increase the familiarity of the technology. Depending on the information portrayed, public will decide whether nanotechnology is beneficial or risky. However it is argued that media has a high impact on public attitude and thus their perception of nanotechnology [23]. Science-related information might help someone to produce benefit or risk perceptions and not only the any news showed by the media.

Public perception evolves along with technology development. Along with the development more information about the technology delivers to the public thus increase familiarity [40]. Becoming more familiar and informed about nanotechnology, public will have different perception and reaction towards the technology. Countries with economic driven by technology shows benefit perception outweigh risk perception among the public [26,41].

Although nanotechnology is mostly accepted by the public, but the risk and benefit perceptions are varied in different application of nanotechnology [42]. Applying nanotechnology in food is concerning the public and is the most unacceptable application whereas electrical appliances is the most accepted one [42–44]. While comparing nanotechnology food and nanotechnology food packaging, public find food packing is more beneficial than nano-food [45]. Providing risk information of nanotechnology to the public escalate people's alertness since negative information are more powerful and influential than benefit information [17]. Labelling a product with label "synthetic nanoparticle" and providing risk information to the product increase risk perception of the consumer compared to a product with no label and risk information [17,46].

CONCLUSION

Sustainability is complex and determined by the interaction between (1) population growth and their needs, (2) shared values of social and culture, and (3) human – built environment and earth limit [47]. Increasing population lead to increasing demand and our world resources is limited. Effective utilization of resources for meeting today demand will not deprive our next generation's to meet their own needs. We are seeking for sustainable solutions that are cheap, efficient, and effective. Nanotechnology offers efficiency and able to achieve material properties which were once too expensive and impossible. Nanotechnology has been touted as enabling technology with the capability to contribute to sustainability. Traditionally, public were seen separated from and impacted by the technology rather than being a part of the development [48]. Controversy in genetically modified organisms (GMO) and mad cow disease in European countries has deteriorated

public trust in government, however, these incidents have become the reason for a new way of communicating technology to the public. Engaging the public and taking into account their perceptions in the early stage of the nanotechnology development will prevent misconception and boost public trust in government, industries and researchers for good governance of nanotechnology for sustainable development.

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