Title: How Post-Normal views of science have contributed to a model of communication about biotechnology.

Author: Bev France

PII:	S0016-3287(10)00232-6
DOI:	doi:10.1016/j.futures.2010.10.005
Reference:	JFTR 1569

To appear in:

Please cite this article as: B. France, How Post-Normal views of science have contributed to a model of communication about biotechnology., *Futures* (2010), doi:10.1016/j.futures.2010.10.005

How Post-Normal views of science have contributed to a model of communication about biotechnology.

Bev France*
Faculty of Education, The University of Auckland, Private Bag 92601, Symonds Street Auckland, New Zealand.

Abstract:

The political debate on genetic engineering in New Zealand during 2001-02 provided a focus for the development of a model for communication about biotechnology. Jerry Ravetz's challenge to develop a pedagogy to explore a Post Normal view of science was taken up by this author when she developed strategies for biology teachers to examine biotechnological processes and products from a Post Normal science viewpoint. This view of system uncertainties strongly influenced the inclusion of risk as an element that affected a person's 'view' of biotechnology within this communication model. Further development of this problem-solving spectrum of Post Normal science is possible if biotechnology is analysed from a technological epistemological perspective where a biotechnological outcome can be judged according to its fitness for purpose. If this occurs there are opportunities for biotechnology to be characterised as an example of Post Normal science from a scientific as well as an technological epistemology. Such analysis could provide opportunity for such an integrative perspective to be proposed and characterised.

*Telephone: + 64 9 623 8899 ext 48439
Fax: +64 9 623 8892
Email: b.france@auckland.ac.nz

1. Introduction

It was at an anti-GE rally in Auckland in 2001 that I realised that the science community I supported was very much in the minority. I was one of a group of about twenty science supporters facing a hostile crowd of over 10,000. Our motley group supported the Royal Commission's report that recommended a cautious approach to genetic engineering (GE) [1] and provided a focus on which the crowd could vent their anger. And they did. They were angry because they believed that the commissioners had not listened to them. We stood with our placards and faced a crowd of angry people shouting “SHAME!”. A man spat at me. Most of it missed. I was scared. At that point a policeman appeared and offered to escort us away. We marched away to the boos of the crowd.

This crowd believed that the Royal Commissioners' report did not reflect New Zealanders' views on genetic engineering, which is often referred to as genetic modification (GM). This demonstration was one of many held throughout New Zealand. The crowd's responses were reflected in newspaper headlines:

- *Clean Green & Angry* [2]
- *Beast is unleashed-but what now?* [3]
- *Rage against the Machine* [4]

The debate raged on and the crescendo was in June/July 2002 when a six-week election campaign was fought largely about genetic modification issues. During this time the 'debate' was fast and furious with disclosures of cover-ups, political intrigues and accusations of dirty politics. Finally, the Labour Party won enough seats to form a minority party. Since that time governments, both Labour and recently National, have cautiously inched their way through a 'case by case' policy on contained GM experimentation with controlled field trials being allowed under strict regulations.

During this time issues of public confidence in science and scientists were under discussion in the media. One explanation for this distrust was a perceived relationship between commercial interests and the funding of science. Dr Morgan Williams (Parliamentary Commissioner for the Environment) commented on a perception of science being overtly controlled by business ([1] p.64).

> "What we have found,… is that the New Zealand community is asking, how independent is our science voice today? … there's a widespread perception that the soul of science is, or has been, bought, and… the objectivity, rightly or wrongly that was bestowed upon science … is not as strong as it was…"

Scientists had also recognised that the public were less trusting of science than before. Dr Roger Wilkinson expressed his disquiet when presenting to the Commission ([1] p.64).

> "People don't trust genetic engineering… they also don't trust genetic engineers. Some groups described how scientists have let us down too many times… Biotechnology companies were described as being interested only in profits."

In an attempt to find out the cause of this mistrust of science and scientists, a research project was commissioned by the New Zealand Ministry of Research, Science and Technology (MoRST) who asked the public about their views of science and scientists. The findings suggested that a distrust of science might be caused from a lack of understanding how science is investigated, debated and resolved within the science community [5]. These researchers suggested that an understanding of the nature of science was an important as knowing about science concepts.

I was not convinced that such a deficit view of science understanding was the reason for this distrust. Even more importantly I had serious doubts if the public should be wooed to assume a scientific view. What was obvious was that the chasm between the public and scientists was wide and there was a need for dialogue. However such a gap needed more than just a conscientious effort (by those who thought they knew best) to improve understandings about science concepts and how science is practised.

At this time a view of unproblematic classroom science, where the 'scientific method' would provide proof and explanations that are removed from complex situations occurring in the real world, was beginning to show pedagogical cracks. In the early 1990s I was part of a group who were questioning this traditional view of science as we were exploring feminist writings about science. The group was called EQUALS=Science and we met monthly to consider ideas from Evelyn Fox Keller, Hilary Rose, Sandra Harding, Judy Wajcman to name a few. We were inspired to attend the GASAT 6 (Gender and Science and Technology) conference in Melbourne in 1991 and as a result of these 'journeys' began to realise that teaching the 'scientific method' was not the answer to providing a realistic experience of science. This mantra gave a false impression of the reality of the messiness and creativity of doing science.

Also we became aware that the science educational research literature was starting to question the relevance of how science was presented in schools. For example, science educators both in Australia [6] and England ([7- 8]) were questioning the relevance of teaching science to prospective producers of science rather than to those who would be future consumers [9].

But it was Jerry Ravetz's paper [10] that opened my eyes to the complexity of science as it is practised and applied in the real world. His challenge to science teachers to ask the 'what if?' questions of their students made me realise how strongly I had relied on the bulwark of traditional science where the paradigm of a 'one size fits all' scientific method eliminated any discussion of uncertainty other than expressions of error and probability.

Even before the eruption of the genetic modification debate my attempts to explore, explain and justify my seemingly diverse reactions to current biological issues seemed emotive and illogical. For example I could justify my opposition to the premature release of rabbit *Calicivirus* into the South Island high country in terms of a high probability that rabbits would become immune to the virus, yet I felt upset by the rejection of the Bioethics Council of xenotransplantation techniques. In the latter case I realised that I was emotionally involved in this issue of xenotransplantation as I had helped a close friend with diabetes present her case for a limited research programme to the Parliamentary Select Committee. In retrospect I now see that in both of these situations, ‘system uncertainties’ and the ‘decision stakes’ were high. It was after reading Jerry's paper that I could see how important it was to ask the 'what-if?' question when considering such issues [11].

In response to Jerry's call for a pedagogy based on Post Normal science I developed and presented a workshop for biology teachers to explore the potential of this approach [12]. The paper from Silvio Funtowicz and Jerry Ravetz [13] that explained and diagrammatically presented an alternative view of science problem-solving strategy where the quality of scientific information is analysed in terms of the uncertainty of knowledge and the conflicting values that could arise for different groups of people, provided me with a tool to examine some biological issues that were in the headlines.

For this workshop the interaction between knowledge and value components of scientific problems was represented by the intensity of uncertainty and decision stakes for each situation. Because these two dimensions of ‘decision stakes’ and ‘system uncertainties’ are displayed as three discrete intervals labelled applied science, professional consultancy and Post Normal science, I asked teachers to qualify their responses to the following issues and place them in the appropriate categories. These issues were in the context of In Vitro Fertilisation, xenotransplantation, DNA fingerprinting, cloning of Dolly the sheep and genetic engineering of food.

At the beginning of the exercise teachers were required to identify their own understanding of risk by rating their personal estimation of risk from most risky to least risky for actions such as driving a car, going skiing, tramping in the high country and being at work. After discussing this risk-rating exercise these teachers were asked to carry out a similar activity using biotechnological examples, and by identifying the needs, benefits and costs of such a procedures as xenotransplantation from the perspective of a producer and consumer. Teachers were quick to see the disparity between their personal response to risk and those that they considered from a dispassionate scientific perspective.

This exercise and these teachers' responses starting me thinking about how closely perceptions of risk are related to the development of trust. As Jerry commented, when there is a perception that science should provide a truthful explanation and uncertainty is introduced into the discussion, the public feels let down or at worst betrayed by science [14].

As identified early in this paper, trust of scientists was not high in New Zealand during this political debate on whether genetic engineering should be forever banned. Jerry makes the point that because scientists perceive uncertainty as an inherent component of the scientific process their expression of this dimension is at odds with the public's expectation of an acceptable level of safety [15]. As a consequence, although scientists understand that certainties in science have not been a part of the repertoire of the scientific community, this apparent deviation from the path of the certainty of 'truth' has led to a feeling of distrust by the public. He comments that what is perceived as being a

> "'withdrawal of trust' is actually a rational response by a public whose demands for safety, encouraged for decades as part of the programme of modernisation are apparently being frustrated and betrayed by the further developments of that same process " ([15] p.813).

Consequently, I started to understand why the public was mistrusting science and scientists. As Jerry commented when risk is expressed scientifically and social scientists estimate its harm there is an inevitable loss of confidence by the public and a perception by scientists that they are misunderstood [15]

2. How beliefs and attitudes are underpinned by perceptions of risk

The way the 'precautionary principle' was used by scientists and those in the so called opposite camp (typically the 'Greens') illustrated these groups' different perceptions of risk. For example 'Greenpeace New Zealand' invoked the 'precautionary principle' to call for a total ban on the release of genetically modified organisms for both field trials and commercial release. Scientists from Crown Research Institutes acknowledged that caution is an element of scientists' methodology when carrying out risk assessment "the purpose of normal risk methodology is to consider the unknowns and to try to quantify those unknowns as part of normal practice". They commented that such an analysis is part of normal practice and is not a cause for banning all future investigation ([1] p.67).

Jerry continued to maintain that these differing interpretations of the 'precautionary principle' demonstrated that each of these viewpoints was underpinned by their differing interpretations and ways of expressing risk [16]. In this situation the statistical view of risk that was valued and expressed by the scientific community contrasted with the Greenpeace community's view that such an expression of risk did not provide a realistic view of the dangers.

This difference in perception of risk between experts and the public was exemplified by scientist Peter Sandman reporting to the Royal Commission when he commented that the public viewed risk as being a combination of 'hazard' and 'outrage' where the hazard was the actual risk and outrage was the public's perception ([1] p. 73). Slovic [17] has identified expressions of outrage (for example, fear, unhappiness, dread, threat and control) and has labelled them as subjective determinants of risk. When these views of risk are used to explain the public's rejection of the Royal Commission's findings it is logical to assume that they would be more interested in the personal consequences of risk whereas scientific experts' opinions are more likely to be based on 'objective', statistical, actuarial data. Margolis comments that these rival rationalities could be expected to add to a communication gap between groups attempting to talk about these issues [18].

Instead of a reliance on quantitative measurement that provides evidence for an expression of uncertainty or a qualitative interpretation of a perceived risk, Wynne [19] suggests that the focus of the debate should be to define when and for what purpose each risk knowledge is legitimate. Consequently, if genetic engineering had been identified as an example of Post Normal science, then invoking the precautionary principle would have provided a mandate for increased public debate rather than a reason to shut down discussion. For example if those who were opposed to genetic engineering had viewed this practice from a Post Normal view rather than an academic view of science they may not have considered it as catastrophic for such system uncertainties to be high. As well as providing an opportunity for the layperson to consider such issues, the biotechnology community would have been required to take into account a range of system uncertainties that are not apparent in the tightly controlled conditions of the laboratory and field trial.

Without this Post Normal view of science both groups were forced into an adversarial position. In fact the group that were protesting against GE were reflecting their role as 'critical citizens' and this expression of their objections was a reminder to the scientific community that public consent for such issues cannot be taken for granted [16].

Development of the communication model

By this stage I became increasingly aware that the public's perception of risk was a very significant influence on how they perceived biotechnology.

At this point I asked my mentor John Gilbert help me identify the elements that might lead to a model of communication between scientists (in particular biotechnologists) and the public. We hoped to identify the components of a communication model that would provide opportunities for different communities to build bridges of communication.

Initially we decided to find out what biotechnologists thought were issues of concern. We asked five biotechnologists to write an article for the official biotechnology journal (*New Zealand Biotechnology Journal*) that would answer the following questions.

- In your field of interest what public concerns about biotechnology need attention by the biotechnology community?
- Are these issues being researched and what is the latest information?
- Are there alternative procedures and projects that need to be brought to the attention of those outside the biotechnological community?

During 2001 and 2002 contexts such as transgenic animals, embryonic stem cells and cloning, environmental impacts of genetically modified organisms, safety of genetically modified foods and issues of intellectual property protection were explored by these biotechnologists. Their articles were published and all have been reproduced in our book "A Model for Communication about Biotechnology" [20].

In each of the articles these biotechnologists made a case for dialogue with the public. For example Gilmour [21] was aware of the need for legislation to keep pace with scientific developments and wanted a continual cycle of evaluation and debate between the 'learned' and the 'lay'. Maddox [22] suggested that more attention be given to the review and modification of relevant intellectual patent laws. McIntyre [23] saw her role as a scientist and communicator "to eliminate the emotional responses of consumers to the perceptions of risk associated with genetically modified foods" (p.56). Glare and O'Callaghan [24] challenged the scientific community to develop field trial procedures that addressed the key issues of the environmental impacts of GMOs.

As expected these biotechnologists expressed the view that the benefits of GM had not been sold to the public. McIntyre [23] requested more research to address public concerns, careful labelling and the provision of GM free options. Similarly Blair [25] made an economic and humanitarian case for research on transgenic animals and, as well as identifying a list of potential benefits for humankind, he suggested that there needed to be an opportunity to discuss such apparent inconsistencies in the public acceptance of transgenic research.

These articles showed that although these scientists were open to discussing the biotechnological enterprise with members of the public they assumed that the public needed to be converted to their modes and ways of expressing their thinking. For example all of these scientists presented their arguments within a precisely defined context rather than outlining their ideas with a broad brush. Their writing style also set up barriers for they presented their argument inductively with a plethora of evidence, thus the argument sometimes was lost within the detail. And, most importantly, although they were careful to explain scientific concepts, there was an assumption that the reader would be familiar with specialist scientific language and be aware of the process of risk-benefit analysis. This assumption of a scientific understanding of risk was qualified with an inherent sub-text, that they were aware that they could not assume that the public agreed with them and a dialogue needed to take place ([20] p.19-21).

In summary, this inquiry of biotechnologists' opinions showed that they assumed that there was common understanding of risk. Furthermore there was an expectation that the public would need to develop their science understandings and as soon as these gaps in the public's education were remedied dialogue would be possible.

Rather than subscribe to this deficit view of the public, John Gilbert and I were aware that building a model than enabled communication would not be a simple matter of ensuring that biotechnologists would be answering the public's questions in a way that ensured their understanding.

We were aware that our initial research had provided information from a 'communicating' group of biotechnologists who: appeared to share a broadly agreed set of common goals, were able to access information and utilised a scientific genre for expressing their ideas through a vocabulary of specialist words that was underpinned by a common conceptual understanding [26]. At this stage the public had not been characterised and we did not want to describe them in terms of knowledge deficiency that would involve the dichotomy of laypeople versus experts [27]), but as a group that uses as its criteria the identification of a common social commitment that engages in some form of voluntary purposeful participation [28].

3. Description of the communication model

We proposed that any communicating group has a view of biotechnology that is made up of the following elements: understandings of the nature of science and biotechnology, understandings of the key concepts and models used in this process, perceptions of the nature of risk and beliefs and attitudes about biotechnology. These have been described in more detail in other sources ([20] [29]) and it is important to note this list of elements have been identified from a literature search as well as the analysis of these biotechnologists' responses. Although the model has not been formally tested we did test the relevance of these elements by analysing a published debate between scientists involved in genetic modification research and genetic modification interest groups [30]. This data provided us with information that these elements were present in this conversation and that it was possible to identify the cognitive status of the participants.

[Insert figure 1 about here]

Figure 1. Elements affecting a person's 'view' of biotechnology

The model is based on the premise that a dialogue between two groups can only occur under specific circumstances, i.e. when there is a 'space' that allows the participants to ask questions of each other and develop some common understandings. This term was developed from the concept of 'problem space' used by Stankiewicz [31].

We postulated that there is a 'search space' which is the intersection in a virtual area of the components of the views of two communities. It is in this search space where people are able to struggle to come to an agreed understanding in spite of their differences in beliefs, attitudes and behaviour. Where there are elements of the views that are common between the two communities communication may be possible, however where there is no commonality there arises a search space where a degree of understanding will need to be developed. When there is sufficient commonality of understandings there will be an opportunity for communication.

Consequently, rather than an aim to convert one group to another's view there needs to be an opportunity for each group in the discourse to explore other people's viewpoints. As Bazerman [32} explains, the act of meaning making is an attempt to enter this search space.

> ".. in desiring to communicate with another, we orient towards each other's discursive universes and figure out what kind of utterance will both be intelligible and successful in accomplishing our ends" ([32] p.347).

The following diagrammatic representation of this search space should not indicate that the arrows are pointing to the heart of the model at 'key concepts and models of biotechnology' because it may be that the participating groups may not wish to find out such commonalities and may be more concerned with how the process will ensure safety. For example when a group of New Zealanders were asked about genetic modification and how this technology could affect their country's 'clean green image' it was pertinent that they did not want to know about the scientific details but were interested on the social, health and environmental impacts on themselves and their country both now and in the future [33]. In other words they were interested in having a conversation about risk.

[insert figure 2 about here]

Figure 2. A model of communication about biotechnology.

4. Consideration of the model from a Post-Normal perspective

Our scientists' responses as well as our literature searches have demonstrated that scientific activity around biotechnology is not confined to academic research in the laboratory. As Jerry has observed biotechnology with its industrial processes of research and development and innovation is part of many scientists' worlds [19].

So what influence did this identification of Post Normal science have on the development of this model of communication? Jerry Ravetz [14] maintains that the heart of the risk debate is the need for citizens to assert democratic control over the process where knowledge provides not only the power to effect species change but also can influence outcomes that have the potential to affect human populations and their environments today and in the future. He argued that such a merging of knowledge with power could have unforseen consequences, and issues involved with this merging need attention by everyone concerned.

Certainly genetic engineering in New Zealand was an example of the transformation of science from its 'academic phase to industrialisation' [14] and the genetic modification debate provided a pertinent and political focus when exploring this new way of looking at science. This debate demonstrated to me that science is not practised in a vacuum, and that the scientific process does not guarantee that scientists can provide answers with a degree of certainty that the public desires. This debate exposed many issues of uncertainty as well as an awareness that the stakes are high for all.

Because we believe that a search space can only occur when some commonality is achieved between the parties involved in communication and that the issue of risk and its expression in each person's beliefs and attitude to biotechnology will make an immediate impact on their ability to bridge those gaps, we have placed the risk element close to the surface of our model as it will have an immediate affect on one's 'view' of biotechnology. It was significant in the genetic modification debate facts appeared uncertain, values were certainly in dispute, decisions needed to be made urgently, and the stakes were high when many New Zealanders saw their vision of a 'clean, green' New Zealand being compromised by the threat of genetic engineering.

5. Suggestions for developing the Post Normal spectrum

Perhaps there can be another way of viewing the interaction of biotechnology and society. Rather than using a scientific lens to examine these interactions of academic science, applied science, professional consultancy and Post Normal Science [13], I propose that because biotechnology provides an example of an industrialised science it can sit more easily within a technological epistemology. When ‘fitness for purpose’ is the criteria for a successful technological solution then it is indefensible to develop a solution that is unacceptable to the public [34}.

When GE is given this technological persona then this antagonistic public reaction to its industrialisation is understandable. Gradwell [35] describes three stages occurring when a 'new' technology is introduced into a society. First there is the 'eureka stage' where there is interest and excitement over a new process; he calls a second stage the 'spaghetti' stage where the technology and its applications are modified by producers and consumers to make it more acceptable to the public, and finally the 'black box' stage is the third stage where the technology is adopted, culturally accepted and has become socially invisible' (ibid, p.256).

If one uses a technological lens then I believe that genetic engineering is at the 'spaghetti stage' and only now the biotechnology community is realising that they must make sure that this technology and its outcomes are acceptable to the public. If one examines such biotechnological processes and projects with a technological lens then there is an epistemological assumption that any technological product or process will be judged on its fitness for purpose rather than its part in the progress towards a 'truthful' explanation. Part of the process of verification of such fitness for purpose is an upfront critique by the consumer. Because it is recognised that there are always unknowns and unintended consequences when a technological outcome is realised, and that the response to this outcome will be influenced by different values across people, places and time, there is a much stronger normative element in such an evaluation than would be anticipated in science ([36]

Even before decisions are made to develop a new technological product or process, decisions about its acceptability are made during the functional modelling phase of the development where the level of impact is calculated before it leaves the designer's bench. Expressing this process in Post Normal terms, an examination of the system uncertainties and decision stakes must be examined during the early stages of its design. At this stage a technologist must be prepared to predict not just whether it will work mechanistically, but its functionality is assessed in terms of its social, cultural and political acceptance.

Of course many biotechnological products and processes do not appear to have gone through this rigorous process, but with the threat of litigation and the potential for outright rejection of many genetic modification products and processes, many companies realise the necessity for this analysis.

I assert that Gallopin et al's [37] suggestion that an analytical research approach to science should be replaced with a more integrative scientific practice mirrors how biotechnology education is perceived in New Zealand. They observe that environmental science comes closest to a practice of Post Normal science research where knowledge of a system will always be incomplete, surprise is inevitable and the system itself is a moving target because of human influences [37] . This research approach that focuses on the connectedness and the dominance of context rather than the development of a decontextualised explanation is much more aligned to a technological view of knowledge development as it is taught within the New Zealand curriculum [38].

Consequently I believe that systems research as practised within environmental research is far more closely aligned to the technological process and as such provides an opportunity for students to see the world where such integration must occur in order for a technological outcome to be considered 'fit for purpose'.

Such a message of integration is a challenge that Bindé [39] issues to educationalists. He asks educational institutions to provide the facility to not only offer up-to-date scientific knowledge but also embed this knowledge system within the historical and social information that will enhance informed multidimensional citizenship (local, regional, national and global).

I propose that there is a potential for developing a deeper understanding of biotechnology and in particular genetic engineering if it was examined from a Post Normal science perspective in conjunction with the technological criteria of 'fitness for purpose'. This integration of science and technology would allow a deeper discussion of what Post Normal can mean for practitioners and the community who are consumers of this 21st Century Post Normal science and technological societies.

References

[1] T. Eichelbaum, J. Allan, J. Fleming, R. Randerson, Report of the Royal Commission on Genetic Modification. Report and Recommendations (vols 1 and 2), Royal Commission on Genetic Modification, Wellington, NZ, 2001. Available at http://www.gm.commission.govt.nz/

[2] Headline from the NZ Herald, published on 19th August, 2001, p. A1.

[3] Headline of a report by Geoff Chapple and Robyn McLean published in Sunday Star Times, September 2, 2001, p. A2.

[4] Headline of an article by B. Zander, published in the Listener, a weekly news magazine on 22nd September, 2001, pp. 28-32.

[5] R. Hipkins, W. Stockwell, R. Bolstad, R. Baker, Commonsense, trust and science: how patterns of beliefs and attitudes to science pose challenges for effective communication. Report to the Ministry of Research, Science and Technology, New Zealand Council for Educational Research and ACNielsen, Wellington, NZ, 2002.

[6] P. Fensham, Science for all: a reflective essay, Journal of Curriculum Studies 17 (1985) 415-435.

[7] D. Layton, Science education and praxis: the relationship of school science to practical action, Studies in Science Education 19 (1991) 43-79.

[8] E. W. Jenkins, School science education: towards a reconstruction, Journal of Curriculum Studies 24 (1992) 229-246.

[9] R. Millar, Twenty First Century Science: insights from the design and implementation of a scientific literacy approach in school science, International Journal of Science Education 28 (3) (2006) 1499-1521.

[10] J. R. Ravetz, Simple scientific truths and uncertain policy realities: implications for science education, Studies in Science Education 30 (1997) 5-18.

[11] J. R. Ravetz, The science of 'what -if?' , Futures 29 (6) (1997) 533-539.

[12] B. France, J. Ravetz, Asking the 'what if?' question. Exploring biotechnological issues from a post-normal science stance. Working paper and workshop delivered at Biolive'99, September 27-29, Waipuna Lodge, Auckland, New Zealand, 1999.

[13] S. O. Funtowicz, J. R. Ravetz, Uncertainty, complexity and Post Normal science, Environmental Toxicology and Chemistry 13 (12) (1994) 1881-1885.

[14] J. R. Ravetz, The merger of knowledge with power. Essays in critical science, Mansell, London, 1990.

[15] J. R. Ravetz, A paradoxical future for safety in the global knowledge economy, Futures 35 (2003) 811-826.

[16] J. R. Ravetz, The post-normal science of precaution, Futures 36 (2004) 347-357.

[17] P. Slovic, Perception of risk, Science 236 (1987) 280-285.

[18] H. Margolis, Dealing with risk: why the public and experts disagree on environmental issues, University of Chicago Press, Chicago, Ill,1996.

[19] B. Wynne, Risk and social learning: reification to engagement, in: D. Golding (Ed.), Social theories of risk, Praeger, Westport, Ct, 1992, pp. 275-297.

[20] B. France, J.K. Gilbert, A model for communication about biotechnology, Sense Publishers, Rotterdam, 2006.

[21] R. S. Gilmour, Embryonic stem cells and human therapeutic and reproductive cloning. New Zealand Biotechnology Association Journal 50 (2001) 49-60 reproduced in: B. France, J. K. Gilbert, A model for communication about biotechnology, Sense Publishers, Rotterdam, 2006, pp. 69-77.

[22] I. S. Maddox, Intellectual property protection: relationship to public perceptions of biotechnology, New Zealand Biotechnology Association Newsletter 49 (2001) 43-47 reproduced in: B. France, J.K. Gilbert, A model for communication about biotechnology, Sense Publishers, Rotterdam, 2006, pp. 97-100.

[23] L. McIntyre, The safety of genetically modified foods. New Zealand Biotechnology Association Journal 52 (2002) 50-58 reproduced in: B. France, J. K. Gilbert, A model for communication about biotechnology, Sense Publishers, Rotterdam, 2006, pp.89-95.

[24] T. Glare, M. O'Callaghan, Environmental impacts of genetically modified organisms. New Zealand Biotechnology Association Journal 50 (2001) 38-48 reproduced in: B.

France, J. K. Gilbert, A model for communication about biotechnology, Sense Publishers, Rotterdam, 2006, pp.79-87.

[25] H. Blair, Public concerns about…Transgenic animals. New Zealand Biotechnology Association Journal 50 (2001) 61-68 reproduced in: B. France, J. K. Gilbert, A model for communication about biotechnology, Sense Publishers, Rotterdam, 2006, pp.63-68.

[26] J. M. Swales, Genre analysis, Cambridge University Press, Cambridge,1990.

[27] J. M. Guttleling, Biotechnology in the Netherlands: controversy or consensus? Public Understanding of Science 11 (2002) 131-142.

[28] Select Committee, Science and society: third report of the select committee on science and society, House of Lords, London, 2000.

[29] J. K. Gilbert, B. France, A model for communication about biotechnology, in: M. Hammann, M. Reiss, C. Boulter, S. D. Tunniculiffe (Eds.), Biology in context: Learning and teaching for the 21st Century. a selection of papers presented at the VIth Conference of European Researchers in Didactics of Biology (ERIDOB), Institute of Education, University of London, London, 2008, pp.139-148.

[30] K. Cronin, L. Jackson, Hands across the Water. Developing Dialogue between Stakeholders in the New Zealand Biotechnology Debate, Victoria University of Wellington, Wellington, New Zealand, 2004.

[31] R. Stankiewicz, The concept of “design space” in: J. Ziman (Ed.), Technological innovation as an evolutionary process, Cambridge University Press, Cambridge, 2000, pp.234-247.

[32] C. Bazerman, The languages of Edison's light, MIT Press, Cambridge, MA, 1999.

[33] L. Hunt, J. Fairweather, F Coyle, Public understandings of biotechnology in New Zealand: Factors affecting acceptability rankings of five selected biotechnologies, Research report No. 266, December 2003, Agribusiness and Economics Research Unit (AERU), Lincoln University, Christchurch, NZ, 2003. Available at www.lincoln.ac.nz/AERU/

[34] B. France, Location, location location: positioning biotechnology education for the 21st century. Studies in Science Education 24 (2007) 88-122.

[35] J. B. Gradwell, The immensity of technology… and the role of the individual, International Journal of Technology and Design Education 9 (1999) 241-267.

[36] V. J. Compton, B. France, Redefining technological literacy in New Zealand: from concepts to curriculum constructs, in: J. R. Dakers, W. J. Dow, M.J. de Vries (Eds), Proceedings of the Pupils' Attitudes Towards Technology (PATT) international design and technology education conference: Teaching and learning technological literacy in the classroom, University of Glasgow, Glasgow, 2007, pp. 259-272.

[37] G. C. Gallopín, S. Funtowicz, M. O'Connor, J. Ravetz, Science for the twenty-first century: from social contract to the scientific core, UNESCO 2001, 2001, 219-229.

[38] Ministry of Education, The New Zealand Curriculum, Learning Media, Wellington, New Zealand, 2007.

[39] J. Bindé, What education for the twenty-first century? Prospects vol XXXII 4 (2001) 391-403.

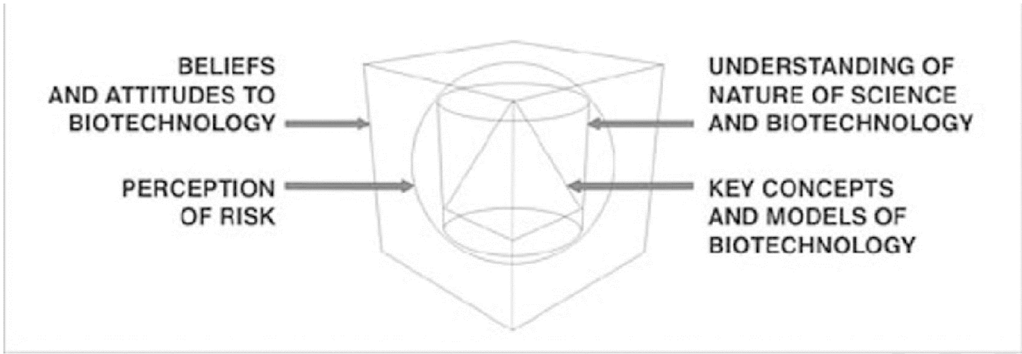

Figure 1. Elements affecting a person's 'view' of biotechnology

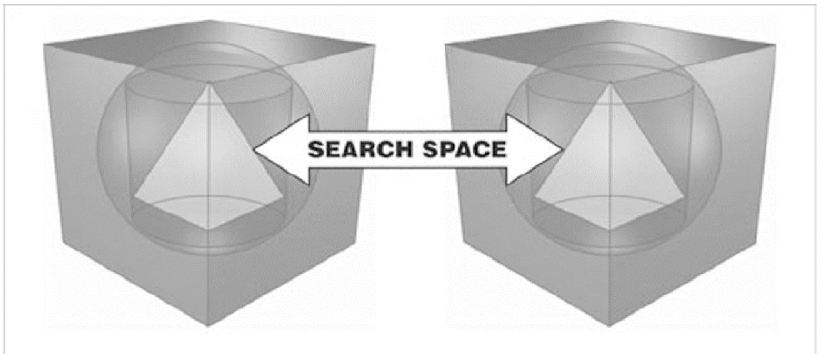

Figure 2. A model of communication about biotechnology.