Comparing Public Responses to Emerging And Nuclear Waste Disposal Technologies: A Case Study- 11380

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ABSTRACT

Scientists who work in emerging technologies focus on the advantages and are surprised by the sometimes negative responses from citizens who question the use of such technologies. Social scientists have explored the sources of this sometimes contentious debate in emerging technologies such as biotechnology and nanotechnology [1]. While radioactive waste disposal does not qualify as an emerging technology *per se*, response to Yucca Mountain as a proposed disposal site shows that tensions remain [2,3,4]. This paper identifies theories and empirical results from multiple literatures to explore and compare public responses to nanotechnology, biotechnology, and nuclear technologies. Several issues arise while exploring what is known about public response to each technology. Given the importance of nuclear waste management and disposal [5] for present and future generations, research from the social sciences may offer a more constructive approach to the substantive problems that may arise for the general public when considering emerging or mature technologies.

INTRODUCTION

Since the 1811 Luddite attack on weaving machines, controversies continue to arise between individuals who embrace new technologies for work and leisure activities, and those who do not [6]. Examples of such controversies today include biotechnology and nanotechnology. Briefly, biotechnology is based upon genetic science with many different applications ranging from genetically modified crops to stem cell research [7,8]. Nanotechnology involves scientific applications ranging from imaging to manipulating matter at the atomic or nanoscale (a nanometer (nm) equals one billionth of a meter (m) or 10^{-9} m) levels [9]. Developers and users of both technologies point to many beneficial uses ranging from overall improvement in public health to consumer products. Critics tend to focus on two areas. First, there are scientific uncertainties with these emerging technologies that have potential environmental or health consequences. Second, some members of the public may have moral and ethical issues surrounding technologies, such as using human embryos to harvest cells for stem cell research [1, 8]. Similar controversies plague mature technologies, such as nuclear technologies, where the public continues to be unfamiliar with the science.

Social scientists have investigated the factors that affect public knowledge of and responses to unfamiliar scientific and technological developments. Simply increasing public knowledge does not necessarily or uniformly lead to increased acceptance. Instead, the findings suggest that public acceptance of new technologies is a function of a complex mix of factors.

Knowledge of these factors can be useful to scientists who interact with the public. This paper presents a preliminary review of the literature concerning the impact of specific factors on public acceptance of technology in three substantive areas: biotechnology, nanotechnology, and nuclear technologies. The first section of the paper presents an overview of the literature, describing the theoretical frameworks and the specific factors that researchers have identified. The methods section describes the case study approach. The results are summarized and discussed. Finally, conclusions are offered relevant to those working in nuclear waste management.

LITERATURE REVIEW: THEORETICAL FRAMEWORKS AND OVERVIEW OF FACTORS AFFECTING PUBLIC RESPONSE

Theoretical Framework

What is known in the literature about controversies between scientists who use a particular technology, versus members of the general public who do not support or who question the use of such a technology? The traditional model of communicating scientific facts assumes a “top-down” approach where the scientific community provides new information to the public and the public is expected to learn this new information [10]. However, the literature on public understanding of science has developed a more nuanced perspective than this kind of one-way, “top-down” model presupposes.

Lewenstein [11] describes the origins and meaning of the term “public understanding of science” since the nineteenth century. He argues that early promoters of science to the general public wanted to build a “public appreciation for the benefits that science provides to society.” Lewenstein also provides a description of the plan created in 1958 by the National Science Foundation to initiate a program specifically entitled “Public Understanding of Science.” In addition, he highlights an earlier program started in 1947 by the Atomic Energy Commission, which was more focused on promoting a positive image of atomic energy to the general public. He makes an interesting observation of an inherent conflict between public relations and education where the goal of each agency – NSF and AEC – was not to provide public relations for itself as an organization but for the fields of science and atomic energy, respectively. A key goal of these early attempts at improving public understanding of science was to create a more receptive public. Lewenstein notes that, at this period of time, NSF was motivated by a “moral certainty in science” and an implicit belief that improved public understanding would result in increased support for science, science education, and research.

In another paper on public understanding of science [12], Bauer, Allum and Miller summarize the development of three paradigms. They describe these in chronological order as: science literacy, public understanding of science, and science and society. Each focuses on a different type of presumed deficit. For the science literacy paradigm, the solution to a perceived deficit in knowledge is sought in educating the public to bring their thinking more in line with that of scientists. This approach may, according to the authors, support a "technocratic" attitude where it is assumed the public is not initially qualified to participate in policy decisions. During the 1980s, researchers highlighted public attitudes towards science in situations where there was a fear that citizens were no longer supportive of science (conceptualized as a sort of attitude deficit). They describe two approaches during this period. One is a "normative-rationalist" approach that assumes that greater knowledge leads to a positive attitude toward science. The other is a "realist-empiricist" approach that recognizes the complex outcomes that result from a combination of values and emotion. The third paradigm, which they refer to as "science and society," highlights deficits in trust of information and of experts, which they characterize as involving a crisis of confidence in public perception of science. The present move toward "upstream" public engagement in considering issues of science policy belongs to this third paradigm.

In short, until fairly recently, many believed that, with respect to new technologies or unfamiliar science, simply educating the public appropriately about the underlying science would bring their thinking in line with that of the scientific community. Increasingly, however, empirical research has revealed that the responses of members of the public to an emerging or controversial technology are complex and can depend upon multiple factors [1]. As the studies described below show, prominent among these are scientific literacy, social values, trust in information source, expected benefits, framing of issues, and self efficacy or belief that the views of stakeholders matter.

Overview of Factors Potentially Affecting Public Response: Empirical Studies

Liu and Priest [1] examine attitudes toward stem cell research. In their paper, they identify and empirically test a variety of influences on attitudes toward the emerging technology of stem cell research. They also recognize the complex relationship that exists between knowledge within the scientific community and actual public response to science-related controversies, which has varied and complex origins. They argue that improving public knowledge may not bring public opinion closer to that of the scientific community because people may not rely upon scientific facts but instead use values or expectations to form an opinion. Drawing from the literature, they also cite a number of potential short cuts, sometimes referred to as heuristic cues, that publics use when making judgments on issues. These include "social ideology, mental schema, religious values, trust in particular spokespeople, intuitive affective reactions or media portrayals." In addition, they discuss media framing of issues as either positive (e.g. nanotechnology) or negative (e.g. stem cell research), which also appears to impact the formation of public attitudes. While reliance on such cues might sometimes appear to be less "rational" than reliance on strictly scientific considerations, all of us (including scientific experts) make use of social factors such as trust or credibility, which are often based on previous experience rather than "raw" intuition, when choosing sides on an issue.

Many scholars in the social sciences who are interested in perception and communication of risks focus on issues related to whether or not individuals from the general public trust information or the information source. Multiple studies provide evidence that the lack of trust in government agencies by members of the public is problematic for effective decision making, as are other social factors [13,14,15,16,17]. These factors are sometimes referred to as making up the "psychometric paradigm" that is associated with the work of Paul Slovic and his colleagues. Bradbury provides a critique of this paradigm, stressing the implicit confusion between perception and reality that is sometimes present [18].

Related to studies of trust and effective decision making are other papers that focus on efficacy. According to Barnett *et al.* public efficacy is "the extent to which people believe that the public might be able to affect the course of decision making [10]." Self efficacy, on the other hand, describes the extent to which a person believes he or she has control over the surrounding environment, while political efficacy describes the extent to which a person believes he or she can get an adequate response from his or her governing system [19].

The sometimes contentious debate between nuclear scientists and those who do not support projects to dispose of nuclear waste, has some similar dynamics as those that characterize emerging technologies more generally. With respect to scientific literacy -- in this case, information about nuclear energy and disposal, Greenberg and Truelove [20] report evidence that the source where they get their information predicts knowledge of nuclear-related information including disposal. However, in such studies, the directionality of causation is often unclear. Those characterized by some researchers, on the basis of underlying attitudes, as "scientific elitists" [21] may make different choices of information sources or have different levels of willingness to learn new scientific knowledge about an unfamiliar technology. Of course, they may also have different levels of education. Rather than information sources determining knowledge or attitudes, it may be knowledge or attitudes that determine information-seeking behavior.

Further evidence of a gap between scientific and popular views is a recent exchange between scholars from the social sciences and co-chairmen Hamilton and Scowcroft of the Blue Ribbon Commission [2,3,4]. The scholars argue that the general public will only support a project characterized by scientific uncertainties if there are large expected benefits (such as money and resources that will be available to individuals and communities), as well as trust in the process. The scholars state that neither of these conditions are met for high level nuclear waste disposal. Based on exchanges such as this one it is clear that there are multiple issues and perspectives on what will make present and future generations better off in the area of radioactive waste management (e.g., plans for disposal versus storage have very different implications for future generations). Finally, the recent budget uncertainties in efforts related to the disposal of high-level wastes are further evidence that politicians perceive they are receiving mandates from the general public to reject disposal sites that are within their particular jurisdictions, a possible manifestation of the so-called "NIMBY" ("not in my backyard") syndrome.

In summary, this brief review of the literature provides several theories and empirical results about the complex relationship between scientists who are familiar with a particular technology and those who do not support the technology. While there are some papers that compare social values and attitudes of biotechnology with nanotechnology using empirical results, there does not appear to be a comparison that includes nuclear waste disposal. Nevertheless, some of the existing literature on nuclear waste management suggests that similar dynamics may be at work and that a more systematic comparison may be useful.

METHOD

This paper compares public responses to biotechnology, nanotechnology and nuclear waste disposal technology with a case study method [22]. Based upon searches in econlit, google scholar, and sage journals online, the following criteria are identified which include evidence of a relationship between knowledge and attitudes toward a technology, evidence that trust matters, evidence that perceived benefits matter and evidence that social values matter. The case study method provides a way to provide opportunities for exploration of potential cross fertilization of research areas common in interdisciplinary research.

RESULTS AND DISCUSSION

Studies measuring public knowledge or awareness of these technologies provide consistent results that confusion persists [21,23]. With respect to public knowledge deficits, the empirical evidence [20] suggests that less than 10% of respondents understood that commercial spent fuel is stored at nuclear power plants. These results also indicate that the public does not understand the difference between storage and disposal which may have project budget implications. As for biotechnology and nanotechnology, some authors report evidence from surveys that general knowledge or familiarity with the technology is mixed [1] and others report that less than 5% of participants are familiar with nanotechnology [23].

Table 1 summarizes the comparison of technologies using four criteria from the social science literatures. The first comparison of technologies involves whether or not evidence exists that there is a positive relationship between knowledge and support for a technology. Surprisingly, the literature provides weak evidence for biotechnology and mixed evidence of this relationship for nuclear technologies. The only technology that provided strong support of this relationship is nanotechnology. It is important to note however that the majority of the studies cited for biotechnology and nuclear technology involved survey data while the one study for nanotechnology was based on a quasi-experimental design.

Table 1: Evaluating public response to alternative technologies using criteria from the social sciences

Criteria to evaluate public response to technology	Biotechnology (e.g. stem cell research)	Nanotechnology	Nuclear Technology
There is evidence that there is a positive relationship between knowledge and attitude for a technology.	Weak evidence [24,25]	Strong evidence [23]	Mixed evidence [26, 25, 27, 20]
There is evidence of a clear relationship between knowledge and trust.	Weak evidence [28, 24]	Evidence [29]	Weak evidence [28,27]
There is evidence that perceived benefits or advantages of technology matter for support of it.	Evidence [24]	Uncertain	Evidence [2,4]
There is evidence that social values matter for support of a technology.	Evidence [1]	Evidence [1]	Uncertain

The second comparison involves whether there is evidence that a relationship between knowledge and trust exists. With respect to biotechnology, authors report a statistically insignificant relationship between self assessed knowledge and trust in authorities [24]. Others report weak evidence that when individuals are unfamiliar with a technology that trust in managers and scientists using the technology weakly supports a positive attitude or support of the technology [25]. Again, there is weak evidence for nuclear technology with respect to knowledge and trust [30, 25, 31, 20]. Quasi-experimental evidence on nanotechnology showed that by improving information and knowledge overall lead to greater support for it. However, it is important to note that this finding was not unanimous, some individuals with more information about the risks had a more negative attitude toward nanotechnology.

The third comparison involves whether perceived benefits matter for public support. According to Rosa et al. [2,4] it does. They provide evidence from previous studies. However, the studies they refer to appear to also comingle benefits with trust issues. Knight [24] reports that benefits matter for public support of biotechnology as well but qualifies this result that moral obligations can outweigh perceived benefits. While the literature on nanotechnology does not appear to examine whether benefits matter directly, the evidence reported by Macoubrie showed that the majority of participants initially had a neutral attitude toward developments in nanotechnology [23]. With more information, both advantages and disadvantages of nanotechnology the majority of the respondents reported a more positive attitude which provides indirect support that benefits matter.

With respect to whether or not social values matter, researchers [21] report evidence from social surveys in the United States, Canada, and the European Union with respect to the opportunities of nanotechnology and biotechnology. They report evidence that the majority of respondents are optimistic about the prospects of each technology with differences for each country across groups with different social values. It does not appear that there are comparable analyses for nuclear technologies across similar social values. Instead the focus appears to be on the relationship between knowledge and attitude covered by our first comparison.

In addition to our comparisons we offer the following observations regarding trust, framing and efficacy. Gaskell *et al.* [21] identify the group labeled scientific elitists as the one with higher institutional trust than the other groups for both nanotechnology and biotechnology. Conversely they report findings that in some groups with low trust also had strong religious beliefs and lower education achievement. Other papers that focus on biotechnology include Barnett *et al.* [10], Liu and Priest [1], and Knight and Barnett [19] where they report evidence that higher levels of trust leads to positive attitudes towards the technologies. However they also report evidence that the relationship is more complex for different groups.

Identification of the issues or framing can impact reactions to new technologies as well. According to Liu and Priest [1] the media tends to frame nanotechnology in a positive manner as opposed to stem cell research that is framed as a “complex mixture of ethical and religious, scientific and medical arguments.” Framing issues may enable “rational” individuals to take short cut strategies when making judgments. Liu and Priest [1] report findings consistent with the literature on “multidimensional aspects of public attitudes toward emerging technologies.”

The concept of efficacy measures the extent efforts matter in decision making. In the area of genetic science, an area of biotechnology Barnett *et al.* [10] report counterintuitive results that do not support the notion that greater public involvement leads to greater trust and acceptability given different values. Knight and Barnett [19] report further evidence that the relationship between attitudes and type of efficacy matters in unexpected ways. Finally, while empirical evidence of efficacy in the area of nuclear waste technologies does not appear to be available, the response to Yucca Mountain provides strong evidence of efficacy by members of the public.

In comparing emerging technologies such as nanotechnology and biotechnology with nuclear waste disposal and identifying a few additional areas related to framing and efficacy the following issues arise. First, framing of issues as either positive or negative appears to have a big effect on whether an individual will have an optimistic or negative attitude toward an emerging technology. In the case of waste disposal, news stories often focus on risks of disposal to the community and reactions to the risks rather than the overall reduction in risks associated with waste disposal (as opposed to no action or where cleanup is required and existing waste remains stored on site). In either case, the issue is framed in a negative manner. However, this finding does not support superficial public relations campaigns either but requires substantive interaction with the public.

Second, different levels of efficacy for groups characterized by different values may lead to unexpected outcomes for managers wanting to complete a project. Specifically, greater participation in decision making and education levels does not automatically lead to higher trust of the decision making process or acceptance of an emerging technology. The relationship among these characteristics is complex and is contrary to the notion that public participation in decisions will always lead to greater support of nuclear projects. Instead, social values matter for learning about a new technology; if complex information appears to conflict with previous knowledge or values, it will probably be ignored or lead to unexpected outcomes counter to the rational model assumed by most decision makers.

Finally, values and attitudes toward emerging technology across society are not uniform but are heterogeneous. These heterogeneous values and attitudes toward emerging technologies may be complicated by potential short cuts made by individuals when forming an opinion. Given nuclear technology is older than biotechnology or nanotechnology, individual experience or family history may lead to even more pronounced differences in attitudes. While this last finding may concern those in public involvement, there are still strong arguments in favor of public participation. Absent public participation opportunities, trust may further erode and mutual misunderstanding foster. A number of ethical arguments exist that are consistent with the promotion of participatory democracy which in the long term rational decision making theory would predict greater levels of trust.

CONCLUSION

This paper explored public responses to emerging technology fields such as biotechnology and nanotechnology with nuclear waste disposal technology. The results of this case study provide evidence that the relationship between public involvement and trust for an emerging technology is not always positively correlated. Indeed given different values and expectations, a uniform approach to public involvement may lead to greater disagreement between the general public and the scientific community. Future efforts in management of waste disposal could involve alternative ways to engage multiple publics by assessing multiple deficits, attitudes, social values, family history, experience with the technology, and trust with recognition that public response can change and measure these changes using quantitative and qualitative research.

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