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Sustainability as a Problem of Design: Interactive Science in the Georgia Basin

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Abstract

This paper reports on the general findings of the Georgia Basin Futures Project, a five year collaborative interdisciplinary participatory integrated assessment project undertaken in the Georgia Basin of Canada from 1999–2004. Key outcomes are discussed with regard to the development and use of participatory scenario-generation models and processes, the involvement of stakeholders and partners in such processes, the development of three urban-scale case studies, the use of such tools and processes in the classroom, the cognitive and behavioural effects of such activities, and the value of such processes for policy analysis. Some comments on the implications of this type of project for interdisciplinary research and project management are also included.

Keywords:

1 Introduction: Interactive Science and Emergent Understandings

The challenge of achieving a sustainable future is a complex and multi-dimensional one, which requires a strongly interdisciplinary or transdisciplinary approach (Becker, 2002; Klein, 2004; Robinson, submitted). Over the past decade a group of researchers and community partners in the Georgia Basin region on the west coast of Canada have developed processes and tools that allowed them to engage

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experts and members of the public in the task of identifying potential sustainable futures for the region, and considering the implications and concrete policies that would bring about these futures. This work builds on a long tradition of futures studies and participatory integrated assessment in the environmental field (e.g., Rothman & Robinson, 1996; Hisschemöller et al., 2001; Beck et al., 2002; Berkhout et al., 2002; Beck et al., 2002; Pereira & Quintana, 2002; van Asselt & Rijkens-Klomp, 2002; Robinson, 2003; Kok et al., 2006; Tansey et al., 2002).

From the extensive literatures associated with these traditions, and the researchers' experiences in developing participatory integrated assessment tools and processes, five strands of work have been identified, which form the basis of our approach. The first is a concern with undertaking research that integrates natural and physical science analyses of environmental systems with social science, health science, and humanities research on the human systems that interact with the environment. The second is a 'backcasting' approach to futures studies based on identifying the various ways people can work collectively or individually toward bringing about a more sustainable world. We applied a form of backcasting in which the choice of desirable futures was left up to the participants in our workshops, who created the scenarios themselves (Robinson, 2003). The third is a participatory, 'problem-based' focus, which leads to the direct involvement of various community partners, or stakeholders, in the research process itself. In our work, model design and implementation was driven by the interests of our stakeholders, rather than by the scientific literature (VanWynsberghe et al., 2003; Carmichael et al., 2004). The fourth is a design approach to modelling (Gault et al., 1987) in which key behavioural relationships are exogenized in order to permit analysis of alternative futures in terms of feasibility and desirability, rather than likelihood. The fifth is the need to determine the appropriate temporal and spatial scale of analysis. Although issues such as sustainability have critical global dimensions, research that is truly problem-centered, policy-oriented, and connected to users must establish temporal and spatial scales that are relevant for decision makers.

When taken together, these ideas and approaches suggest that it is useful to think about sustainability in both substantive and procedural terms. From a *substantive* point of view, we view sustainability as requiring the reconciliation of three imperatives: the ecological imperative to stay within biophysical carrying capacity, the economic imperative to provide adequate material standards for all, and the social imperative to provide systems of governance that propagate the values that people want to live by (Robinson & Tinker, 1997). These characteristics are very general and do not specify in detail the outcomes, policies or measures required to achieve sustainability in any particular context. Instead they set a context and direction within which those details can be worked out. One reason for this is that such details are best explored in participatory processes in which alternative outcomes can be explored and options chosen that reflect the learning involved in such processes. Thus we define sustainability in *procedural* terms as the emergent property of a discussion about desired futures that is informed by some understanding of the ecological, social and economic

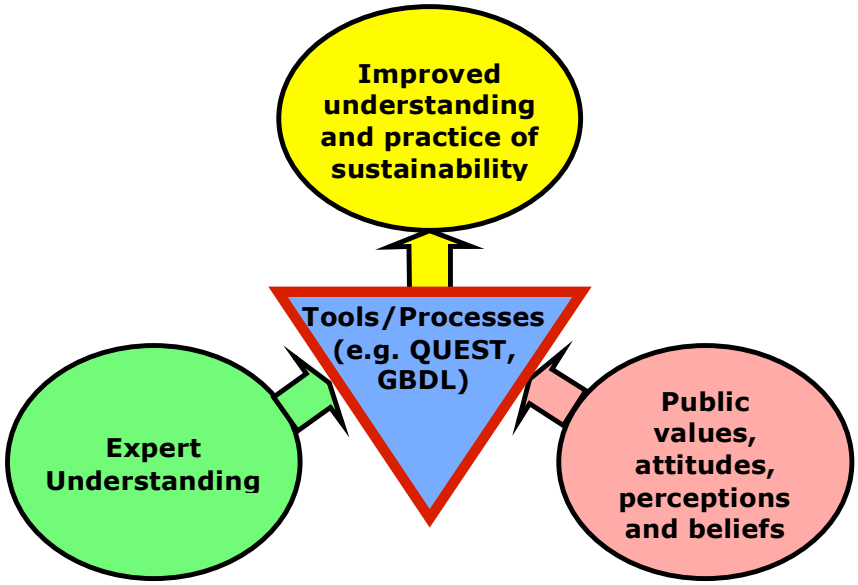


Figure 1: Emergent understanding of sustainability

consequences of alternative courses of action (Robinson, 2004). This means that the choice about what sustainability means in concrete terms for a given context and group emerges from a social learning process, where expert knowledge is combined with public attitudes, preferences and beliefs. Using various tools and processes, both are tested against an analysis of the consequences and trade-offs associated with particular course of action, facilitating adjustments to plans as learning occurs (see Figure 1).

This approach to sustainability underpinned the development of the Georgia Basin Futures Project (GBFP). The GBFP is a collaborative interdisciplinary research project that engaged stakeholders in the Georgia Basin region of western Canada in thinking through the implications of trying to achieve a desirable future.

2 The Georgia Basin Futures Project

The Georgia Basin Futures Project (GBFP) was a five-year regional participatory integrated assessment exercise that combined public values, preferences and beliefs with expert knowledge in the production of scenarios for the future of the area in western Canada known as the Georgia Basin over the next forty years. The key goals were to:

- increase public involvement in the discourse about issues of sustainability;

- explore pathways to sustainability in the region, and;
- create a database of public preferences, values, and acceptable and unacceptable trade-offs.

The overall goals of this exercise were to provide a picture of how participants feel and think about sustainability issues and to evaluate how the use of computer-based simulation tools affects the beliefs, values, and behaviours of the users of those tools (Tansey et al., 2002).

Research in the project was undertaken by a core team of about twenty co-investigators and research collaborators, research staff members, about thirty graduate students, and several administrative staff members working in conjunction with sixteen non-governmental organizations, government, and private sector partners in the community.

Expert analysis of key relationships among the social, ecological, and economic systems in the Georgia Basin together with stakeholder-identified key issues guided development of a number of software tools for engaging stakeholders in sustainability issues. These tools were used in several interactive processes, including workshops and classroom applications. The effect and effectiveness of this approach to engaging different publics with interactive software tools were evaluated.

2.1 Georgia Basin QUEST

The methodological core of the project was the development and use of a Georgia Basin version of the QUEST modeling system[1] (Rothman et al., 2002; Carmichael et al., 2004). QUEST is a computer-based system for scenario generation and evaluation that was designed to encourage public participation in thinking about sustainability in a regional context. Through QUEST, users explore different scenarios for the future in terms of their social, economic, and environmental characteristics. The goal was to acquaint users with the complex realities of decision making, specifically the uncertainties involved, the necessary trade-offs, the degree to which local outcomes can be influenced by local decisions, and the role of subjective values.

Through the adoption of the "feel" and user-friendliness of a computer game, QUEST scenarios actively involve the user in their creation and evaluation. To support ease of use and learning, significant emphasis was placed on the development of the interface through which users explore scenarios.

QUEST includes a dual scale spatial capability, which allows consideration of how global forces affect local outcomes. At the global scale, four scenarios are offered, representing different pathways of global development (Raskin et al.,

[1]The QUEST model developed for the Georgia Basin represents the 3rd generation of QUEST software. References to QUEST in this paper refer to this generation. A 4th generation of QUEST, called MetroQuest, has since been further developed by one of the GBFP partners, Envision Sustainability Tools Inc. It is tailored for municipal use, and has now been implemented or is currently under construction in ten different Canadian cities and regions. See www.envisiontools.com.

1998). Each global scenario gives rise to different regional implications, such as population growth and regional trade. Reflecting the fact that global choices are not within the purview of local decision-makers, workshop participants were typically asked to choose what they considered to be the most likely global scenario. At the regional scale, scenario choices included personal transportation, the density and location of urban growth, the style of neighborhoods, agricultural trends and practices, forestry practices, economic activity and practices, water conservation, energy efficiency, government taxation and spending, and personal choices like diet and consumption practices. The consequences of these decisions affect human well-being, environmental quality, economic and social health, and the long-term ability to maintain all these results. In contrast to the global scale choices, participants were typically asked to choose preferred (rather than likely) regional options. This allows the rest of the scenario generation process to follow the backcasting process (Wilson et al., 2006), exploring the desirability and feasibility of alternative futures. Of course once a desirable future is chosen it is also possible to change the global scenario choice and see what the implications are for the regional scenario outcomes.

QUEST does not provide a picture of the most likely future and is not intended to reflect a detailed understanding of all the complex systems involved. Instead, it captures broad representations of an integrated system, and helps users learn about the linkages between choices and possible consequences and the trade-offs society faces in deciding among available options.

2.2 Community Engagement and Policy Analysis Methodologies

A critical element of the project related to the involvement of stakeholders and community partners in the research process. The project built on the tradition of participatory integrated assessment modeling (Kasemir et al., 2000; van Asselt & Rijkens-Klomp, 2002; Tansey et al., 2002) and adopted an approach that is based on an explicit recognition of the value-laden nature of scientific analysis and modeling. This translates into a need to incorporate community-based partners and the interested public directly into the research activities in two ways. First, by working with partner organizations in the community, the project has incorporated public values, preferences, and concerns into the process of model design and implementation (VanWynsberghe et al., 2003). Second, through an elaborate process of community engagement, the project has included the interested public in dialogue concerning sustainability and in the generation of preferred sustainability scenarios using those modeling tools to support several community engagement exercises: three regional case studies, expert workshops, classroom use, a large exhibition space at the region's science museum for children (Science World), workshops to support cultural model theory research, and web-based use and collection of information. (Robinson & Tansey, 2006). Both of these activities supported the ongoing sustainability efforts of our community, business, and governmental partners.

Three local, subregional case studies were developed at three different scales

of political community in order to test the feasibility of our tools and methods for exploring local sustainability scenarios. Case studies hold significant advantages as a research method that provide a sense of context and a richness of detail that exceeds virtually every other approach to analysis. (Yin, 2003; Flyvbjerg, 2001; Mitchell, 1983; Merriam, 1988). In these studies, local municipal or regional governments collaborated to host workshops, using QUEST to explore regional sustainability scenarios and to contribute to the development of policies for sustainability (Savelson et al., 2005). The jurisdictions ranged from an island community of 3,000 persons to an association of municipalities representing two million people. Participants included policy makers, technical government staff, and interested members of the public. The case studies provided data for conducting a cross-case analysis of possible approaches to community-based sustainability efforts, discussed later in the paper[2].

To support the emphasis on implementation in the case studies, we adopted a model of facilitated behaviour change from the health promotion community called the Precede-Proceed model (Green & Kreuter, 1999). This model focuses on methods for facilitating behavioural or policy-related changes. The model has been applied to topics including stop-smoking campaigns and breast cancer screening. We applied Precede-Proceed to the issue of facilitating sustainable behavioural change and policy by embedding a QUEST-supported scenario exploration and policy analysis process into a Precede-Proceed workshop framework (Savelson et al., 2005). The participants included partner organizations, and stakeholder groups. Each workshop group developed a desired future scenario and explored the implementation measures that would be required to realize that scenario.

A teaching and learning team created a set of curriculum guides and resource packages to support learning about sustainability, using QUEST. The materials were applied in several classes and at different grade levels (Rogers, 2003).

During 2001, an interactive video-based version of QUEST was created for young audiences. The video was used at the local childrens' science museum (Science World). Approximately 18,000 people, mostly elementary school students, played this version of QUEST between 2001 and 2003, using interactive touch pads set into the seat arms of the 200-seat theater at the museum.

Another series of workshops was designed and implemented to study the effects of exploring future scenarios, using QUEST, on individuals' perceptions of what sustainability means and self-reported actions toward achieving it. Cultural models or folk theories are widely shared ways of thinking about and organizing the world and its contents. Individual elements are interconnected and that they provide a source of explanations and predictions (Kempton & Falk, 2000). Our hypothesis was that GB-QUEST extended this thinking by supporting a definition of sustainability as a collective effort to make change. We also anticipated that differences in beliefs about sustainability were impacted by the QUEST experience as a function of gender, age, and being born in Canada. The

[2]A book on the three GBFP case studies is currently being written and is expected to be published in early 2007.

'culture and cognition' research component set up several processes to test the impacts of playing QUEST on the mental models of sustainability and on the propensity or desire to take actions as a result of the learning in the workshops[3]. Data was gathered from 188 participants who attended one of 14, four-hour-long facilitated scenario-building sessions. Each workshop included 10 to15 participants.

2.3 Other Tools and Engagement Efforts

In addition to GB-QUEST, several interactive software tools were developed in the GBFP, including the refinement of a personal Climate Change Calculator and a Sustainability Tools and Resources website for helping community groups and individuals establish themselves and interact with other groups. In addition, the GBFP combined forces with a research group at Natural Resources Canada to develop a prototype of a web-based digital library to facilitate the integration of natural resource and social science information (Geographic Information System maps, images, and text) into a comprehensive and interactive information resource to support sustainability research, community-focused decision making, and public consultation activities in the Georgia Basin (Journeay et al., 2000; Talwar et al., 2001; Harrap et al., 2006). The Georgia Basin Digital Library (GBDL) was designed to provide a framework for understanding issues of regional sustainability through an information architecture that integrates principles of data warehousing, object-oriented data model design, knowledge representation and community mapping. Concepts of sustainability were represented in the digital library through the use of semantic networks that connect individual topics with a distributed network of geographically referenced information assets. The premise in developing this complementary suite of interactive learning tools was that individuals and groups need a shared sense of place and purpose (context and focus) in order to develop a meaningful understanding of what sustainability might mean for a specific community or region.

3 Key Outcomes of the GBFP

Some of the major findings of the GBFP are discussed here. They are divided into nine areas:

- the development of scenario-generation models;
- the definition and exploration of sustainable futures;
- the use of our models in participatory processes and the involvement of stakeholders and partners in such processes;
- the development of three urban-scale case studies;

[3]The results of the "culture and cognition" work in the GBFP is being published in a forthcoming paper. Contact the authors for further detail.

- the cognitive and behavioural effects of such activities;
- the use of such tools and processes in the classroom;
- the value of such processes for policy analysis;
- the development and use of digital library tools; and
- the challenges of managing the research and partnerships in this project.

3.1 Development of modeling tools

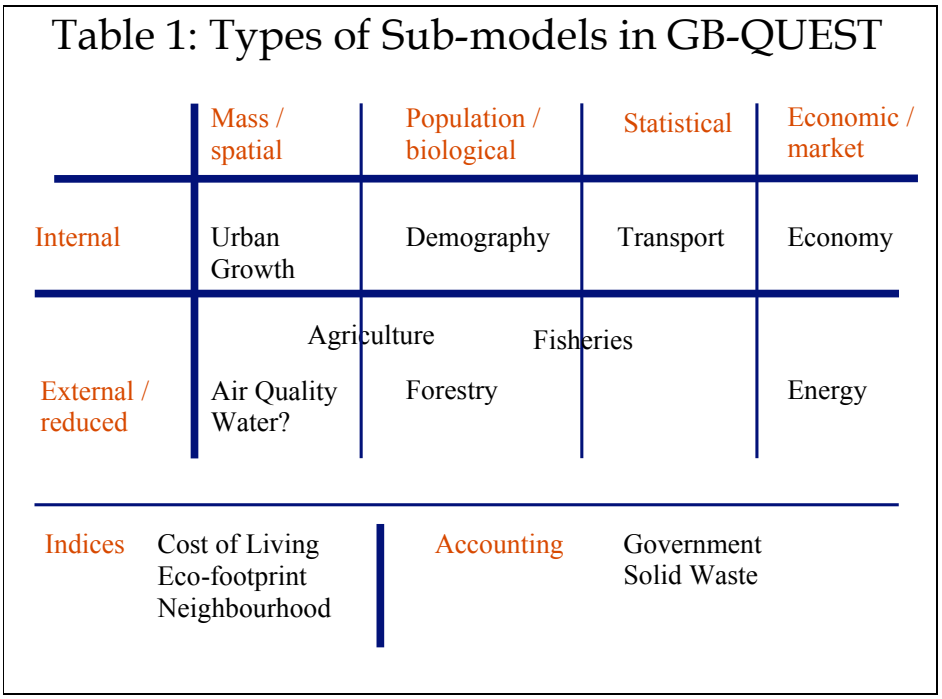
The first lesson derived from the model development work on Georgia Basin QUEST was that the tension between being 'true to life' (accurately reflecting the dynamics the model describes) and 'fun to use' (offering an enjoyable and interesting experience for the user) is a very real one. The natural reflexes of academic modelers, in our experience, are to endogenize behaviour (i.e., to predict) and to improve models by adding more complexity. The first of these reflexes works against a prime objective of our scenario analysis process, which is to have the user make many of the behavioural decisions so that they can learn about the consequences of different behaviours, and also so they can explore futures that may be less likely but nevertheless desirable. The second reflex works against the need for users to iterate quickly enough through the scenario creation and evaluation process that they can experience a QUEST session in one half day or less. Being 'fun to use' also requires the distillation and explanation of complex information into simple, easy to understand formats. This is a challenge seldom addressed by academic modelers. Expert models are typically not well suited to distilling complex information into simple formats that may be communicated to a general audience.

The result of these tensions is that in every case where we had academic modelers working with us in developing QUEST, we ran into major constraints on our ability to produce models that were sufficiently general and simple to be used in the ways intended. The challenge was compounded by the fact that expert models are typically system-specific and therefore difficult to integrate from a coding perspective.

For certain sub-models, we resolved this problem using 'executive summary modeling': creating sub-models that summarized some of the key behaviors and regularities of more complex 'professional' models. At a very general level this approach was satisfactory, but it quickly became apparent that a) not all sub-models required this approach, and b) procedures had to be customized for each sub-model that did require such an approach. The result was a very eclectic approach in which quite different kinds of sub-models were built, connected and calibrated over a period of several years (see Table 1).

A second lesson concerned the critical role of spatial and temporal scales in model development. Because we were committed to an approach to modeling that started from the user's perspective, QUEST's spatial and temporal scales needed to be consistent with the cognitive frame of users. Serendipitously, we

Table 1: Types of Sub-models in GB-QUEST. Internal models were developed specifically for GB-QUEST; External models rely on parametrisation and simplification of separate models.



discovered that a time frame of 40 years, which we had chosen because it was long enough to allow turnover of most long-lived capital stocks (thus allowing the scenario to show significant changes in outcomes than would be the case with a shorter timeline), was also a time frame that was meaningful to most participants. Workshop participants indicated that one hundred years, on the other hand, was beyond their time horizon of interest.

A 40 year time scale is very appropriate for certain issues, but inappropriate for others. Appropriate temporal and spatial scales vary by discipline and issue. As a spatial example, water conservation policies are determined locally in the region, but forestry policies are set provincially (at a larger scale). As well, what constitutes a water issue is different on the coast than it is in a dry, agricultural part of the region. As a temporal example, transport-related policies may be enacted and lead to significant outcomes within a decade, but greenhouse gas-related policies will not significantly affect climate change impacts for several decades. As a result, although a 40-year time scale is appropriate for many of the issues addressed within QUEST, it limited what we could say meaningfully about some critical issues, such as forestry management and climate change impacts. This raised interesting issues about how to deal with possible outcomes after the formal scenario time frame.

It was clear that most users of QUEST were most interested in exploring scenarios at the local scale. At the same time, local possibilities and consequences often depend critically on large scale phenomena, such as global trade, world oil prices or climate change. As noted above, our approach to this tension was to build a dual level spatial capability into GB-QUEST, and to differentiate strongly in how these two levels were presented, and 'played'. This dual level approach not only preserves the backcasting orientation of the scenario analysis process, but it does so in a way that we think helpfully illustrates a central tenet of complex adaptive systems thinking: systems are hierarchical and choices at one level become constraints the next level down. Residents of the Georgia Basin do not get to choose global futures; these futures instead act as constraints on regional conditions. But at the regional level, much more choice exists. We believe this is a fruitful way to communicate the linkages between global and regional futures, and to provide global context for regional choices.

A third lesson concerned balanced representations of sustainability issues. Because the focus of the GBFP was on sustainable futures, we began with the intent to model all three legs of the sustainability stool: ecological, economic and social. However we found it relatively difficult to build sub-models in QUEST on many of the social issues, such as poverty, equity, and crime, which were of interest to our partners and stakeholders. In these areas, descriptive information is abundant and current indicators may exist, but causal relationships are poorly understood. The result is that GB-QUEST is much stronger in the economic and environmental areas.

Perhaps the final, most general lesson from our work in building QUEST is that building an integrated model that addresses a wide variety of economic, environmental and social issues is a lengthy and expensive process. Altogether, the work of many colleagues over six or seven years underlay the development

of a version of GB-QUEST that we could use in workshops[4]. Many intended capabilities, such as advanced zooming of spatial maps, were not accomplished.

3.2 How to Define and Explore Sustainability?

Before even getting to the point of taking QUEST out to the community, the GBFP research team found itself engaged in two major debates concerning how to accomplish the project's goals (Robinson & Tansey, 2006). The first debate concerned whether quantitative modeling, such as that embedded in QUEST, adds value to or detracts from efforts to explore sustainability through participatory processes. Some members of the research team were either deeply skeptical about the value of such modeling in principle, or concerned about how much of the budget and effort in the project was devoted to the development of QUEST relative to developing other more qualitative forms of participatory process. Those holding these views tended to believe that quantitative modeling was at best a distraction from the important issues that the GBFP was intended to address, and at worst deeply misleading, since it focused attention only on those issues easily reducible to such analysis (thus excluding many other important issues) and also reinforced a kind of technical and technocratic bias to the project.

This issue raises important questions about the role, status and meaning of formal models in participatory processes aimed at fostering regional sustainability. Underlying these questions are others related to the relationship between narrative-based approaches to understanding and communicating sustainability issues and formal modeling approaches. These questions are in turn connected to deep disciplinary and epistemological divisions among different fields of study. A strong characteristic of recent global modeling work is the attempt to combine narrative storylines with modeling analysis (Swart et al., 2004) and this was an explicit goal of the GBFP. However, despite the strong attempts to build explicitly interpretive and qualitative processes into the GB-QUEST model and also the processes of using GB-QUEST, this issue was not resolved within the research team. Interestingly, it seemed less of a concern to our partners and stakeholders, but this of course does not mean that it is not a real issue[5].

The second debate concerned the purpose and possible effects of our modeling workshops. As noted above, a key characteristic of the QUEST approach is that the users themselves create the scenarios and decide what outcomes they prefer. Several members of the research team were concerned that this meant that some participants might choose 'unsustainable' future scenarios, and that the research team, or QUEST, was not providing enough guidance as to which futures were 'really' sustainable and which weren't.

[4]Based on this learning and much subsequent work, Envision Sustainability Tools is now able to build a MetroQuest model for virtually any Canadian city in approximately 6 months, depending on the level of detail and complexity desired. Applications outside Canada are significantly more expensive in time and money.

[5]This issue continues to be a major focus of attention in more recent work (Carmichael et al., 2005). Two PhD students at UBC are now writing dissertations on these issues.

This issue raises very interesting questions about the relative roles of 'expert' and 'lay' understanding in explorations of sustainability. Can stakeholders choose the 'wrong' scenario? Is it up to the research team to provide authoritative judgements as to what is sustainable? How do normative and ethical judgements about sustainability play out relative to technical or scientific judgements about, say, environmental or social impacts of different choices or policies? The project team decided that participants would be the judges of whether a scenario was sustainable, recognizing that the structure of QUEST had a strong influence upon their judgment. This was consistent with our assertion that sustainability is an emergent property of a discussion of alternative futures (the workshop) informed by some understanding of the consequences of different courses of action (revealed by the QUEST scenarios and our interpretive commentary), but it did not fully resolve the issue within the research team.

3.3 Community Engagement Processes

In our initial funding application we focused much attention on the development of the GB-QUEST model and relatively less on the design of the processes in which this tool would be used. As a result, our initial experiences in using QUEST in workshops were less than satisfactory. Indeed, the first and perhaps most powerful lesson learned in the GBFP was that just as much time and thought needs to be given to the design and management of the modeling workshops as to the model development process itself. Much of the important learning in the project happened after the GB-QUEST scenario was created, in the subsequent discussion of how preferred outcomes could actually be implemented.

A second lesson concerned participant perspectives of and desires for information at a variety of spatial scales. Workshop discussions and comments indicated clearly that most users of QUEST were interested in exploring scenarios at the local scale. At the same time, local possibilities and consequences often depend critically on large scale phenomena, such as global trade, world oil prices or climate change. QUEST's dual scale spatial capability allowed both global and regional scales to be explored, and was designed to differentiate strongly in how these two scales were presented and 'played'. In workshop use, participants were typically asked to choose the most likely of the four global scenarios. The regional consequences of that choice were unpacked as the workshop continued. The choice then calibrates the regional scenario by determining several variables such as population growth and regional trade. Observational evidence from the workshops showed an interesting response to the fact that global scenarios impacted the Georgia Basin: disappointment. Several explanations are possible, the one most consistent with some other findings suggests that players don't really know the extent to which the outside world interacts with and affects the region. Many participants wanted to explore choices and consequences on a local (subregional) scale. QUEST included global and regional choices, and offered the ability to view subregional impacts, but regional choices sometimes did not provide the level of detail relevant at the local scale.

This was a significant problem, particularly in the three municipal case studies (see discussion below), as most users wanted to see the consequences of their choices for their own community in order to use QUEST as a community-based decision support tool. Our conclusion was that QUEST-type models need to operate at a smaller, community-level spatial scale if they are to strongly engage users[6]. This is operationally challenging, as many of the issues of interest operate at larger scales, so regional approaches cannot be discarded, yet local capabilities should be enhanced.

A third lesson was that partners and participants often had very different intended workshop goals than the project members had anticipated, and that these goals require a wide range of tools and supporting materials. QUEST is principally a visioning and communication tool. Though QUEST was not designed to be used as a planning tool (the spatial resolution is too coarse; the topic-area scope too broad), it was often seen as such by users, particularly municipal planners or analysts. We learned to be very explicit about the fact that GB-QUEST was not designed, and could not be meaningfully used, to offer planning advice (e.g., where to add new roads). Instead, its function was to reveal the general consequences associated with different courses of action in order that users could understand the various trade-offs associated with different choices and come to some judgement about what kinds of futures were possible, sustainable and desirable.

A fourth lesson was that different stakeholder and user groups had very different needs and desires. The GBFP had formal partnership arrangements with sixteen government, NGO and private sector organizations and engaged many others through its various forms of public outreach. It was not possible to build a single model, or a single workshop process, that worked for all our partners. This led to the development of several other tools and processes, including refinement of our climate change calculator, our STAR website for helping community groups organize themselves and the Georgia Basin Digital Library (developed in partnership with Natural Resources Canada)(Talwar et al., 2001). However, we learned how difficult it was to design, implement, test and then apply these tools in a meaningful way in a five-year period.

A fifth lesson concerned the challenges involved in communicating complex information in simple, easy to understand formats. In order to involve the general public in the creation of desirable future scenarios, the project created a web-based version of GB-QUEST which users could play on-line. Created scenarios could be submitted to an electronic database. The web version was launched in 2001. It was removed from the web after several months. Dialogue with users indicated that QUEST was too complex to be understood on the web, unless accompanied by live support or explanations. On-line supporting materials, including both simple and detailed descriptions, proved unhelpful to users, and we were unable to support the technical and substantive requests we received via email. This experience reinforced our view that QUEST needed

[6]This is a key reason that the MetroQuest system subsequently developed by Envision Sustainability Tools Inc. operates at the municipal, not regional scale. See http://www.envisiontools.com.

to be used in workshop settings, where members of the project team were able to facilitate the process of using QUEST and provide information on both GB-QUEST itself as well as background information on the issues addressed.

Changing our research process to emphasize facilitated workshops required us to adjust certain goals. The project planned to create a large database of scenarios which could be analysed to develop a picture of the views and preferences of users about alternative future choices. In the event, this did not happen, for several reasons. First, the failure of the web-based version meant that we were not able to collect the large number of scenarios we had intended. Second, building and testing GB-QUEST was much more time-consuming (and expensive) than we had expected so that an operational version only become available late in the five year period of funding we had available. Third, facilitated scenarios were able to create meaningful preferred scenarios, but required significant time investment. In a half-day workshop, for example, we were rarely able to do more than create a single collective scenario, and perhaps one or two iterations. This greatly reduced the number of scenarios created to several dozen scenarios, which in turn reduced the scope of possible evaluation. This database was compiled only in the final days of the project and analysis is currently underway.

The length of time that it took participants to immerse themselves in the scenario-generating process was a major constraint on workshop design and goals. Although GB-QUEST was capable of generating multiple iterations in order to select a desirable scenario, it turned out to be difficult to do more than a single and partial iteration in a half-day workshop, which was often all the time that participants were willing to commit[7]. Much of the workshop time was allocated to background discussions and questions regarding sustainability, questions of clarification concerning how GB-QUEST worked, and to debating each of the 6 to 10 choices presented to participants. Moreover, early versions of GB-QUEST displayed the results without any indication of how they came about (i.e., which input choices had given rise to these results). This was frustrating to users who had to use a trial and error approach to understanding causal linkages. Later versions of GB-QUEST indicated which input variables were associated with each individual output but this was of limited utility given the time constraints on model iteration (each scenario required approximately 4 minutes to generate).

These problems concerning the speed of scenario generation led to a major methodological breakthrough in QUEST design, based partly also on our work in the Geocognito project (Carmichael et al., 2005). This was to create a slightly simplified version of GB-QUEST, run all possible combinations of the model in advance, and store all possible scenarios in a scenario library database. This allows the results of any combination of inputs to be instantly available to workshop participants when an input is chosen or changed, eliminating model run-time from the point of view of the user. This advance is a fundamental improvement in user interaction. Though it came too late to be

[7]Ironically, though most participants were unwilling to take part in a full day workshop, a common response in our post-workshop evaluations was that the workshop was too short.

used in GBFP workshops, it holds the promise of truly interactive and iterative workshop processes, which will allow the social learning and second order backcasting approaches to reach their full potential[8].

A sixth lesson that emerged was that interactivity and visualization can be very powerful ways of engaging users. The fact that a very primitive video-based version of QUEST was run three times a day, five days a week for almost two years at Vancouver's Science World, attracting about 18,000 'players' was strong evidence of the power of such approaches. This has led us to focus even more of our attention on the design and operation of the interfaces of our tools, leading to an ongoing set of successor projects to the GBFP, focused on the development and testing of new processes of landscape visualization, information visualization and adaptive interface design and their use for community engagement processes (Carmichael et al., 2005).

Finally, we discovered that many partners have a significant interest in exploring alternative futures. Indeed it is not too much to say that we witnessed a large latent demand for processes that allow citizens to engage in discussions about the future of their region. Political decision-making processes in Canada are focused on party platforms and campaign promises and offer little opportunity for citizen's to think through and compare different long-term scenarios for their region. Though we were not fully able to meet that demand, we think we have demonstrated the remarkable power of such interactive simulation tools and processes.

3.4 Municipal-scale Case Studies

In order to test the value of our approach at the sub-regional level, we developed three municipal case studies. We chose three jurisdictions that represented very different scales: Bowen Island, a small community of about 3000 people; Richmond, a suburban community of 170,000; and the Greater Vancouver Regional District, an association of 22 municipalities with a combined population of 2 million. In the case of Richmond and GVRD, we engaged with the municipal government organization and offered to hold QUEST workshops with their staff and whoever they felt should be involved from community. In the case of Bowen Island, the process was more informal, and involved contacting residents more directly.

Several findings emerged from the case study analyses. First, despite the compatibility between the QUEST and Precede-Proceed approaches, it proved difficult to combine the general vision of sustainability generated through QUEST play to the more specific implementation and behavioural dimensions of change at the municipal level. Given the large, bioregional spatial scale of GB-QUEST, this was particularly true of the Bowen and Richmond case studies but even in the case of the GVRD, with a much larger land area, a real disconnect existed between the scenario scale and the behavioural/policy scale. This is of

[8]This database approach to model design is a fundamental feature of the MetroQuest version of QUEST being developed by Envision Sustainability Tools and applied across Canada.

course a general problem in trying to link biophysically-derived boundaries to often-smaller political or administrative ones. Our experiences suggest there is a need for the link to the local to be very direct, if users are to be meaningfully engaged.

Second, the case studies revealed the critical importance of the political dimension in such workshopping proceeds. The goals of our case study partners ranged from co-learning to education to manipulation. In one case, the municipal officials we were dealing with did not want either the public or other officials to be involved in the workshops. Each of the three communities ended up using the workshops in entirely different ways, reflecting both the administrative and political priorities at each scale. The choice of participants proved to be critical since different participants might have come up with entirely different conclusions and learnings.

As a third finding, we noted a big difference between those partners who wanted to use the workshops as a vehicle for deciding what sustainability goals might be most appropriate and those who saw the purpose as exploring how best to achieve existing or predetermined goals. This question in turn plays out against the political and administrative situation in which the workshops were being held. A jurisdiction that has just developed and promulgated a set of sustainability goals or policies is likely to be less interested in exploring alternative goals, and more interested in examining how to achieve existing goals, than a jurisdiction without such goals and policies.

A fourth set of findings concerned participants' sense of engagement. One aspect was positive: most of the participants in the three municipal case studies reported in the post-session interviews that the workshops led to an increased sense of 'connectedness', where they developed a more holistic and integrated sense of sustainability issues. However this was counter-balanced by a problem that came up in each of our case studies: our inability to support an ongoing process of behaviour or policy change. In essence the GBFP provided a vehicle where a community or the research team could engage some of its stakeholders in thinking through alternative futures and the changes that might be required to get to those futures, but we had no responsibility or mandate for making any of those changes happen. To the extent that expectations are raised in the minds of participants that these workshops will be part of a process of actual implementation or policy change, then the net effect of holding the workshop can be frustrating and disempowering.

A related finding concerned the scale of engagement. By its very nature, research has a finite duration and intensity, often dictated by the funding available. Problems in the real world, however, are not part-time and do not end when the research is over. The more the research is able to actually connect and provide useful input to such problems, the harder it is manage the time of researchers (especially graduate students who are often the most involved) in ways that truly engage with our partners, while respecting the boundaries of what is possible and realistic without giving rise to unfulfilled expectations. It is critical to make clear at the beginning what the limits and possibilities are, in order to avoid these problems.

3.5 Evaluating the cognitive and behavioural impacts of the workshops

The 'culture and cognition' research component set up several processes to test the impacts of playing QUEST on the mental models of sustainability in players and on the propensity or desire to take actions as a result of the learning in the workshops.

The quantitative findings indicate that younger individuals and males were more likely to endorse the view that the earth is being destroyed by humans. In addition, younger individuals tended to be more positive about conservation and its importance for sustainability. Differences existed between Canadian and non-Canadian born participants. Canadian born individuals were more likely to endorse the consumption of environmentally friendly products, but less likely to be supportive of development and using public transportation.

More substantively, when asked about implementation issues, there was a strong emphasis in participant's response upon transportation choices. This was perhaps in part due to the prominence of such issues in the current political economy of the Vancouver region but in any case, there was evidence of a greater tendency to see linkage between land use and transportation after playing QUEST.

A core finding of the 'Impacts' work was that participants in the QUEST workshops tend to think in a somewhat disorganized way about sustainability. It was impossible to determine whether QUEST increased or decreased the aggregate level of disorganization. Instead it might be said that regional sustainability is an extremely complex issue and the model can at least provide useful shortcuts and heuristics that help people understand the interaction between the subsystems is seeks to represent.

Several other findings from analyzing the workshops and QUEST using a cultural models approach are highlighted elsewhere; here we offer a broad understanding of the implications for thinking about sustainability

Implications of experiential, moment-in-time decisions. QUEST places the user in a position where they are asked to "imagine" on the spot, to think backwards over time and to anticipate a future as well as the steps to get there. There was some indication that participants found it easier to articulate the possible causes of specific outcomes than to anticipate the possible outcomes of specific actions. For example, participants could speculate on the causes that might give rise to lower emissions in vehicles (such as changes in modal transportation shares) more easily than they could anticipate the various effects of changes in such shares on emissions and other variables.

Implications of interdisciplinary focus. QUEST is interactive and it involves making quick decisions, seeing the results of these choices, and then possibly changing them. To respond to this dynamic learning tool, participants must expand upon foundational ideas in order to build an understanding of new and complex ideas. The 'Impacts' work also suggested that playing QUEST

expanded the focus of the sustainability discussion beyond the question of human impacts and considerations toward a more general focus on the well-being of other species, and the environment generally. Given the relative paucity of biophysical data in QUEST, this is a somewhat surprising but positive finding. It suggests that widening the temporal and spatial scope of discussion, and providing even a limited amount of information on biophysical impacts, may contribute to a greater emphasis on environmental values.

Implications of linking causes and effects. QUEST has the ability to generate scenarios and then show the results of the individual variables that gave rise to these scenarios. Our ability to run a sophisticated thought experiment that includes an explanation of what will happen and why is, according to a cultural-based learning theory, a learning process because we can build on, change, or critique existing models. For example, in the transportation scenarios above, it is revealed that participants identify working and shopping closer to home as factors that can reduce the transportation pressure of a doubled population to just 20%.

Implications of including collective as well as individual choices. Learning about one's cultural models is a guided process and guidance is embedded in the design of QUEST. Central to QUEST is a shift in the locus of the action from the individual to the collective. A major design feature of the QUEST model was to reveal the consequences of collective decisions having to do with such issues as land use, transportation infrastructure, urban form and energy systems; this finding is an important confirmation that QUEST has succeeded in highlighting the importance of such collective decisions. Given the strong tendency for much of the environmental education literature to focus on individual choices and behaviours, this is an important result. On the other hand, there was fairly strong resistance on the part of participants to include economic considerations in the sustainability discussion. This may reflect a view that economic considerations usually work against and trump environmental and social effects, but in any case it points to the difficulty of taking an approach that tries to integrate social, environmental and economic factors.

Implications of game-like interface and use of analogy. QUEST draws on the familiar experience of game playing as an analogue for sustainability. Analogies are part of a cultural models theoretical framework. When faced with new information, we employ familiar analogues for making sense of difficult ideas. QUEST uses familiar sources of information (scores, tradeoffs, and iterations) and therefore intuitive sources of understanding, rules, means, and goals.

In sum, and to the extent that these findings can be generalized, they have potentially important implications for participatory integrated assessment processes like the GBFP. QUEST is an important tool for effecting conceptual

change, even when participants are only exposed to it in a single workshop. This suggests that backcasting approaches, where participants try to think through how best to achieve desirable futures, may be more intuitive, more appealing and more comprehensible than more traditional forecasting approaches. It also supports the assertion that sustainable beliefs and practices are indeed an emergent property of a continuing dialogue, to which such a workshop can contribute.

The project was not designed to collect longer-term data by returning to participants after their QUEST experience to see if any of these effects were sustained. Such an approach would likely be a promising avenue for future research. In any case, the short-term effects recorded by this project give some reason for optimism about the cognitive effects of using models like GB-QUEST in participatory integrated assessment projects.

3.6 Teaching and learning

Some GBFP team researchers developed novel approaches to sustainability education for use in secondary school classrooms. This included developing and testing curriculum based on tools developed in the project, as well as studying the relationships between education for sustainability and existing ethical and political features of secondary school classrooms. Considerable work was undertaken to create curriculum material for the project's Climate Change Calculator. Unfortunately, despite repeated attempts, no opportunities were found to use this material in the classroom. Similar, but more fruitful efforts went in to developing curriculum around QUEST. GB-QUEST and it's second-generation predecessor, Lower Fraser Basin QUEST, were tested in several high school classrooms as part of a study of implicit and explicit ethical and political features of secondary school classrooms (Rogers, 2003). It was theorized that only by starting from existing ethical and political understandings of classroom participants could the potential for sustainability education be revealed. The initial study involved a sub-group of a grade eleven Social Studies class (9 students), who met once per week over a three month period. The subsequent study involved two entire grade eleven Biology classes (53 students), meeting 2 to 3 times per week for a three week period.

The initial findings of this work were that the use of QUEST in the classroom encouraged more discussion of the ethical dimensions of sustainability and, in some cases, there was evidence of increased sophistication in thinking about the concept of sustainability. QUEST appeared to be helpful in developing critical thinking skills and linking choices with long-term consequences. Each of these findings were found to depend on the specific teaching and learning practices present in the classrooms in question, including the ethical and political components of such practices. The latter are only rarely explicit. Instead they are typically implicit in participants' understandings, as well as in how the authority underwriting such understandings is established (Rogers, 2003). This finding is consistent with those of other project components concerning the critical role of facilitation in such exercises.

At a more practical level, the use of QUEST in the schools was severely

limited by the technological requirements it imposes. The high schools we considered for this work were typically not easily able to accommodate QUEST in the classroom.

Another key lesson related to implementation was that the success of QUEST in classrooms depends on the capacity to secure a place in relevant learning communities. This means that it is critical to enlist the support of the teachers and school administrators involved, which in turn requires that it be technologically feasible and intellectually appealing to use QUEST, and even more importantly, that QUEST sessions serve clearly defined pedagogical purposes connected directly to specified learning outcomes for specific course. This requires a major investment in developing curriculum material and learning packages and then 'marketing' them to teachers.

3.7 Policies and strategies

One goal of GBFP was to contribute directly to policy development on sustainability issues in the region. To this end, the project hosted a number of 'policy and strategy' workshops, with involvement from provincial, federal and municipal officials. The workshops were designed to complete the last major step in the backcasting process, which links endpoint scenarios to tangible policy interventions in the present. A key goal was to see if GB-QUEST could be helpful in developing a policy agenda that was meaningful to such participants.

The dominant themes in the scenarios that emerged from these exercises was a focus on local government policies, the creation of a level playing field for environmental policy relative to other policy domains, tax shifting policies intended to penalize unsustainable practices and reward sustainable ones, and a focus on the employment that might be generated by investment in sustainability at a regional level. There was an evident tension in these workshops between wanting to use GB-QUEST as a backcasting tool to develop visions of sustainable futures, and a forecasting tool to explore 'what if' configurations. This tension, which also occurred in the case studies workshops, was often expressed as a tension between realistic (forecasting) and unrealistic or idealistic (backcasting) approaches.

Again similar to the case studies workshops, it was found to be difficult to move from the GB-QUEST scenarios to actual policy issues. In the case of the strategies workshops, this seemed to be primarily due to the scale mismatch and time constraints mentioned in previous sections. Participants expressed the view that the sessions should be longer, but the reality was that it was hard to get them to the half-day workshop sessions. As in some of the case study workshops, there was a tendency for expert participants to get rather technical about those areas for which they had expert knowledge, which tended to bore or alienate those with less expertise.

Three major conclusions can be drawn from the strategy workshops. The first is that initiatives of this complexity take time and cannot meaningfully be compressed into a single day. If these initiatives are to become embedded in policy process and if they are to have influence, then participants need to be

given the time to play, learn and understand the tools and processes involved. Secondly, many policy makers were uncomfortable with the idea of developing strategies for scenarios that they were not involved in creating. We entered some of the workshops with pre-fabricated scenarios, while in other cases only a limited number of choices could be made. Many participants would have preferred to develop scenarios that reflected their own version of the future for the region. Finally, many participants found it difficult to distinguish between desirable and feasible policy interventions.

Future applications of Quest in policy settings would give greater priority to the amount of time necessary to develop the skills necessary to use to tool and would seek to embed the entire process more formally in long range planning processes at the organizational or regional level.

3.8 Other tools and engagement efforts

One of the key lessons learned through evaluation of the uptake and use of these tools was the need for tighter coupling between sustainability learning/decision support tools and the process of community-based planning and decision making. This has led to several related academic and public sector research projects focused on exploring new ways to represent sustainability at local and regional levels, and the development of integrated decision support tools to facilitate the uptake, use and critical evaluation of scenario modeling in support of place-based planning and policy development (Tansey et al., 2004; Carmichael et al., 2005). The coupling of Web-based knowledge integration systems and scenario modeling tools within a social learning network provides a venue for exploring viable sustainable development strategies and building coherence in policy negotiations across jurisdictional boundaries. Together, the approaches explored in the GBFP and related follow-on projects help contribute to a wider and deeper understanding of environmental, social, and economic issues, and offer the potential for transforming the ways in which regional urban centres and surrounding rural communities use and share information to make decisions about their collective future.

3.9 Partnerships, project management and interdisciplinarity

Given the array of researchers, disciplines, partners, tools and processes involved in the GBFP, the management and administration of the project was itself very complex. Some significant lessons were learned about how best to manage such a project.

The first critical lesson was the need for a strong and adequately supported project management team. Our initial project budget was heavily weighted to graduate students, post doctoral fellows and research costs. Although we had some budget for project management it quickly became apparent that it was inadequate to handle the burden of research management and coordination, communications and outreach, partner management and workshop planning and

management. Based on advice received at a workshop on these issues we held before the GBFP started (Robinson, 1998), we adopted a fairly centralized budget management process, to counter-act the centrifugal tendencies of university research projects.

Part of the problem in trying to provide support for problem oriented research is that the culture of academia does not lend itself to an extremely interdisciplinary, participatory, task oriented project like the GBFP. While universities around the world are increasingly formally committed to research with these characteristics, this formal support has not yet often carried over into changes in the internal reward structure of the university that would eliminate significant disincentives to such practices, especially for junior faculty, research staff, and graduate students (Moore et al., 2005).

GBFP involved a number of non-academic partners, not just as audiences and users of the research but as co-designers of the research program. Modes of interaction ranged from significant financial support for model building, to provision of data and personnel time for different components of the project, to hosting and organizing workshops, to provision of advice on project design and management[9]. This required a very high level of engagement with key partners, and required the articulation of a co-production model of research whereby the various roles and responsibilities are clearly defined. Since both the financial and in-kind contributions of partners were critical (the original funding from the Social Sciences and Humanities Research Council of Canada of $2.4 million was supplemented by about $3.4 million in cash and in-kind contributions from partners), we developed several principles for partners involvement intended to maximize value to both sides. The first was the principle of "no net increase" where we recognized that our partners were already fully occupied and had effectively no time for additional activities of the scale we were interested in. We could therefore only make a case for such partnership if we could identify joint activities which both sides would have undertaken anyway. The second principle was one of "mutual benefit", whereby these joint activities would provide benefits to both partners if done jointly. We found that partners responded very favourably to approaches based explicitly on these two principles.

However, partner involvement of the type that occurred in the GBFP leads to issues about the control of the agenda. Particularly where issues are politically sensitive there is often some desire on the part of partners to structure and manage the way issues are addressed, and particularly the kinds of solutions that are generated (cf. Baldwin, 2000, pp. 189–190). This reflects the reality within which decision makers must operate, of scarce resources and competing agendas.

Finally, we discovered an unavoidable tension between our desire to engage partners and users actively and contribute to a process of social mobilization around sustainability issues in our region, and our desire to do academically credible research. This in turn raises issues about the question of quality control

[9]This is compatible with, but extends beyond, the "user-collaborator" mode of interaction noted by Shove & Rip (2000, p. 177)

and rigour in participatory research (Baldwin, 2000). While we subscribe to the arguments of Functowicz and Ravetz about the need to think in terms of extended peer communities (Funtowicz & Ravetz, 1993; Gibbons, 2000), it is not very clear how that approach can be institutionalized in the university system.

4 Concluding Remarks

The GBFP operated at the interface of science and society. It goals were to combine expert knowledge and public attitudes, preferences, and values in ways that give rise to a new understanding of complex ecological, social, and economic systems that will be useful to stakeholder and institutions grappling with the practical problems of sustainability. The result is a form of research that corresponds very closely to what Gibbons calls "context-sensitive science" (Gibbons, 2000), a form of Mode 2 knowledge production (Gibbons et al., 1994).

A key characteristic of the GBFP was a fundamental commitment to forms of interactivity that recognize the value-laden nature of science in the policy process and the need for stakeholder input into both the development of integrated assessment tools and the development of scenarios. Such input is required for at least two reasons. First, policy decisions about sustainability are inherently normative. Experts have no mandate, or any special knowledge, concerning such explicitly value-laden questions as 'what is the best path to a sustainable future?' Second, a significant barrier to achieving such futures is lack of public acceptance of the changes required. Politicians cannot make policy decisions that require significant change without a supportive political constituency. Both of these reasons suggest that new approaches to engaging different publics in the complex public policy issues that surround sustainability are essential to build understanding of the policy trade-offs in the public and to learn what trade-offs and choices may be acceptable.

The GBFP pioneered approaches intended to respond to this challenge. We have found an immense interest on the part of participants from the general public and local government agencies in exploring desirable futures. We also found that that this was a difficult and complex process. Timeframes of forty years are no barrier to participation but the spatial scale of a region the size of the Georgia Basin is a challenge for participants who tend to want to focus on more local issues. In virtually all cases, however, participants were interested in exploring the nature of the choices and consequences of their future scenarios. To return to the definition of sustainability discussed earlier, engagement was understood as both a process and an outcome. The researchers slowly accumulated evidence about the types, amounts and benefit of learning about sustainability. We believe that our original instinct was correct: providing information about sustainability in terms of trade-offs and values was critical. What was less well understood was the amount of analysis and exploration necessary to create the appropriate tools to support this dialogue.

The use of interactive tools like QUEST was found to contribute to community activities to promote sustainability at the municipal scale in several

communities. It has been less successful in contributing to the specific needs of regional government policy development. These findings suggest that a preferred audience for such engagement may be individuals and groups, including politicians, who do not have expert knowledge of specific sustainability issues. Classroom pilots of QUEST-based curriculum indicated a possible significant role for such techniques in school curricula.

Users of QUEST are strongly disposed to make choices about preferred futures that reflect a strong environmental ethic. There is a desire to find scenarios that express those values without compromising other goals, such as economic growth or employment. The discussions that ensue explore issues that are not typically part of public and political debates in the region, suggesting a strong latent and unmet demand for such interactive processes. There is some evidence that the processes we undertook had some impact on the mental models and attitudes of various participants and that they were perceived as useful ways to address sustainability issues by those participants. At the same time, we discovered limitations in the approaches we used and were somewhat frustrated by the necessarily finite and short-term nature of our engagement.

An important question raised by the use of computer-based tools in the GBFP is the degree to which information technology can provide ways to engage large numbers of people in sustainability issues without trivializing the issues or misleading users about the consequences of particular choices. One danger is that of converting normative questions of deep moral and political significance into purely technical questions related to the choice of technology or behavior. For this reason the GBFP separated the analysis of the consequences of particular technological and behavioral choices (the realm of the scenario analysis using QUEST) from the discussion of the desirability of those outcomes and the means that may be required to realize them (a discussion that occurs outside the model). As noted above, this latter discussion was often the richest and most informative part of the workshops. In this sense the role of the technology is to provide a basis for stimulating informed discussion of ethical and political questions.

The GBFP was based on the view that science and technology embed normative values that must be made explicit if informed choices are to be made (Jasanoff & Wynne, 1998). The project tested the idea that complex public policy issues can be illuminated by the development and use of scenario analysis tools and processes that allow citizens to express their views about their preferences and point out the consequences of their choices. We discovered that the key to our workshop process was indeed that these scenarios were created not by experts but by the users. This made the process more engaging, created a higher degree of user buy-in to the process and a greater sense of responsibility for the outcomes, led to significant learning, and produced results that embody ethical and moral judgements about the desirability and acceptability of alternative future scenarios. Although we did not accomplish all the initial goals of the GBFP, this seems a fruitful basis for our subsequent work in this field.

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6 Bibliography

Baldwin, S. (2000), 'Interactive social science in practice: New approaches to the production of knoweldge and their implications', *Science and Public Policy* **27**(3), 183–191. 186, 187

Beck, M. B., Fath, B. D., Parker, A. K., Osidele, O. O., Cowie, G. M., Rasmussen, T. C., Patten, B. C., Norton, B. G., Steinemann, A., Borrett, S. R., Cox, D., Mayhew, M. C., Zeng, X.-Q. & Zeng, W. (2002), 'Developing a concept of adaptive community learning: Case study of a rabidly urbanizing watershed', *Integrated Assessment* **3**(4), 299–307. 166

Becker, E. (2002), Transformation of social and ecological issues into transdisciplinary research, *in* UNESCO/EOLSS Publishers, ed., 'Knowledge for sustainable development: An insight into the Encyclopaedia of Life Support Systems', Vol. 3, UNESCO, Paris, pp. 949–963. 165

Berkhout, F., Hertin, J. & Jordan, A. (2002), 'Socio-economic futures in climate change impact assessment: Using scenarios as 'learning machines',', *Global Environmental Change* **12**, 83–95. 166

Carmichael, J., Talwar, S., Tansey, J. & Robinson, J. (2005), Where do we want to be? making sustainability indicators integrated, dynamy and participatory, *in* R. Phillips, ed., 'Community Indicators Measuring Systems', Ashgate Publishing, Ltd., London. 175, 178, 179, 185

Carmichael, J., Tansey, J. & Robinson, J. (2004), 'An integrated assessment modeling tool', *Global Environmental Change* **14**, 171–183. 166, 168

Flyvbjerg, B. (2001), *Making social science matter: Why social inquiry fails and how it can succeed again*, Cambridge University Press, Cambridge. 170

Funtowicz, S. & Ravetz, J. (1993), 'Science for the post-normal age', *Futures* **25**(7), 739–755. 187

Gault, F., Hamilton, K., Hoffman, R. & McInnis, B. (1987), 'The design approach to socio-economic modelling', *Futures* **19**(1), 3–25. 166

Gibbons, M. (2000), 'Mode 2 society and the emergence of context-sensitive science', *Science and Public Policy* **27**(3), 159–163. 187

Gibbons, M., Limonges, C., Nowotny, H., Schwartzman, S., Scott, P. & Trow, M. (1994), *The new production of knowledge: The dynamics of science and research in contemporary societies*, Sage, London. 187

Green, L. W. & Kreuter, M. W. (1999), *Health promotion planning: An educational and ecological approach*, Mountain View, Mayfield. 170

Harrap, R., Talwar, S., Journeay, J. M., Brodaric, B., Grant, R., van Ulden, J. & Denny, S. (2006), The Georgia Basin digital library for sustainable development: A digital library approach to addressing the societal relevance of geoscientific knowledge, *in* A. K. Sinha, ed., 'GeoInformatics: Data to Knowledge', Vol. Special Paper 397, The Geological Society of America, pp. 21–34. 171

Hisschemöller, M., Tol, R. S. J. & Velinga, P. (2001), 'The relevance of participatory approaches in integrated environmental assessment', *Integrated Assessment* **2**, 57–72. 166

Jasanoff, S. & Wynne, B. (1998), Science and decisionmaking, *in* S. Rayner & E. Malone, eds, 'Human Choice and Climate Change, Volume 1—The Societal Framework', Batelle Press, Columbus, OH. 188

Journeay, J. M., Robinson, J., Talwar, S., Walsh, M., Biggs, M., McNaney, K., Kay, B., Brodaric, B. & Harrap, R. (2000), The Georgia Basin digital library: Infrastructure for a sustainable future, *in* 'GeoCanada 2000 Conference', Calgary, Alberta. 171

Kasemir, B., Schibli, D., Stoll, S. & Jaeger, C. C. (2000), 'Involving the public in climate and energy decisions', *Environmental Monitoring and Assessment* **42**(3), 32–42. 169

Kempton, W. & Falk, J. (2000), 'Cultural models of Pfiesteria', *Coastal Management* **28**, 349–361. 170

Klein, J. T. (2004), 'Interdisciplinarity and complexity: An evolving relationship', *E:CO special double issue* **6**(1–2), 2–10. 165

Kok, K., Patel, M., Rothman, D. S. & Quaranta, G. (2006), 'Multi-scale narratives from an IA perspective: Part II. participatory local scenario development', *Futures* **38**, 285–311. 166

Merriam, S. B. (1988), *Case study research in education: A qualitative approach*, Jossey Bass, San Fransisco, CA. 170

Mitchell, J. C. (1983), 'Case and situation analysis', *The Sociological Review* **31**(2), 187–211. 170

Moore, J., F., Quayle, M., Robinson, J., Sawada, B., Spiegelman, G. & Van-Wynsberghe, R. (2005), 'Recreating the university from within: Collaborative reflections on the University of British Columbia's engagement with sustainability', *International Journal of Sustainability in Higher Education* **6**(1), 65–80. 186

Pereira, A. G. & Quintana, S. C. (2002), 'From technocratic to participatory desicion support systems: Responding to the new governance initiatives', *Journal of Geographic Information and Decision Analysis* **6**(2), 95–107. 166

Raskin, P., Gallopin, G., Hammond, A. & Swart, R. (1998), Bending the curve: Toward global sustainability, A report of the global scenario group, Stockholm Environment Institute. 168

Robinson, J. (1998), Interdisciplinarity, interactivity and program management in the Tri-Council Eco-Research Program: A practical guide, Report of a workshop sponsored by The Social Sciences and Humanities Research Council of Canada, UBC. 186

Robinson, J. (2003), 'Future subjunctive: Backcasting as social learning', *Futures* **35**, 839–856. 166

Robinson, J. (2004), 'Squaring the circle: Some thoughts on the idea of sustainable development', *Ecological Economics* **48**(4), 369–384. 167

Robinson, J. (submitted), 'Being undisciplined: Some transgressions and intersection in academia and beyond', *Futures*. 165

Robinson, J. & Tansey, J. (2006), 'Co-production, emergent properties and strong interactive social research: The Georgia Basin Futures Project', *Science and Public Policy* **33**(2), 151–160. 169, 175

Robinson, J. & Tinker, J. (1997), Reconciling ecological, economic and social imperatives: A new conceptual framework, *in* T. Schrecker, ed., 'Surviving globalism: Social and environmental dimensions', MacMillan, St. Martin's Press, London, New York, pp. 71–94. 166

Rogers, L. (2003), Situating ethical and political inquiry alongside inquiry into science in science classroom practices, *in* 'Canadian Society for the Study of Education (CSSE) Annual Conference', Winnipeg. 170, 183

Rothman, D. S. & Robinson, J. (1996), Growing pains: A conceptual framework for considering integrated assessments, Sustainable development research institute discussion paper series, University of British Columbia. 166

Rothman, D. S., Robinson, J. & Biggs, D. (2002), Signs of life: Linking indicators and models in the context of QUEST, *in* H. Abaza & A. Baranzini, eds, 'Implementing sustainable develompent. Integrated assessment and participatory decision-making processes', Edward Elgar, Cheltenham (UK). 168

Savelson, A., VanWynsberghe, R., Frankish, J. & Folz, H. (2005), 'Application of a health promotion model to community-based sustainability planning', *Local Environment* **10**(6), 629–647. 170

Shove, E. & Rip, A. (2000), 'Users and unicorns: a discussion of mythical beasts in interactive science', *Science and Public Policy* **27**(3), 175–182. 186

Swart, R., Raskin, P. & Robinson, J. (2004), 'The problem of the future: Sustainability science and scenario analysis', *Global Environmental Change* **14**, 137–146. 175

Talwar, S., Journeay, J. M., Harrap, R., Robinson, J., Grant, R., van Ulden, J., Biggs, D., Walsh, M. & McNaney, K. (2001), Building geolibraries for sustainability: Balancing form and function to generate knowledge, *in* 'Digital Earth 2001 Conference: Beyond Information Infrastructure', Fredericton, New Brunswick. 171, 177

Tansey, J., Carmichael, J., VanWynsberghe, R. & Robinson, J. (2002), 'The future is not what it used to be: Participatory integrated assessment in the Georgia Basin', *Global Environmental Change* **12**(2), 97–104. 166, 168, 169

Tansey, J., Journeay, J. M., Talwar, S., Robinson, J. & Broderic, B. (2004), 'Navigating pathways between policy and science', *Horizons* **6**(4), 70–73. 185

van Asselt, M. & Rijkens-Klomp, N. (2002), 'A look in the mirror: Reflection on participation in integrated assessment from a methodological perspective', *Global Environmental Change* **12**, 167–184. 166, 169

VanWynsberghe, R., Moore, J., Tansey, J. & Carmichael, J. (2003), 'Towards community engagement: Six steps to expert learning for future scenario development', *Futures* **35**, 203–219. 166, 169

Wilson, C., Tansey, J. & LeRoy, S. (2006), 'Integrating backcasting & decision analytic approaches to policy formulation: A conceptual framework', *The Integrated Assessment Journal* **6**(4), 143–164. http://journals.sfu.ca/int_assess/index.php/iaj/article/view/253/225. 169

Yin, R. (2003), *Case study research: Design and methods*, 3rd edn, Sage Publications, Thousand Oaks, CA. 170