Assessing attitudes and cognitive styles of stakeholders in environmental projects involving computer modelling

Fabio Boschetti[1,3], Claire Richert[4], Iain Walker[2], Jennifer Price[2] and Leo Dutra[1]

[1] CSIRO Marine and Atmospheric Research, Australia
[2] CSIRO Social and Economic Sciences Program, Australia
[3] School of Earth and Geographical Sciences, The University of Western Australia
[4]AgroParisTech, France

Abstract

For modellers, stakeholder acceptance of a model usually hinges on data accuracy, model reliability, and problem uncertainty. For social scientists, model acceptance by stakeholders also depends on model context, type of problem, implications of the model, characteristics of the audience and stakeholders, the charisma and reputation of the modeller, and much else. In this paper, we review some tools from the cognitive and social psychology literature employed to study cognitive styles, worldviews and political ideology. From them, we select items which are relevant to assessing these features in stakeholders of environmental projects involving the use of computer modelling. By adding other items specifically designed to gauge attitudes towards complexity, science and computer modelling itself, we propose a questionnaire a modeller could employ early in a project in order to understand the type of audience the modelling results will have to be communicated to. This can help better design the communication and engagement process. We test the questionnaire with a representative sample of the Australian population and with a stakeholder team involved in the management of a regional fishery. The results point to the importance of considering worldviews and cognitive variables such as open-mindedness and trust in science and modelling.

Keywords: Communication of model results; worldviews; stakeholder engagement; decision making; attitudes; cognitive styles.

1 Introduction

Stakeholder involvement early in research projects that require the use of models and simulation tools is thought to be critical to ensure that scientific results, including those arising from computer modelling, are accepted, trusted, understood and thus acted upon (Bramwell et al., 1999a; Bramwell et al., 1999b; Lee, 1999; D'Aquino et al., 2003; van den Belt, 2004; Aas et al., 2005; Dray et al., 2006; Lomas, 2007). This message seems to be confirmed by specific field studies, by the growing body of literature in the areas of Adaptive Management and Management Strategy Evaluation (MSE), as well as by the general observation that model results are more readily included into policy making when stakeholders have been familiarised with the use of computer modelling (Forrester, 1994).

Nevertheless, the assumption that stakeholder involvement is a necessary and sufficient condition to successfully communicating modelling results should not be left unquestioned. Computer modelling is at the core of much economics policy at government, transnational and corporate levels, affecting the lives of billions; still, we do not expect taxation officers, say, to give presentations of economic modelling results in local community halls before the resulting policies are adopted. At the opposite extreme, extensively communicated modelling results related to climate change are not accepted by a sizeable portion of the population despite the models being supported by the scientific community at large and widely discussed in non-specialised media.

Acceptance of scientific and modelling results thus appears to be highly contextual, depending on the type of problem addressed, the social, political and economic implication of the message, the type of audience and the charisma and reputation of the messenger, among other factors. While this is well known to social scientists, modellers are often ill-prepared to address this problem: for a modeller, acceptance of model results is usually discussed in terms of data accuracy, model reliability and problem uncertainty, not in terms of the messenger or the audience. This document summarises the effort of modellers with expertise in the natural sciences in familiarising themselves with issues related to the communication and acceptance of model results. It reviews ideas taken from cognitive and social psychology and, to a lesser extent, from the philosophy of science. Because of the number of fields and the width of the issues addressed the review is obviously not exhaustive; it specifically focuses on developing a questionnaire that a modeller could employ early in a modelling project in order to assess the type of audience the model results will have to be communicated to, which can help design better communication and engagement processes.

2 Beliefs, cognitive styles, stances, worldviews, attitudes and ideologies

We all know some ‘facts’. According to philosophers, knowing means believing that these facts are true. A crucial question is *how* we come to such belief. This has been a topic of philosophical inquiry since antiquity and is at the core both of how we interact with our environment on a daily basis and of how we acquire formal, scientific knowledge. It is important to state that the generation of knowledge also involves social factors, thus going beyond the process of collecting measurable evidence, analysing it and theorising about how the world works. This applies to scientists themselves as well as to the public (Latour et al., 1986). This document addresses specifically the cognitive and social aspects of this process.

Work in cognitive psychology suggests that when we have to make a choice two decision-making modes are available to us. One is unconscious, it has little cognitive load, is very quick and performs best when prompt action is required. It may be based on learnt heuristics (Sorriaux et al., 1968) or on ‘easy-to-evaluate’ emotional attributes, such as ‘goodness’ or ‘badness’ (Hsee et al., 2003; Wilson et al., 2006). It has a likely evolutionary origin since it is essential for survival, but is known to lead to non-optimal decisions and to logical fallacies (Sorriaux et al., 1968; Tversky et al., 1974; Tversky et al., 1983); in the rest of the document we call this decision-making mode as *instinctive*. The second mode is conscious and involves our rational apparatus; it has higher cognitive load, it is slower and works best when time for deliberation is available because it needs extensive analysis and contextual knowledge to specify whether attributes are relevant or not; in the rest of the document we refer to this decision-making mode as *deliberative*. Some examples of instinctive and deliberative decision-making styles are discussed in Section 0 in the description of the Thinking Dispositions and system dynamics questions. Our distinction between instinctive and deliberative modes resembles Kahneman’s (Rippl, 2002) recent distinction between system 1 and system 2 thinking. It is important to note that the modes are not mutually exclusive as they work in parallel. However, it is common to have one dominating the other (Wilson et al., 2006).

People display different cognitive styles, which are individual differences in how we process, store and structure information. They affect the mental models we use to represent our understanding about how the world works. Consequently, they have a direct influence on how we form beliefs (how we decide what facts are true) and how we use such beliefs to make choices. Cognitive styles affect decision making via several mechanisms, which we summarise as follows:

1. How both decision-making modes interact (instinctive vs deliberative) and which one prevails in different situations.

2. Once we decide to use a deliberative decision-making mode, how much effort we are willing to dedicate to the task and how much complexity we are willing to handle.

3. Once some problem understanding is reached, how willing we are to re-evaluate it and possibly to modify it when new information is available.

4. How comfortable we are at dealing with and accepting uncertainty in both our knowledge and information received.

These points are obviously relevant to the communication of any scientific work, including numerical modelling, because they relate directly to how much information the stakeholders wish to receive, how they receive it, how much effort they dedicate to understanding its details, how willing they are to change their attitudes and opinion in the light of model results and how comfortable they are to account for scientific uncertainty in their decision making. They also relate to the balance or tension between the *deliberative* and *instinctive* mode which is employed in communicating and interpreting model results. For example, providing statistical summaries about problems that are ethical in nature (e.g. effects of climate change, genocide) may fail to trigger the emotional reaction needed to generate an action (Small et al., 2006; Slovic, 2007).

There is a vast literature on these topics, under several key words, including: ‘Need for Closure’, ‘Personal Need for Structure’, ‘Need for Cognition’, ‘Uncertainty Orientation’, ‘Open-minded Thinking’, ‘Latitude of Acceptance’, just to name a few. Of particular interest for our discussion are the interrelations between these concepts, which we analyse below.

A good starting point of this discussion is the criteria used to decide whether, given a problem, the instinctive or the deliberative problem-solving mode should be employed. Much research on this topic originates from the observation that people often do not follow simple logical inference rules in their decision making, committing what are defined as ‘logical fallacies’ (Tversky et al., 1974; Tversky et al., 1983). This observation led to a considerable discussion on whether such fallacies should be interpreted as a) ‘real’ logical mistakes, b) ‘simple’ errors due to lack of effort or attention, c) misunderstanding of the required task, d) application of a decision making process which, while effective in most real life situations, is unsuitable to the specific task or even e) the experimenter’s misconception of what the correct answer to the proposed task should actually be (Sorriaux et al., 1968). Considerable experimental work led Stanovich and colleagues (Stanovich et al., 1998) to notice that one class of behaviour (defined as ‘Thinking Dispositions’) was as predictive as tradition intelligence (IQ in the rest of the document) at explaining different performances on these tasks. Inspiration for this work originated in the search for mental faculties which, unlike IQ, could be improved with short-term practise (Baron, 1985).

These Thinking Dispositions relate to the adequacy of the cognitive style used to address a specific task. They are often associated with the idea of intellectual curiosity and adventurous thinking style and include a) the disposition to weigh new evidence against a previously held belief, b) the disposition to spend effort and time on a task, c) the will to consider alternative opinions and evidence and switch perspectives if justified, d) the will to de-contextualise, e) a disposition for reflectiveness vs impulsivity and f) the active search for information that disconfirms one's belief thereby resisting confirmation bias (Baron, 1985; Kruglanski et al., 1996; Stanovich et al., 1998).

A related concept is that of ‘Need for Cognition’ (Cacioppo et al., 1982) described either as "a need to structure relevant situations in meaningful, integrated ways", “a need to understand and make reasonable the experiential world" (Cohen et al., 1955) or more intuitively as enjoying thinking, a "quest for reality" (Murphy, 1947), a "need to understand" (Katz, 1960). Need for Cognition correlates with ‘positive’ Thinking Dispositions, IQ and a preference for complex vs simple cognitive task (Cacioppo et al., 1982).

Two pieces of evidence related to the concept of ‘Need for Cognition’ are relevant to modellers. First, Cohen (Cohen, 1957) noticed that the order in which the description of a problem and its possible solution are presented affects attitude change differently in people possessing a high vs low ‘Need for Cognition’. The latter, being probably less motivated to think about the communication, are more likely to be engaged by explicitly detailing the problem first. Second, individuals with low vs high ‘Need for Cognition’ are more likely to focus on the deliverer (speed of speech or assumed expertise, for example) rather than on the content of a message. Of course, this issue is also affected by the affective importance of the message conveyed and the receiver’s personal commitment to the specific issue.

While Thinking Dispositions and Need for Cognition address the willingness and even enjoyment in undertaking conscious mental deliberation, two related concepts, Need for Closure (Kruglanski et al., 1993) and Personal Need for Structure (Thompson et al., 1989; Thompson et al., 1992; Neuberg et al., 1993) address preferences for specific ways to organise beliefs.

Given that we interact with an overwhelming complex reality, we need to structure our understanding of the world into manageable mental representations. The Personal Need for Structure refers to preference for complex vs simpler mental models. Like the *instinctive* decision-making mode mentioned above, simple mental models allow for less effort in processing novel information by allowing us to make a choice without having to understand each individual event in its particulars. However, unlike the *instinctive* decision-making mode, these mental models are conscious and are processed rationally.

Evidence from the Personal Need for Structure literature suggests that people differ in the extent to which they prefer to deal with events and choices in a simple, unambiguous way (Thompson et al., 1989; Thompson et al., 1992). A person high in Personal Need for Structure is likely to prefer well-bounded, relatively distinct categories to interpret new events. As it is reasonable to expect, this attitude correlates negatively with Need for Cognition and IQ; however such correlations are weak, which suggests that it relates to somewhat independent cognitive processes.

Personal Need for Structure also has direct relevance to the presentation of scientific and modelling results to stakeholders. Stakeholders with high Personal Need for Structure are likely to seek clarity and simple explanations and use simple inferential heuristics (Moskowitz, 1993) while feeling discomfort with ambiguous or uncertain situations (Thompson et al., 1992). These individuals are also likely to be particularly receptive to information which employs or reinforces currently accepted interpretations rather than questioning their validity, since discarding an existing mental model results in the uncomfortable challenge of either accepting a new, possibly more complex, one or facing uncertainty and ambiguity (Neuberg et al., 1993).

A closely related concept is the Need for Closure, which has been studied mainly in relation to resistance or openness to persuasion (Kruglanski et al., 1993). It is defined as "the desire for a definite answer on some topic, any answer as opposed to confusion and ambiguity" (Kruglanski, 1989). When presented with a piece of novel information, different levels of Need for Closure may elicit different responses depending on how much *a priori* information is available. In general (Kruglanski et al., 1991), people high in Need for Closure display less need for further information when their initial confidence in a hypothesis is high and more need when their initial confidence is low. When an accepted mental model is available, a stakeholder with high Need for Closure may be unwilling to re-evaluate his/her position (Kunda, 1990; Kruglanski et al., 1991; Kruglanski et al., 1993; Kruglanski et al., 1996), but, when an accepted model is not available, such stakeholder may be particularly willing to adopt the proposed mental model, since this provides the highly desired closure.

From the above description one may be led to think that the stereotype of the scientist, as one who seeks evidence, considers multiple explanations, challenges common beliefs and accepts peer criticism, summarises many of the ‘positive’ features of Thinking Attitudes, Open mindedness, Uncertainty Orientation and Need for Cognition. One may also be led to think that such a stereotype summarises a fairly uniform set of beliefs and dispositions. Nevertheless, the philosophical literature also discusses the difference in cognitive styles which scientists and philosophers use to form beliefs and refers to them as ‘stance’ (Baumann, 2011; Chakravartty, 2011; Ladyman, 2011; Rowbottom et al., 2011; Steup, 2011; van Fraassen, 2011). Stances are attitudes towards scientific and philosophical enquiry which represent the different approaches scientists and philosophers choose to adopt in their work. They represent the difference between, say, an empiricist who values measurements and experimental work vs a theoretician who cherishes form, simplicity and elegance. Scientists and philosophers can also differ depending on whether they believe all stances have an equal intrinsic value or whether such value should be determined by their success at meeting specific scientific objectives. A careful reading of such literature suggests that probably the most important difference between ‘stances’ in the philosophical literature and ‘cognitive styles’ in the cognitive psychology literature lies in the strict requirement for the stances to display the internal logical consistency which is usually associated with rigorous scholarly work.

The concepts we discussed so far focus on the individual. Social psychology has studied similar phenomena as they relate to the interaction between individuals and their social environment. The fundamental concepts in this approach are the ones of worldviews and ‘attitudes’[1]. Worldviews describe our understanding, at times unconscious, of how the world around us functions and our place within it.

In this article, we will consider worldviews as defined in the Cultural Theory perspective. First developed in the field of cultural anthropology by Mary Douglas (Douglas, 1966; Douglas, 1970; Douglas, 1985) this perspective has been extended by Aaron Wildavsky, Michael Thompson and colleagues (Douglas, 1982; Thompson et al., 1990) and applied in psychology as a means of identifying typologies in risk perception (Dake, 1991; Dake, 1992; Steg et al., 2000a; Lima et al., 2006).The theory describes risk perceptions as being socially constructed and linked to the shared values and beliefs within cultural groups. The social structures of different groups are reinforced by blame for danger being attributed to institutions thought to violate the socially accepted standards of the group (Douglas, 1970). This may explain why people perceive dangers differently and why they focus on particular threats at the expense of others. Selective attention to specific risks is therefore thought to represent cultural biases, or patterns of values and beliefs used to justify behaviour – known as worldviews (Wildavsky, 1987).

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[1] For an interesting summary of the history of the concept of attitude see Fleming, D.M., 1967. Attitude: The history of a concept. Perspectives in American History, I: 287-365.

The grid-group framework (Figure 1) of cultural theory delineates these ways of life along two dimensions (Douglas, 1970; Douglas, 1982). The grid dimension describes the extent of social prescriptions thought to constrain individual behaviour, and can be thought of as the degree of social regulation and role definition within a culture (Wildavsky, 1987). The group dimension describes the strength of group boundaries and ties among group members, and can be thought of as the emphasis placed within a culture on the needs of the collective compared to the needs of individuals. Wildavsky (Wildavsky, 1987) suggests that a hierarchical worldview is formed in strong groups with clearly defined social roles and constraints on behaviour, which justifies institutionalised authority and inequality. He goes on to describe strong groups with few constraints on behaviour as forming an egalitarian worldview that emphasises equality and voluntary consent. Groups with few behavioural constraints and weak boundaries and ties are thought to form an individualistic worldview which emphasises competition and self-regulation. Finally, groups with weak boundaries and ties combined with constrained behaviour may form a fatalistic worldview where people feel controlled and apathetic.

The grid-group framework describes four different belief systems regarding the nature of human behaviour, identifying who is responsible for unwanted events and policy solutions for managing risk. These beliefs are specific types of rationality which are neither right nor wrong, but are unprovable and involve biased processing of information. The four ways of life described above also entail a set of beliefs about the natural environment, and humans' relationship to it– known as 'myths of nature' (Grendstad et al., 2000). These general beliefs "are plausible, rather than demonstrably true" ((Dake, 1992), p 24) and are thought to influence behaviour indirectly by guiding specific beliefs, attitudes, and norms (Stern et al., 1995; Steg et al., 2000a). The hierarchical myth of nature describes the natural environment as tolerant and resilient, but only up to a point defined by experts from established social institutions, beyond which irreparable damage is incurred (Dake, 1992). The natural environment is presented as fragile and interconnected in the egalitarian myth of nature, with radical changes in human behaviour and society viewed as the only way to ensure environmental conservation. The individualistic myth of nature holds that the natural environment is benign and able to adapt to human activity, with deregulation and technological solutions presented as the best strategy for environmental management. The natural environment is viewed as unpredictable and uncontrollable in the fatalistic myth of nature (Dake, 1992).

There is debate regarding whether 'myths of human-nature' or 'myths of nature' should play a primary role in cultural theory (Ellis et al., 1997); however, the overwhelming majority of research in this area has been concerned with the nature of human relationships described in the grid-group framework (Grendstad et al., 2000). This research emphasis assumes that human relationships to the environment are but a consequence of social relations; however, the direction of this assumed causality remains questionable. In light of the limited empirical findings on myths of nature, the current research has been designed to explore potential relationships between these general environmental beliefs and a range of attitudinal variables.

Attitudes determine what we think, how we feel and how we evaluate certain issues (Petty et al., 1998; Augoustinos et al., 2006) and are in turn influenced by our worldviews. Evidence suggests that attitudes towards different topics (for example gun control, immigration, same-sex marriages, environmental regulation) are strongly related: when we look at a social group at large, attitudes are highly correlated and display strong hierarchical structures which are often associated with political affiliation (Kerlinger, 1984).

Much work in this area is directly relevant to the communication of scientific information on environmental issues, because of the social implication of debates like climate change, acid rain, genetically modified food and water management (Kahan et al., 2007).At the core of many of these debates lies a polarisation (Heath et al., 2006): at one extreme there is support for free-market ideology and ‘environmental apathy’, understood as a lack of interest in environmental issues and the tendency to dismiss their significance. This stereotype usually holds right-wing views of social and political issues and places high importance on economic growth. People subscribing to these views are more likely to be sceptical about attributing negative environmental causes to human drivers and unsupportive of intervention on environmental issues. At the other extreme, there are ‘eco-centric’ beliefs, according to which nature deserves protection for its own intrinsic value. This stereotype usually holds left-wing views on social and political issues and places lower importance on economic growth. People subscribing to this view usually oppose sceptic attitudes and are more likely to support pro-environment initiatives. It is well documented that information and its interpretation is often filtered and classified according to a person’s belief and worldview (see (Liebman et al., 2002; Lewandowsky et al., 2005) for examples as well as (Kahan et al., 2007) addressing specifically the issue of climate change)[2].

Evidence of a relation between cognitive styles and ideological attitudes is provided by a meta-analysis of several studies (Jost et al., 2003), showing that political conservatism is predicted by, among others, factors like uncertainty tolerance, openness to experience, need for order, structure and closure. These empirical correlations have prompted a number of authors to seek ways to simplify the relation between cognitive styles and attitudes via a small number of variables, often via two-dimensional representations. An example of such a representation is given by the “cultural cognition thesis” (Kahan et al., 2007), which is one formulation of cultural theory derived from the work of (Douglas et al., 1982). Alternative representations of worldview have also been given in ‘Amount of Regulation’ & ‘Amount of Social Contact’ (O'Riordan et al., 1999), ‘RightWing Authoritarianism’ & ‘Social Dominance Orientation’ (Duckitt et al., 2009), ‘Malthusianism-Cornucopiansim’ & ‘Holism-Mechanism’ (Jackson, 1995).

An even more encompassing simplification of these issues is provided by the psychological process of ‘Uncertainty Orientation’ (Sorrentino et al., 1984; Sorrentino et al., 2000). It states that the way we deal with uncertainty and whether we withdraw from or are attracted to it, affects nearly all aspects of our life. In turns, this may be the result of the way we perceive the world around us. If we perceive it as a source of potential danger, we may tend to seek safety, which usually comes with certainty. If we perceive it as safe and full of opportunities, we may favour exploring it and may thrive in uncertainty. Uncertainty Orientation may underlie Right-Wing Authoritarianism & Social Dominance Orientation (Duckitt et al., 2009) work.

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[2] It should be noted that a uni-dimensional measure going from left-wing (liberal) to right-wing (conservative) attitudes is today believed to be insufficient to represent people’s attitudes to social and political issues. Rather, a two-dimensional approach based on two distinct ideological attitudes, Right-Wing Authoritarianism (RWA) and Social Dominance Orientation (SDO), is a better predictor of individual attitudes and provides a better explanation of experimental data Duckitt, J. and Sibley, C., 2009. A Dual-Process Motivational Model of Ideology, Politics, and Prejudice. Psychol Inq, 20: 98-109. (see and references within). Nevertheless, while these dimensions express different values, motivational goals and rationale for choice of values, both can be powerful predictors of similar social attitudes and political orientation: people strong in either RWA or SDO are likely to support right-wing conservative political parties in general, although in different flavours and for different reasons Unger, R.K., 2002. Them and Us: Hidden Ideologies-Differences in Degree or Kind? Analyses of Social Issues and Public Policy, 2: 43-52, Mirisola, A., Sibley, C.G., Boca, S. and Duckitt, J., 2007. On the ideological consistency between right-wing authoritarianism and social dominance orientation. Personality and Individual Differences, 43: 1851-1862.. Furthermore, empirical evidence confirms that RWA or SDO share very similar views in regards to environmental issues (Kahan, D.M., Braman, D., Slovic, P., Gastil, J. and Cohen, G.L., 2007. The Second National Risk and Culture Study: Making Sense of - and Making Progress In - The American Culture War of Fact. SSRN eLibrary.

In summary, people employ different cognitive styles to form the beliefs upon which they make choices. The cognitive styles they use are strongly affected by their worldviews and in particular by the perception of the world as either safe or dangerous. This perception expresses itself as ideological attitudes, which determine what we think, how we feel towards some matters and how we evaluate certain issues (Augoustinos et al., 2006), including environmental problems. A scientist communicating scientific and modelling results to stakeholders with potential relevance for policy making and behaviour change, will necessarily encounter these issues at a number of levels. Firstly, a stakeholder may or may not dedicate the effort necessary to understand the scientific message and appreciate its complexity; secondly, (s)he may or may not be willing to account for the uncertainty which is inherent in most environmental debates; thirdly, (s)he may or may not be willing to trust the scientific advice as an independent source of information; most importantly, (s)he may or may not be willing to change opinion as a result of the new information (see (Tversky et al., 1974; Slovic et al., 1977; Dutra et al., 2011)), if this information challenges his/her current mental models and ideological attitude. All these possible behaviours constitute a challenge for scientific communication and may require different communication styles; as a result it is useful for the communicator to gain some indication of the type of audience (s)he is addressing. In the next section we describe some tools which are available to achieve this.

3 Monitoring the stakeholders of a modelling project

Scales purposely developed to evaluate the occurrence of logical fallacies, cognitive styles and ideological attitudes have been developed in the related literature. A modeller interested in using these tools can not only rely on scales already tested for validity and robustness but also compare the results obtained in specific environmental projects against the ones reported in the original studies.

There are some potential drawbacks with this approach which are specifically relevant to environmental projects using computer models. First, the questions used to study logical fallacies may appear to have little relevance to environmental studies. Second, some of the questionnaires used to assess cognitive styles are fairly long. Finally, questionnaires developed to assess ideological attitudes may appear to ask ‘politically incorrect’ questions, to probe personal values a stakeholder may not be willing to share and to be perceived as making too explicit a link between a specific problem at hand and larger political issues, especially when the use of computer models may be perceived as providing an otherwise neutral approach. Here we address some of these issues.

The main aim behind the analysis of logical fallacies is to establish which thinking mode, instinctive or deliberative, people employ and, if they choose the deliberative one, how much cognitive effort they are willing to invest. Some of the questions employed in this original research (Tversky et al., 1974; Tversky et al., 1983) were designed to test whether people follow basic rules of probability: as an example, the probability of the concurrent occurrence of two events (A and B) cannot be larger than the occurrence of either A or B in isolation. Evidence shows that, under certain circumstances, people may employ mental associations and heuristics that lead to judgements which defy this rule (Sorriaux et al., 1968; Tversky et al., 1974; Tversky et al., 1983).

An alternative approach to evaluating the thinking modes is provided by the Cognitive Reflection Test (Frederick, 2005; Hoppe et al., 2011). Its appeal lies in its simplicity, since it includes only three questions which are designed to prompt a quick, intuitive but incorrect answer. The correct answer can be obtained with little cognitive effort, but only provided people resist the temptation to side-step the deliberative cognitive mode. As a result, Thinking Dispositions, but not IQ, are tested.

A different, but related, approach studies fallacious logical thinking applied to basic system dynamics[3] (Moxnes, 1998; Moxnes, 2000; Sweeney et al., 2000; Sterman et al., 2002; Sterman et al., 2007; Sweeney et al., 2007; Sterman, 2008; Cronin et al., 2009; Moxnes et al., 2009). These employ tests based on variations of a simple concept: how the amount of a quantity in a container changes in time depending on the difference between what goes in and what is taken out. Their appeal lies in the obvious relation to environmental problems in which conservation of mass strictly applies: a person who does not understand the accumulation process may under/over spend (creating financial damage), under/over exploit (creating environmental damage), under/over emit (creating pollution damage), etc. The main outcome of this research is that a) the vast majority of the general public, including well over two thirds of mathematically proficient, highly trained individuals, fail at the tests (Sterman, 2008), and b) misjudging this simple dynamic may result in people overexploiting a resource (Moxnes, 1998; Moxnes et al., 2009), which may in turn lead observers to misinterpret the cognitive mistake for greed (Hardin, 1968).

For what regards the analysis of cognitive styles, tests specifically designed to assess 'Open-minded Thinking' (Stanovich), 'Thinking Dispositions' (Stanovich), 'Need for Closure' (Kruglanski), 'Personal Need for Structure' (McShane, 2006), 'Need for Cognition' (Petty) and 'Uncertainty Orientation' (Smith et al., 1994) are available in the literature and on-line. Importantly, because of the correlation between some of these cognitive styles, occasionally very similar questions occur in multiple questionnaires. In Appendix A we suggest a final list of questions, obtained by limiting repetitions, which represents most of the issues the analysis of cognitive styles tries to address. In the next Section we summarise our preliminary experience with the proposed questionnaire.

4 Analysis of Questionnaire Results

Data were collected from two sources. 250 individuals, chosen as unbiased representatives of the Australian population, responded to an online version of the questionnaire. In the rest of the document we call this 'Australia survey'. Also, 17 stakeholders of a project aimed at addressing possible impact on climate change on fisheries in the South-East of Australia (http://www.frdc.com.au/environment/south-east) responded to a written version of the questionnaire. In the rest of the document we call this 'SEAP stakeholders survey'.

As explained above, the questionnaire presented in Appendix A comprises parts of already validated scales and newly designed ones. As a result, our analysis is divided into 3 steps. First, we calculated the Cronbach alpha coefficient for each scale in order to verify its internal consistency. Second, we calculated the correlation matrix of the chosen constructs to understand their relation. Finally, we compared the results of the Australian survey with those of the SEAP stakeholders.

For the sake of clarity, in the rest of the document we call *variables* the overall list of cognitive styles, constructs, attitudes and social variables we study (as used in the questionnaire and as listed in the rows and

[3] System dynamics is a discipline which aims to study how systems evolve in time as a result of internal processes. It mostly focuses on the effects of feedback loops, time delays, flows, stock accumulation, thresholds and the interplay of dynamics at different spatial and temporal scales. It is usually employed for educational and training purposes in order to understand and identify classes of behaviours arising from apparently different, but structurally similar, systems. For a nice review see Meadows, Donella. (2008). Thinking in Systems: A Primer. Earthscan.

column of Table 4) and we call *items* the individual questions used to assess each variable. We also group sets of variables into three classes: *Cognitive Styles*=[Open-mindedness, Need for structure, Need for closure, Uncertainty orientation, Need for cognition, Thinking dispositions, Uncertainty orientation], *Attitudes*[4]=[Attitude toward models, science, risk, complexity, Environmental commitment and concern, Trust in experts, Trust in non experts, Attitude toward scientific presentation, Preference for scientific communication, Reflection test], *Worldviews*=[Egalitarian, Hierarchical, Individualistic and Fatalistic myths of nature] and *Social Variables*=[Age, Gender, Occupation and Education level (the latter only for the SEAP stakeholders)].

4.1 Variables' internal consistency

We calculated the Cronbach alpha coefficient for Cognitive Styles and Attitudes variables. Cronbach alpha is used in psychology to evaluate the reliability of a test, i.e. its propensity to measure a single construct. It estimates the percentage of the test variance that comes from all common factors between the items: a scale is reliable if it has high homogeneity[5] (Cronbach, 1951).

For each of these variables we calculated the Cronbach alpha and then checked whether the value increased after removing some individual items. The highest alpha so obtained indentified the most internally consistent set of items related to the variable. This set of items was included in the further analysis and is marked with an asterisk in Appendix A. Finally, we removed the variables for which the Cronbach alpha was lower than 0.6. The rest of the analysis discussed below refers specifically to the variables displaying a Cronbach alpha >0.6, as listed in Table 3: *Cognitive Styles*=[Open-mindedness, Need for closure], *Attitudes*=[Attitude toward models, science, risk, Environmental commitment and concern, Trust in experts, Trust in non experts, Reflection test]. The Cronbach alpha calculation was not carried out on the Worldviews variables since they consist of a single item.

It is common practise to consider a value of alpha=0.7 as a threshold for reliable internal consistency and 0.6< alpha<0.7 as acceptable or questionable consistency (Nunnally et al., 1994; George et al., 2003), although analysis of constructs with alpha<0.6 can be found in the literature. Here we used alpha=0.6 as a threshold because we are mainly interested in observing the general trends and relations among the different variables. We are aware that the internal consistency of some of the constructs we analysed is questionable and that we have to improve the questionnaire to make it more reliable.

4.2 Correlation among variables

We calculated the Pearson's coefficient between each variable as shown in the correlation matrix in Table 4 and discuss the main results in the following sections.

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[4] Here the terms *Attitudes* and *Worldviews* are understood as labels for these groups of variables, rather than according to the traditional cognitive meaning as previously discussed in the paper.

[5] It is worth noting that the internal consistency of a scale (its reliability, as measured by alpha) is different from the *validity* of a scale, which refers to the extent to which scores on the scale represent the construct of interest

Relation between Cognitive Styles and Attitudes
As expected, we found a significant negative correlation between "open-mindedness" and "need for closure". Notably though, the correlation was only moderate, indicating that these two constructs are not the opposite of one another.

The more open-minded a person is, the more likely she is to display positive attitudes toward science and environment and to have better than average results on the cognitive reflection tests. Interestingly, open-minded people are less disposed to trust the information provided by non-experts (i.e. their family and friends, their doctor, their community, information available in the newspapers, on television and on the internet). Hence, we can assume that open-mindedness does not only indicate the willingness of a person to consider as many alternatives as possible when dealing with a problem, but this construct is also related to the ability of a person to weigh information differently according to the credibility of its source.

In the same way, respondents who trust the information provided by experts tend to display a positive attitude toward computer modelling, science and the environment.

On the contrary, people who score highly on the need for closure scale are more inclined to mistrust science and to avoid risk and display poorer performance in the cognitive reflection tests.

Attitudes toward science, computer models and environment are positively correlated and people who score high on these constructs have a higher propensity to trust the information provided by experts. Moreover, individuals who exhibit positive attitudes toward science and computer models perform better in the cognitive reflection test.

We conclude this session with a final comment on the results of the System Dynamics test. Our data (not shown) confirm the information provided in the literature (Sterman et al., 2007; Sterman, 2008; Boschetti et al., 2011) according to which the vast majority of the responders (~70%) fail at the test. In the case of the South-East Australia Program (SEAP) stakeholders this percentage was even higher (88.4%), while the SEAP stakeholders fared 76.5%. As a result, the test provides little variance and discriminatory power. Nevertheless, we still recommend its use for two reasons. First, unlike other system dynamics tests (Sweeney et al., 2000) a question addressing CO_2 accumulation and climate change has an immediate environmental focus and current relevance. Second, we have used this question in a number of workshops and we realised it can have a profound impact on the attendees. Most of them will be very confident of having answered correctly. When the test is discussed (anonymously) in the workshop session, the realisation of having failed the test can have a profound impact, partly because of the expectation of being able to answer correctly such an apparently simple question and partly because it relates to an environmental problem of great relevance, rather to an abstract mathematical puzzle. We have experienced a number of workshop attendees approaching us in session breaks telling us that the experience was crucial in leading them to finally recognise the importance of computer modelling in their applications.

Relation between Social Variables and Attitudes
In the online questionnaire, we asked the respondents about their occupation. In particular, they could either indicate the precise occupation or choose among the following categories: government, private sector, education, self-employed and research. Only 51.6% of the people chose one of the proposed options (14.0% Government, 23.6% Private sector, 7.6% Education, 5.2% Self-employed and 1.2% Research), the others reported their occupation with their own words. We then assigned to each occupation an integer from one to four which is designed to describe the level of decision-making involved in the occupation. The more decisions a person is expected to take in her work, and the more people these decisions may impact, the higher the number associated with her occupation is. For example, we related unemployment

and retirement to 1, professions from the private sector to 2, occupations connected to education, engineering and research to 3 and occupations from the governmental sector to 4. As this classification is subjective and partly arbitrary, the results related to the variable need to be treated as tentative. In the future it may be useful to employ a more accurate way of measuring this variable.

Nevertheless we observe that, unsurprisingly, the higher education level a person has achieved, the higher her decision-making level in her occupation will be. These two variables have similar connections with the other constructs. That is to say that respondents who have high education level and/or high level of decision-making are more likely to display open-mindedness and a positive attitude toward science, to be attracted by risk and to perform better at the cognitive reflection test (although the correlation between the "Reflection test" and "Occupation" is only marginally significant at p =0.06).

In Table 5 we show some results from the comparing between male and female responders. Men tend to exhibit a more positive attitude toward computer modelling than women, they seem to consider risk more favourably and to get better results in the cognitive reflection test. Conversely, women seem to trust more than men the information provided by non-experts.

Relations among Worldviews

Although issues have been identified with the application of cultural theory at the individual rather than cultural level (Rippl, 2002; Tansey, 2004), Douglas herself (Douglas, 1970) described the grid-group typology as an account of the distribution of values within a population, with individuals moving across typologies according to choice or circumstance. There is some debate regarding whether it is theoretically possible for a single individual to exhibit multiple competing worldview orientations at once (Kahan et al., 2007); however, Douglas's position suggests that worldview perspectives need not be conceptualised as independent or mutually exclusive. Indeed, cultural theory is commonly assessed empirically using the four separate worldview scales developed by Dake (Dake, 1991; Dake, 1992) which supports the view that the different worldview perspectives can indeed exist in varying degrees within a single individual.

As individuals occupy different groups in different social settings (like their workplace, family, and community) we contend that individuals can exhibit multiple competing worldview orientations at once. To overcome the problems associated with classifying individuals within worldview typologies (Rippl, 2002; Tansey, 2004) the current research assessed relationships between a range of social and cognitive variables and individuals' general beliefs about the environment stemming from worldview perspectives (i.e. their support for the four myths of nature).

Myths of nature have been identified as an important feature of worldview (Wildavsky, 1987; Dake, 1992; Steg et al., 2000b); however, surprisingly little research has focussed on the measurement of this construct and the relationships with other variables (Grendstad et al., 2000). The measure of worldview myths of nature used in this research (Price, unpublished manuscript) was adapted from (Steg et al., 2000b) in order to provide more consistency between the four myths in terms of sentence structure, and provision of the relevant policy solutions outlined in literature (Thompson et al., 1990; O'Riordan et al., 1999). By allowing research participants to indicate their levels of agreement with each myth nature statement the current research explored the possibility of individuals exhibiting multiple competing worldview orientations at one time.

The results suggest that general beliefs about the environment stemming from worldviews may indeed be inter-related, with myths of nature from worldviews positioned high on the group dimension (egalitarian and hierarchical) displaying a moderate statistically significant positive relationship (r= 0.38). This relationship did not hold for myths of nature from worldviews positioned low on the group dimension, with individualistic and fatalistic worldviews only demonstrating a weak positive relationship (r=.15**). Furthermore, the negative relationship between the egalitarian myth of nature and those myths from worldviews low on the group dimension (individualistic and fatalistic; r=-.27 and r=-.21 respectively) suggests that relative emphasis placed on the group plays a pivotal role in individuals' general attitudes towards the environment. Taken together these results suggest that it is likely that high group worldview beliefs can exist simultaneously within a single individual. This is consistent with previous research that suggests hierarchical and egalitarian myths of human and physical nature are inter-related (Grendstad et al., 2000).

In line with previous empirical findings, the current research suggests that as general beliefs about the environment, myths of nature may influence environmental behaviour indirectly through specific beliefs, attitudes and norms (Stern et al., 1995; Steg et al., 2000b). The strong significant positive relationship between the egalitarian myth of nature and individuals' expressed level of environmental commitment (r=0.58) clearly demonstrates a link between general environmental beliefs and more specific beliefs related to environmental behaviour. This relationship is also consistent with findings that egalitarian worldviews are linked to environmentalism (Steg et al., 2000b) and support for climate change policies (Leiserowitz, 2006).

Despite these encouraging findings, it should be noted that the relationships demonstrated between the different general beliefs about the environment in this study should be interpreted cautiously as only one item was used to measure respondents' agreement with each myth of nature. It is difficult to assess the psychometric attributes of single item measures, which are prone to random errors and less likely to encapsulate the complexity of a psychological constructs (Nunnally et al., 1994)(Nunnally and Bernstein, 1994, McIver and Carmines, 1981, and Spector, 1992). This suggests that it may be worthwhile to seek alternative ways to measure myths of nature as a dimensional construct. Further research is currently underway to develop valid and reliable scales assessing these general environmental beliefs stemming from worldview perspective. In the meantime, the myths of nature questions will also be retained in their current form, to allow for comparisons to be made between different stakeholder groups, as discussed in the next section. We conclude that worldview beliefs are a fruitful area of research for modellers and that further work in terms of operationalising and measuring worldview may not only clarify debates in the literature but provide useful insights into the factors influencing peoples' interpretation and acceptance of models.

4.3 Comparison between Australian and SEAP questionnaire results

Since the original purpose of the questionnaire is to provide researchers with some characteristics of their audience in order to help them improve the communication of their work, we compared the results of the survey presented above with the responses of stakeholders in an environmental project. Therefore, we asked 17 stakeholders involved in a program aiming at adapting fishery and aquaculture sectors to climate change (South-Eastern Australia Program-SEAP) to respond to the questionnaire. Then, we computed the means for the constructs previously selected and compared them with the results displayed by the representative sample of the Australian population. The results, including statistical significance via a t-test, are displayed in Table 6.

The two groups differ on several constructs. SEAP stakeholders were more open-minded and had a lower need for closure. This is a positive result: as the purpose of the SEAP project is to develop solutions to adapt to climate change, it suggests that people involved in this program may be willing to consider different alternatives. The finding that open-mindedness is positively correlated with environmental commitment confirms previous results. Likewise, SEAP stakeholders exhibit greater environmental commitment and concern and they display a more positive attitude toward science. These findings are not surprising since the SEAP project is based on the belief that the climate is changing, that this phenomenon will impact some sectors of the Australian economy and that the scientific knowledge may help address some of its consequences. Moreover, SEAP stakeholders are more attracted by risk and have better results on the cognitive reflection test. These observations may be related to their higher level of decision-making required in their occupations compared to the average Australian population.

5 Discussion and directions for further research

This work is at the intersection of cognitive, computer and environmental sciences, an area with a sparse literature and ample room for further development. Here we discuss four directions of immediate relevance which deserve future research. First, it is important to collect data on the constructs we present in this work; it is important to understand a how they relate to decision making and how they may vary between different stakeholder teams. The questionnaire we propose can be a first step in order to standardise this data collection.

Second, the questionnaire can obviously be improved. The literature on this topic is vast and fast developing; this may result in improved sets of questions for different constructs. Of particular relevance is the need for shorter questionnaire which could be easily used without requiring too much commitment from the stakeholders or taking too much time in usually busy workshops and meetings. When these shorter sets of questions are available, a compromise will need to be found between shortening the questionnaire, allowing for the inclusion of more constructs and a potential reduction in robustness as a result of fewer items per construct.

Third, it is important to understand to what extent the use of this questionnaire actually improves, directly or indirectly, the ability of modellers to communicate their results and relate to the stakeholders in their projects. In this area, significant changes may be subtle and may take time to occur, while more immediate changes may induce optimism but prove ephemeral or cosmetic. Suitable methods to evaluate the effectiveness of this tool need to be tested or developed.

Finally, it is possible that being asked to answer a questionnaire of this type may raise the stakeholders' awareness of the impact of these issues in the decision making process, with potentially unexpected outcomes. One such example has been described in Section 4.2, with the low rate of success on the System Dynamics question offering an avenue to stakeholders to appreciate the important of computer modelling. It will be important for researchers using this questionnaire to be alert to detect outcomes of this type and capitalise on them.

6 Conclusions

Most modellers are trained in the natural sciences. For them, uncertainty is usually understood in terms of knowing 'too little' and models can be seen as a tool to reduce such uncertainty by providing, capturing or synthesising missing information. In the social arena, uncertainty is also represented by knowing 'too differently' (Brugnach et al., 2008; Boschetti, 2011). Widely different views are not necessarily reconciled by providing missing information. Filtered through the lenses of different worldviews, attitudes and cognitive styles, the same scientific information can lead to very different conclusions. Effective communication of scientific knowledge and effective stakeholder engagement depends on being aware of and adapting to the range of views present within the stakeholder group as well as within the scientific team.

The questionnaire we propose addresses most of the topics we discussed above and can be seen as a tool designed to obtain a snapshot of the social environment in which a computational model will be used in the broadest sense. This snapshot can then lead modellers and other researchers to move in this environment and ensure that engagement and communication are not jeopardised by misjudging the attitudes and possible barriers both stakeholders and researchers bring into the project.

The questionnaire is purposely general and as result it does not address project-specific issues. Given the highly contextual nature of many environmental and social problems, in certain cases this can be a drawback. Researchers may overcome this limitation by either adding further items or by modifying specific questions to make them more relevant to the local context. However, the generality of the questionnaire can also be an advantage because it offers the possibility for comparisons, both between different projects, between different stages in long-term projects and between different environmental and social issues. It can thus represent a means for developing a growing body of experience in the interaction between modelling research teams and their audience. This is the direction we aim to pursue in our future projects.

7 Figures and Tables

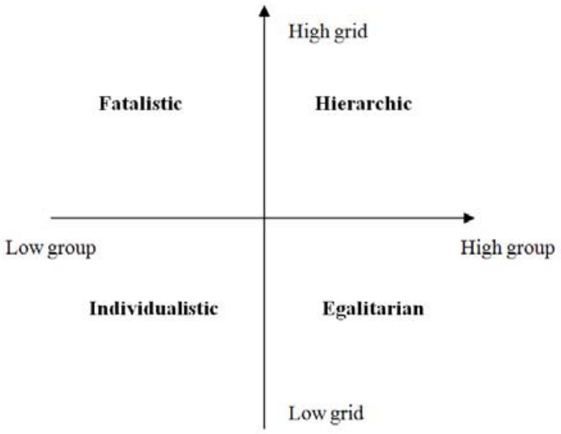


Figure 1. The grid-group model of worldviews (following (Fleming, 1967; Forrester, 1994)).

Table 1: Gender and age distribution of the two samples.

Variable	Australian sample distribution	SEAP sample distribution
Gender	Male: 55.2%	Male: 70.6%
	Female: 44.8%	Female: 29.4%
Age	18-30: 13.6%	<25: 0%
	31-45: 28.4%	25-50: 64.7%
	46-60: 26.8%	50-75: 35.3%
	61-75: 24.0%	>75: 0%
	>75: 7.2%	

Table 2. Number of items per construct used in the proposed questionnaire. The rating scale used is as follows. A=[Disagree strongly, Disagree, Neutral, Agree, Agree strongly]; B=[Not at all, Not much, I am not sure, Reasonably well, A lot]; C: For each item, people have to choose between two statements. D: The reflection test consists of the three questions in (Frederick, 2005; Hoppe et al., 2011) and of the problem described in (Sterman, 2008); for each correct answer, we allocated 1 point to the respondent

Construct		Number	Rating method
Worldview myths of nature		4	A
Cognitive styles	Open-mindedness	16	A
	Need for structure	7	A
	Need for closure	14	A
	Uncertainty orientation	6	A
	Need for cognition	5	A
	Thinking dispositions	3	A

Uncertainty orientation	3	A
Attitude toward computer models	6	A
Attitude toward science	5	A
Attitude toward risk	5	A
Attitude toward complexity	7	A
Environmental commitment and concern	8	A
Trust in the information provided by experts	4	B
Trust in the information provided by non experts	4	B
Attitude toward scientific presentation	3	C
Preference for scientific communication	3	C
Reflection test	4	D
Social variables	4	-

Table 3: Constructs with an acceptable internal consistency in the Australian survey (Cronbach alpha>0.6).

Constructs	Final number of items	Cronbach alpha coefficient
Open-mindedness	8	0.65
Need for closure	4	0.69
Attitude toward computer models	6	0.78
Attitude toward science	5	0.75
Attitude toward risk	5	0.63
Environmental commitment and concern	7	0.80
Trust in the information provided by experts	4	0.76
Trust in the information provided by non-experts	4	0.76
Reflection test	3	0.69

Table 4: Correlations among the key variables. Bold numbers refer to statistically significant relations (p<0.05)

	Egalitarian	Hierarchic	Individualistic	Fatalistic	Open-mindedness	closure	Computer models	science	Risk	Reflection test	trust_expert_info	trust_nonexpert_info	commitment	age	gender	occupation	education level
Egalitarian myth of nature	1.00	**0.38**	**-0.27**	**-0.21**	0.06	0.01	**0.17**	**0.13**	0.01	-0.04	**0.37**	0.08	**0.58**	0.06	**-0.16**	0.02	0.02
Hierarchical myth of nature	-	1.00	**0.17**	**-0.17**	-0.02	0.02	**0.28**	**0.16**	-0.06	-0.03	**0.40**	0.06	**0.31**	0.07	0.05	-0.01	0.01
Individualistic myth of	-	-	1.00	**0.15**	**-0.25**	**0.17**	0.10	-0.01	**0.15**	0.05	-0.01	0.08	**-0.19**	0.07	**0.23**	-0.02	0.04

nature																	
Fatalistic myth of nature	-	-	-	1.00	**-0.19**	**0.20**	**-0.16**	**-0.20**	-0.09	**-0.13**	**-0.21**	0.02	**-0.14**	-0.10	0.00	0.00	-0.12
Open-mindedness	-	-	-	-	1.00	**-0.43**	0.08	**0.42**	0.05	**0.28**	0.05	**-0.18**	**0.22**	0.06	0.09	**0.15**	**0.15**
closure	-	-	-	-	-	1.00	0.04	**-0.14**	**-0.26**	**-0.21**	-0.09	0.08	0.00	0.07	-0.07	**-0.15**	**-0.19**
Computer models	-	-	-	-	-	-	1.00	**0.42**	-0.01	**0.20**	**0.38**	0.11	**0.40**	-0.05	**0.14**	0.09	0.11
science	-	-	-	-	-	-	-	1.00	0.02	**0.19**	**0.31**	-0.09	**0.33**	-0.07	0.12	**0.17**	**0.21**
Risk	-	-	-	-	-	-	-	-	1.00	0.05	-0.06	-0.06	-0.05	0.02	**0.27**	**0.14**	**0.22**
Reflection test	-	-	-	-	-	-	-	-	-	1.00	0.07	-0.06	0.04	0.03	**0.22**	0.12	**0.29**
trust_expert_info	-	-	-	-	-	-	-	-	-	-	1.00	**0.34**	**0.38**	**-0.16**	0.00	0.11	0.01
trust_nonexpert_info	-	-	-	-	-	-	-	-	-	-	-	1.00	0.11	-0.12	**-0.17**	0.04	-0.11
Environmental commitment	-	-	-	-	-	-	-	-	-	-	-	-	1.00	0.03	-0.04	0.11	0.00
age	-	-	-	-	-	-	-	-	-	-	-	-	-	1.00	**0.19**	**-0.20**	0.00
gender	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.00	0.05	0.02
occupation	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.00	**0.23**
education level	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.00

Table 5: Comparison of the scores of men and women. The scores for the constructs “Attitude toward computer models”, “Attitude toward risk” and “Trust non-experts” can range from 0 to 5. The scores for the variable “Reflection test” can range from 0 to 3.

Construct	Women		Men		P-value associated with the T-test between women and men results
	Mean	Standard deviation	Mean	Standard deviation	
Attitude toward computer models	3.43	0.43	3.57	0.53	2.29E-2
Attitude toward risk	2.50	0.52	2.79	0.53	2.14E-5
Reflection test	1.05	1.14	1.57	1.12	4.48E-4
Trust in the information provided by non-experts	3.33	0.61	3.09	0.72	5.88E-3

Table 6. Comparison of the stakeholders group and the Australian representative sample. P-values in bold red are lower than 0.05 and the associated test is considered statistically significant.

	Australia		**SEAP**		
	Mean	Standard deviation	Mean	Standard deviation	P-value related to the t-test
Egalitarianism	3.85	0.95	3.94	0.90	ns
Hierarchism	3.40	1.01	3.47	0.94	ns
individualism	2.98	0.96	2.35	1.06	p < .001
Fatalism	3.42	1.08	2.65	1.27	p < .001
Open-mindedness	3.58	0.46	4.27	0.32	p < .001
Need for closure	3.13	0.63	2.37	0.57	p < .001
Attitude toward computer models	3.50	0.49	3.46	0.39	ns
Attitude toward science	3.70	0.59	3.07	0.46	p < .001
Attitude toward risk	2.66	0.54	3.04	0.43	p < .001
Reflection test	1.82	1.56	2.65	1.39	p < .001
Trust in information provided by experts	3.07	0.73	3.18	0.68	ns
Trust in information provided by non experts	3.20	0.68	3.19	0.61	ns
Environmental commitment/concern	3.63	0.61	3.83	0.36	p < .001

8 Appendix A – Proposed Questionnaire

This session contains the proposed questionnaire.

8.1 Worldviews

Read each statement and decide whether you agree or disagree with each statement as follows:

1=Disagree Strongly,2=Disagree Moderately,3=Neither Agree nor Disagree,4=Agree Moderately, 5=Agree Strongly

(There are no right or wrong answers so do not spend too much time deciding on an answer. The first thing that comes to mind is probably the best response)

1. The environment is fragile and will only be protected if there are large changes in human behaviour and society [__]*

2. The environment can be managed by the government and experts if there are clear rules about what is allowed[__]*

3. The environment can adapt to changes and technology will solve environmental problems eventually [__]*

4. The environment is unpredictable and we can't control what happens [__]*

8.2 Preference for scientific communication

Which of the following statements best matches your view (*please tick* ***one* *box*):**

I like when information is presented:

1. in a simplified, condensed and intuitive manner ☐
2. in a very comprehensive form, so I can understand and check most details ☐

Which of the following statements best matches your view (*please tick* ***one* *box*):**

During a presentation, a competent person should:

1. be able to explain difficult things in a very simple manner. ☐
2. spend a lot of time to explain a difficult issue. ☐

Which of the following statements best matches your view (*please tick* ***one* *box*):**

A scientific presentation should:

1. show the main results in an entertaining way, without too many dull and tedious technical details ☐
2. be informative and fairly detailed; I am interested in understand how some results have been obtained, how reliable they are and their level of uncertainty ☐

8.3 Cognitive styles

Read each statement and decide whether you agree or disagree with each statement as follows:

1=Disagree Strongly,2=Disagree Moderately,3=Neither Agree nor Disagree,4=Agree Moderately, 5=Agree Strongly

(There are no right or wrong answers so do not spend too much time deciding on an answer. The first thing that comes to mind is probably the best response)

1. People should always consider evidence that goes against their beliefs [__]*
2. I like to find out why things happen [__]
3. I don't like situations that are uncertain [__]*
4. It’s enough for me that someone gets the job done; I don’t care how or why it works [__]
5. A person should always consider new possibilities when managing a natural resource? [__]*
6. When trying to solve a problem I often see so many possible options that it's confusing [__]
7. When thinking about a problem, I consider as many different opinions on the issue as possible [__]
8. I don't like to go into a situation without knowing what I can expect from it [__]
9. I believe that loyalty to one's ideals and principles is more important than open-mindedness [__]*
10. It's ok to be undecided about some things [__]
11. I dislike unpredictable situations [__]
12. When I am confused about an important issue, I feel very upset [__]*
13. I dislike questions which could be answered in many different ways [__]*
14. Changing your mind is a sign of weakness [__]*
15. I like to have the responsibility of handling a situation that requires a lot of thinking [__]
16. I like to spend a lot of time and energy thinking about something related to a decision I need to make [__]
17. When considering most conflict situations, I can usually see how both sides could be right [__]
18. I like to do things that I've learned well over and over, so that I need to think less about them [__]
19. When faced with a problem I usually see the one best solution very quickly [__]
20. The notion of thinking abstractly is appealing to me [__]
21. Mostly, we already know most we need to know to solve the problems we face [__]*
22. Wise people make fast decisions [__]*
23. If I think longer about a problem I will be more likely to solve it [__]
24. Abandoning a previous belief is a sign of strong character [__]
25. I become uncomfortable when the rules in a situation are not clear [__]
26. Certain beliefs are just too important to abandon no matter how good a case can be made against them [__]*
27. Considering too many different opinions often leads to bad decisions [__]*
28. I believe that laws and social policies should change to reflect the needs of a changing world [__]
29. In most social conflicts, I can easily see which side is right and which is wrong [__]
30. I always see many possible solutions to problems I face [__]
31. I do not usually consult many different opinions before forming my own view [__]
32. Safety first [__]*
33. I take risks regularly [__]*
34. I really dislike not knowing what is going to happen [__]*
35. I usually view risks as a challenge [__]*
36. I view myself as a risk seeker [__]*

8.4 Cognitive reflection test (from (Frederick, 2005))

Please answer the following questions

1. A bat and a ball together cost 110 cents. The bat costs 100 cents more than the ball. How much does the ball cost? [__]*

2. If it takes 5 machines 5 min to make 5 widgets, how long would it take 100 machines to make 100 widgets? [__]*

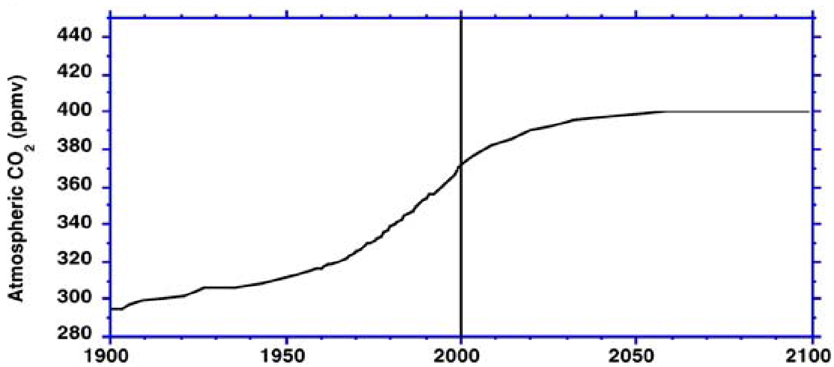
3. In a lake, there is a patch of lily pads. Every day, the patch doubles in size. If it takes 48 days for the patch to cover the entire lake, how long would it take for the patch to cover half of the lake? [__]*

8.5 System Dynamics: stocks and flows (from (Sterman, 2008)).

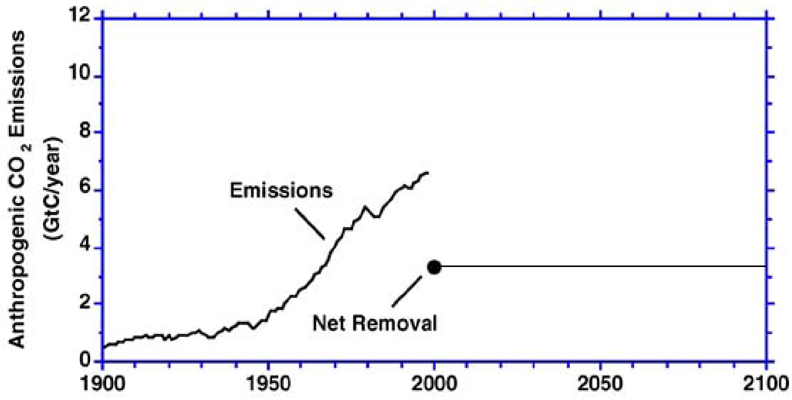
The Intergovernmental Panel on Climate Change (IPCC) has stated that carbon dioxide (CO_2) and other greenhouse gas emissions are contributing to global warming.

The amount of CO_2 in the atmosphere is affected by natural processes and by human activity. CO_2 emissions resulting from human activity have been growing since the start of the industrial revolution. Natural processes gradually remove CO_2 from the atmosphere (e.g. plant life taking up CO_2). Currently this rate of removal of CO_2 is approximately half the rate at which CO_2 is added to the atmosphere and consequently concentrations have increased from preindustrial levels.

Now consider a scenario in which the concentration of CO_2 in the atmosphere gradually rises to 400 parts per million, which is about 8% higher than the level in 2000, and then stabilises by the year 2100, as shown here:



The graph below shows CO_2 emissions from human activities. The black dot shows the rate at which CO_2 is removed from the atmosphere in 2000. Please draw your estimate of an emissions trajectory between 2000 and 2100 that could produce the CO_2 concentration graph above. Assume the rate of CO_2 removal remains constant (as shown by the horizontal line extending between years 2000 to 2100),



Please provide any comments or explanations here:

8.6 Attitude towards Science

1. I strongly believe in science [__]*
2. I believe Science can provide solutions to environmental problems [__]*
3. I do not believe Science can provide solutions to social problems [__]*
4. Science has caused more problems than it has resolved [__]*
5. I am reluctant to use technology (including computers and models) to address complex natural and social problems [__]*

8.7 Attitude towards complexity

1. Simple approaches are best when solving complex issues [__]
2. The best way to address a very complex problem is by breaking it down into small parts [__]
3. I prefer avoid complex problems if I can [__]
4. I enjoy addressing complex problem [__]
5. I think that there is limit to understanding complex problems [__]
6. The vast majority of social and environmental problems we face are very complex [__]
7. The world around us is simple; humans make it difficult [__]

Which of the following statements best matches your view (*please tick **one box*):**

Certain issues are so complicated because:

8. they need a lot of information to be properly understood ☐
9. we have not understood them yet, otherwise they would look much simpler ☐

8.8 Attitude towards computer models

Which of the following statements best matches you (*please tick **one box*):**

1. I do not know what computer modelling is ◻
2. I have a rough idea of what computer modelling is ◻
3. I have seen computer modelling at work or its results in some occasions ◻
4. I am familiar with computer modelling ◻

Read each statement and decide whether you agree or disagree with each statement as follows:

(*please state, for* <u>*each*</u> *item, whether you 1=Disagree Strongly, 2=Disagree Moderately, 3=Neither Agree nor Disagree, 4=Agree Moderately, 5=Agree Strongly)*

1. I trust the results of computer models [__]*
2. The results of computer models can help taking decision about important matters [__]*
3. Using computer models can teach how real systems work [__]*
4. Using computer models is like toying; its result cannot be taken too seriously [__]*
5. I would like to learn how to use computer modelling [__]*
6. Computer modelling will become more and more common in the future [__]*

8.9 Trust & Information

1. When something is very complicated, I am happy for experts to deal with it [__]
2. I trust very knowledgeable people more than less knowledge ones [__]
3. I trust scientists [__]
4. I trust most people responsible for making decision which affect my life [__]
1. We all need information to form our opinion about environment and social problems; how much do you trust the information provided by:

   - Scientists [__]*
   - Environmental organisations [__]*
   - Federal Government [__]*
   - Local Government [__]*
   - Family and friends [__]*
   - Your doctor [__]*
   - People from your community [__]*
   - Television, Newspapers & Internet [__]*
   - Books & other publications [__]

8.10 Attitude towards the environment

1. I am personally committed to preventing environmental problems [__]*

2. I am personally committed to improving environmental problems [__]*

3. Environmental problems are not as important as many other problems facing the world today [__]*

4. I am concerned about environmental problems because of the potential consequences on
   (*please state, for* <u>*each*</u> *item, whether you 1=Disagree Strongly, 2=Disagree Moderately, 3=Neither Agree*

nor Disagree, 4=Agree Moderately, 5=Agree Strongly)
My wealth [_]* My lifestyle [_]* My health [_]* My community [_]* The World [_]*

8.11 Census data

Please indicate your age

What is your gender?
☐ Female ☐ Male*
Please select the category which best describes your occupation
☐ Government ☐ Private business ☐ Research ☐ Education ☐ Others *

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