Putting the Cart behind the Horse: Using Interface Driven Modeling to Help Regional Stakeholders Craft an Understanding of Sustainability

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ABSTRACT

This thesis examines the theoretical underpinnings of an innovative approach used in developing a computer based educational tool. The tool itself combines two fundamental design philosophies from a previous modeling and scenario building exercise with an urgent need to more effectively engage regional stakeholders in the complexities and intricacies of sustainability. The result is a powerful learning tool aimed at stimulating dialogue and increasing understanding about regional growth and development issues.

In order for this approach to be useful it was necessary to develop and incorporate a set of design criteria that improves the effectiveness of the simulation. Effectiveness, in this context, is defined as motivating an individual to change their behaviour based upon the information presented by the simulation. In order to understand the link between information and behavioural change, or action, the thesis turns first to the body of research that exists on behaviour motivation, in particular the field of social psychology. A considerable amount of the literature concentrates on explaining human behaviour by way of two key constructs, attitudes and outcome expectancy.

However, as we shall see, attempts to explain environmentally responsible behaviour, which is used in this instance as a surrogate for sustainability, by way of these two constructs have been at best inconsistent. In order to overcome these shortcomings, researchers have developed a number of multi-construct models, which have been somewhat more successful at explaining specific behaviour. When considering the complexities of sustainability, in conjunction with attributes of a computer simulation however, the conclusion is that the set of design criteria must be derived from a more
multi-disciplinary body of research. Conveniently, many of the studies reviewed from the social psychology literature are cognizant of this shortcoming, and lead directly to additional areas of research. For instance the energy conservation literature quickly leads beyond the typical attitudinal and expectancy explanations, and delves into the fields of persuasive and effective communication.

This casting of a wider net ultimately allows for the development of a more comprehensive set of criteria. By using this expanded set of constructs, it is possible to both clarify and strengthen the role of a computer simulation, in so doing, move beyond considering the link between information to action to focus on the relationship between information and understanding. Two additional benefits to considering a wider range of constructs, namely recognizing the importance of the environment in which the simulation is used and understanding the supporting role played by ancillary material, are also uncovered, and their contributions explored.

The result is a set of design criteria that embody the characteristics of a new approach to modeling known as Interface-Driven Modeling (IDM), which weights equally the need to employ a powerful user interface with the necessity of using credible models and data. Leveraging the power of the Socio-Economic Resource Framework (SERF), and its fundamental design philosophies Backcasting and the Design Approach to Modeling, IDM becomes a third key departure from more traditional socio-economic modeling exercises.

The manifestation of this approach is the Quasi-Understandable Ecosystem Scenario Tool (QUEST), a product of the University of British Columbia's Sustainable
Development Research Institute. Although QUEST embodies the philosophies of Backcasting and the Design Approach to Modeling, this thesis concentrates on exploring the theoretical foundations of IDM. Interestingly however, the IDM approach has been developed as much from the heuristic process of developing QUEST as it has from the literature reviewed in this thesis.

By employing the design criteria explored in this thesis, it is argued that QUEST and its delivery methods can be combined to increase public understanding about sustainability in the Lower Fraser Basin of British Columbia. This thesis contends that this elusive public understanding, not solely information provision, is an important step towards creating an increased commitment to sustainability from regional stakeholders.
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PREFACE

This is an innovative thesis for several reasons. First, it describes the author's role in a larger, collaborative project – the design and development of the Quasi-Understandable Ecosystem Scenario Tool (QUEST); a computer based education tool. Second, it is composed of two separate, yet equally important components: 1) this paper, which explores both the theoretical and historical roots of the software and describes how the theory manifests itself in the software and 2) the software itself, which is contained on the CD-ROM that accompanies this document. Finally, the thesis describes only a portion of the ongoing journey that has characterized the development process. Indeed QUEST, along with our understanding of this modeling approach and the implications of sustainability itself, continues to evolve.

I am cautiously optimistic that QUEST will someday be recognized as the catalyst for a Kuhnian paradigm shift in the discipline of scenario creation and futures modeling (Kuhn, 1970). In addition, I am hopeful that this thesis will serve as an example of a similar paradigm shift that needs to take place in academic research and study, reflecting recognition of the increasing importance of interdisciplinary research and collaborative endeavours.
ACKNOWLEDGEMENTS

I would like to thank a number of people, without whose help neither this thesis nor QUEST would likely have ever been completed. First and foremost fellow QUEST creators Dr. John Robinson and David Biggs. John’s passion for teaching and devotion to an innovative and often unpopular approach to thinking and communicating about sustainability infected me the moment I met him. Dave Biggs, a.k.a. Mr. True to Life, who was John’s partner in crime when I first arrived at SDRI, and is now mine at Envision, has been the perfect compliment to my role as Mr. Fun to Use.

QUEST would never have been completed without the efforts of many other researchers, grad students and champions, all of who have supported the cause and contributed tremendously on many different levels.

I would also like to thank the members of my advisory committee. Dr. Maria Klawe, in addition to an unimaginable schedule and remarkably dynamic career found the time to be not only a member, but an enthusiastic supporter, advisor and ally to both QUEST and my work. Imperative to my finishing at all has been Dr. Les Lavkulich, who managed to convince the sages at UBC that my thesis was worth waiting for, which is particularly admirable given its somewhat unconventional nature.

Of course I could not have completed this endeavour without considerable support from friends and family, but particularly Jan, who has endured endless revisions to both QUEST and this thesis. At least now the thesis is done.
1.0 INTRODUCTION AND CONTEXT

The intent of this introductory section is to explain the rationale for developing a computer based simulation as a means of helping people understand sustainability. The first part explores the need for and urgency of such thinking, while the second traces the roots of computer simulations and the impetus for the design approach employed.

TIME TO EMBRACE SUSTAINABILITY

The beleaguered state of Canada's Maritime fisheries is indicative of an increase in both the frequency and magnitude of responses from the global ecosystem to the impacts of human activity. The Atlantic fishery is now virtually non-existent, and despite much rhetoric about change, one could infer from the on-again off-again talks between Canada and the US that the Pacific salmon fishery is destined to a similar fate.

While there would appear to be an increasing awareness of environmental issues, as evidenced by the frequency these issues are found in the media, actions taken in response to these tensions are for the most part inadequate to remedy the situation. Although it is true that recycling programs have reduced the amount of solid waste we produce, and that CFCs are no longer used in cooling systems and aerosol cans, on numerous other fronts the situation is much less impressive.

Researchers Robinson and Tinker (1997) note that, "[a]s we move towards the twenty-first century human institutions, from local to global, are facing a range of ecological, economic and social challenges" (p. 71). The struggle to reconcile these three imperatives, as Robinson and Tinker refer to them, is at the foundation of sustainability
research. They point out the inadequacy of thinking about each of these imperatives separately, and as an alternative, suggest that an interdisciplinary approach is required.

Although developing a public understanding about these issues is likely a daunting task for the average person, many sustainability researchers agree that it is a priority. In British Columbia's Lower Fraser Basin (LFB) for instance, in part as a result of a healthy economy and in part due to a striking natural setting, this tension exists due to both rapid population growth and increasing urbanization. Sources estimates that in the next 30 years the region's population will nearly double, rising above the 3 million level early in the next century, forcing regional planners to balance long term planning objectives with short term pressures (GVRD, 1993; McMartin, 1994).

Current development trends in the LFB could lead one to surmise that the region’s inhabitants appear to be on the one hand aware of the issues, while on the other either unwilling to commit to or unable to comprehend what needs to be done to bring about change. This lack of progress cannot be attributed solely to the region’s planners and governments; regional stakeholders need to bear some responsibility for ensuring the continued ecological, social and economic health of their region. Exploring and understanding this paradox is at the heart of this thesis.

**Harnessing the Power of Computer Models**

One approach for improving public understanding about regional issues has been to harness the power of computer simulations and models. *Limits to Growth* (Meadows et al., 1972) spawned an interest in the use of computer models as a means of helping people grapple with complex social issues. In Canada, one thread of this new discipline
emerged at the University of Waterloo, and the Sustainable Society Project (SSP) (Robinson et al., 1996a; Robinson et al., 1996b).

One of the key tools SSP researchers used to explore alternative futures in Canada was the Socio-Economic Resource Framework (SERF); a computer based modeling tool. The design of SERF was guided by the premise that rather than focusing on forecasting probable futures, models should help users explore alternative futures using Backcasting techniques (Robinson, 1988). Additionally, by employing The Design Approach to Socio-Economic Modeling, which makes the user part of the model’s feedback system, SERF was better suited to creating and exploring alternative future scenarios (Gault et al., 1987; Hoffman and McInnis, 1988). Although these two key design philosophies represented a crucial departure from more traditional modeling exercises, there was still one key component missing.

The next step in this evolution of modeling is a computer simulation being developed at the University of British Columbia’s Sustainable Development Research Institute (SDRI). The Quasi-Understandable Ecosystem Scenario Tool (QUEST) aims at helping regional stakeholders grasp the complexities and intricacies of sustainability. Although researchers in the field of computer modeling and simulation continue to develop methods aimed at fostering understanding about complex issues, QUEST is based upon an innovative design philosophy that focuses development on the user interface before any substantive modeling takes place.

As a result of their involvement with SSP project, SDRI colleagues John Robinson and Dave Biggs recognized the importance of creating a computer simulation based on
the design approach and capable of backcasting, but that was significantly more user-
friendly and fun to use. This new scenario-building environment would enable users to
create and explore alternative futures based upon real data in a thought-provoking yet
entertaining way. When I arrived at SDRI in the fall of 1993, I added my software
development skills and an interest in exploring how to make computer based learning
tools more effective to the SSP/SERF experience of Robinson and Biggs.

During this time QUEST was conceived as a means of synthesizing much of the
research being undertaking from the Lower Fraser Basin Eco-Research Project (LFB
Project). The LFB Project was a 4-year, interdisciplinary project aimed at exploring the
impacts of human activity on the ecologically sensitive Lower Fraser River Basin of
British Columbia (Healey, forthcoming). The design of QUEST was intended to reflect a
tension between being Fun-to-Use and being True-to-Life, which served to illustrate our
fundamental design philosophy; that making the simulation interesting was as important
as making it realistic.

THE MISSING STEP: INTERFACE DRIVEN MODELING

As a result of the experience with SERF, it was decided that the development of
QUEST should start before the technical modeling issues were finalized. Thus, the focus
of the early development activity was on the creation of a powerful, thought provoking
user interface. The decision to begin developing the interface before the models were
completed is the point at which a third, crucial departure was made from the path of
traditional modeling exercises. By focusing on the interface before the underlying
models, QUEST has been developed to be user-friendly first, and a computer model
second, enabling us to create a piece of software that, thus far, has been very effective at stimulating debate and discussion about sustainability.

Not only did this departure result in a simulation that is fundamentally user-oriented, but it also influenced the development of the underlying models. Rather than attempting to create models of the various regional systems, such as land use and transportation, that were highly sophisticated and precise, the QUEST team developed models that were more concise, and easy to understand. This departure from a more traditional modeling regime emanated primarily from the fact that the interface that had been developed would not support overly complicated detail-laden outputs. This result is indicative of a process that values Fun-to-Use as being equally important as True-to-Life, and is at the heart of an approach to modeling we refer to as Interface Driven Modeling.

The development of the Interface Driven Modeling (IDM) approach has evolved in parallel with QUEST, and has several key characteristics. First, the approach requires that the design and development of the scenario building interface be a fundamental component of the project. The need to make a model understandable by anyone other than a modeler is not of primary concern to many in the discipline of computer modeling, yet it was the first and one of the most important steps in the process of building QUEST.

Second, the development of the modeling interface needs to take place in an environment that is not prejudiced by data issues or modeling objectives. This means that the interface needs to be developed first and that subsequently the data and models are designed and build to suit the interface, as opposed to the reverse. This allows the
interface development to be guided by a need to be effective and user-friendly, and allows consideration of design criteria that reflect this thinking.

Third, that these design criteria be based on solid theoretical foundations, and reflect an understanding of the complexities and intricacies of imparting understanding about a concept as sophisticated as sustainability. This entailed an exploration of the fields of social psychology, behaviour motivations and effective communication, disciplines not ordinarily considered by computer modelers. Although initially difficult, this foray into other social sciences has significantly strengthened not only QUEST, but also the understanding of how to make use of such tools. It has led to a clearer picture of the difficulty people have in understanding and embracing sustainability, and helped to improve our effectiveness in doing so.

Finally, QUEST has benefited from a heuristic design process. The development has been influenced not only by theoretical attributes, but also from feedback about previous versions, the combination of which have greatly affected both model design, and subsequently data collection. Indeed this point underscores the premise that QUEST represents simultaneously a powerful tool for exploring alternative futures and an equally important means of researching our effectiveness in such endeavours. Not only does QUEST help people understand sustainability, it aids researchers who strive to improve the means of delivering this understanding.

**Thesis Outline and Author's Contributions**

During the 5 years that QUEST has been under development the conceptual framework and fundamental design principles have been continually evolving. In fact
this heuristic process has been fundamental to QUEST’s evolution into a powerful learning tool. My role has been to develop these design criteria, and in the process of crafting QUEST from the conceptual framework, ensure that the development embodied these criteria.

The conceptual framework for QUEST evolved from design meetings and discussions involving John Robinson, Dave Biggs and myself. These discussions tended to focus on the strengths and shortcomings of preliminary versions, and resulted in a number of key design changes. During the process of developing this framework I was the key link to the theoretical constructs explored in this thesis.

These design discussions, coupled with my increasing theoretical knowledge helped to shape the development of QUEST. Along with this fundamental design work on the interface and subsequently the models, my continued exploration of the theoretical explanations of the link between information and action enabled me to develop new and innovative computer based presentation and display techniques, which served to further improved QUEST’s effectiveness.

My initial interest in making the software user-friendly has taken me in new and often unexpected directions. Following this introductory section, the thesis investigates the link between information and action by exploring the body of research that exists on behaviour motivation, in particular the field of social psychology. For me, these previously undiscovered disciplines have provided some valuable insights in the development of an effective user interface.
Subsequently, the motivation for environmentally responsible behaviour, used as a surrogate for pro-sustainability behaviour, is explored. The intent of this literature review is to uncover the key contributors to behaviour motivation, and determine if these factors can be influenced by QUEST. The result is somewhat surprising however, as it led to the recognition of the value of taking a broader approach, based on a number of constructs rather than trying to focus on a key behaviour motivator.

This in turn leads to a change in perspectives, from exploring the information-action link to investigating the more relevant process of transforming information into understanding. By reexamining some of the literature from earlier sections in this new light, in addition to exploring literature on effective communication and the use of computers in education, it is possible to better understand the role a computer simulation can play in the process.

The third section extracts the salient points from the theoretical discussions, and synthesizes this information into a set of design criteria. A crucial component to the QUEST approach is the recognition of the importance of indirect factors. In fact, the inclusion of these external factors is one of the key characteristics that differentiate QUEST from more traditional modeling exercises.

In the next section the manifestation of these design criteria in the most recent version of QUEST is discussed. As a result of applying these criteria, QUEST has developed into a powerful learning tool, capable of engaging regional stakeholders in the process of crafting and understanding future scenarios.
Finally, there is some discussion of the implications of developing this set of design criteria, and the implications this has for further QUEST development and applications.
2.0 THEORETICAL FRAMEWORK

"Grounded in the work of economists, statisticians, and philosophers, the study of behaviour decisions has become an essentially interdisciplinary endeavour, with important contributions coming from cognitive, social and organizational psychology." (Ajzen, 1996: p. 297)

Thinking about what motivates a particular action is very common. One researcher (Aronson, 1995) suggests that many people are amateur social psychologists because "most of us spend a good deal of our time interacting with other people" (p. 7). However, amateur suppositions about behaviour motivation are likely to prove insufficient in trying to thoroughly understand the process. Fortunately, researchers in the fields of cognitive, social and organizational psychology study and conduct experiments in order to understand what influences people's behaviour. As a precursor to developing a set of design criteria, the following section reviews the literature describing the theory and application of behaviour research in an attempt to understand the link between information and action.

FUNDAMENTAL PRINCIPLES

Many researchers maintain that attitudes are an appropriate and effective indicator of behaviour (See for instance Gross and Niman, 1975; Kim and Hunter, 1993; Sutton, 1998). The premise that attitudes can be used to explain behaviour was first documented by Allport, (1954), and is at the foundation of a number of models of human behaviour. Elms (1976) notes that grasping the relationship between beliefs, values and attitudes is paramount to understanding attitudinal-behaviour models.
Beliefs are based upon our cognitive understanding of how things are, how they work, and how they relate to other things. This understanding may be based upon our own knowledge, or upon acceptable social views (Elms, 1976). Values are affective, meaning they are based on emotions as opposed to knowledge, and indicate a person’s wishes or desires. Unlike beliefs, values always have some behavioural implications, since they tend to indicate how a person will behave in a given situation. Finally, attitudes, which Gleitman (1995) defines as an “emotionally tinged social view” (p. 420) describe an individual’s positive or negative feelings about an object. They can be thought of as combining cognitive (beliefs) and affective (values) components, and are widely cited as good predictors of both behaviour and behaviour intentions (Ajzen, 1996).

Attitudes are characterized as being evaluative; in other words they are thought to make up some sort of mental position that people hold about an object. People hold attitudes about many different things, and these attitudes vary from person to person. People’s attitudes, although thought to be fairly enduring, can change if they are presented new information, or they find themselves acting in a manner that is not consistent with their attitudes. If attitudes are general evaluations people have about themselves, others, issues or objects, then, it is posited that these dispositions can be used to explain why people behave in a certain manner. For example, individuals who hold the attitude that guns are a prime source of violent crime would be likely to support strict gun control legislation.

The literature is rich with examples that both support and criticize the attitude-behaviour link (See for example Sutton, 1998). Although there is contention on how
attitudes affect behaviour, many researchers agree that in certain circumstances there is some correlation between attitudes and behaviour. Elms (1976) cites a number of factors that may contribute to the inconsistency that often exists between attitudes and behaviour. Of particular interest is the premise that behaviour is rarely the result of a single attitude.

Explanations of behaviour based upon outcome expectancy or outcome value are also common in the literature (Mitchell, 1974; Bolles, 1972). This type of theory attempts to explain behaviour in terms of an individual expecting or valuing the outcome of a particular action. According to Maddux et al. (1986),

"the tendency to perform a behaviour is the product of the reinforcement value of the expected outcome and the expectation that a specified behaviour or behaviours will produce that outcome" (p. 783).

For instance, an individual's actions might be guided by economic incentives, often the rationale for choosing one product over another, or because a particular outcome gives a perception of value or desirability, as might be the case when choosing a travel destination.

Ajzen and Fishbein's (1980) Theory of Reasoned Action (TRA) is an often-cited behaviour model based on outcome expectancy and value theory. The TRA postulates that an individual's intention to act is based upon a positive or negative evaluation of performing the action and their perception of the social significance of performing the action. Ajzen (1988) notes that "people intend to perform a behavior when they evaluate it positively and when they believe that important others think they should perform it" (p. 117).
As is the case with attitudes, there is considerable literature on the effectiveness of outcome expectancy based constructs at explaining behaviour. For instance, Maddux et al. (1986) determined that both outcome expectancy and outcome value had an independent association with behavioural intentions.

ENVIRONMENTALLY RESPONSIBLE BEHAVIOUR

Since the impetus for this work is the importance and urgency of helping regional stakeholders embrace sustainability, it would be desirable to explore research on sustainability-motivated behaviour. Unfortunately, there exists no literature that deals directly with the manifestation of such behaviour. Thus the following section reviews the literature on environmentally responsible behaviour, which is used as a surrogate.

The research on environmentally responsible behaviour ranges from exploring the motivations for energy conservation to studying recycling, consumption patterns and transportation choices. Reinforcing the supposition that attitudinal and rational choice models, although frequently cited, are inconsistent, Oskamp et al. (1991) found that individuals with pro-ecology attitudes were not more likely to engage in recycling than individuals who did not hold pro-ecology attitudes.

Literature on the effectiveness of energy conservation programs provides additional criticisms of both the attitudinal and outcome expectancy models’ ability to explain consumer behaviour. Gonzales et al. (1988) and Robinson (1991) both note that programs based on the premise that people will adopt behaviour because of pro-environmental attitudes or economic incentives have not been effective. Stern (1992), while critical of programs based on these principles, places the blame for failed conservation programs on
both psychological researchers and energy conservation program designers. He notes that each side takes too simplistic a view of the other's possible contribution to the problem.

Perhaps, Newhouse (1990), who is guardedly optimistic about the link between attitudes and behaviour, describes the situation best.

"Although there is a recognized discrepancy between attitude and behaviour in many studies, the discrepancy may partially be the result of poor research design and confounding factors, such as social norms. The closer the target and action entities across attitudinal and behavioural measures, the greater the use of "multiple act" criteria, and the smaller the normative expectations expressed by the researcher or by society, the higher the consistency between measured attitudes and behaviours." (p. 31)

Her sentiments suggest the importance of considering other factors. In fact there is considerable literature that explores the relationship between behaviour and other constructs. Some researchers contend that values, defined by Dunlap et al. (1983) as "the standards that guide or determine attitudes and behaviour" (p.146), can be used to explain behaviour. Again the literature is somewhat contradictory. Dunlap et al. (1983) found a correlation between individual's ranking of personal values and their tendency towards recycling. On the other hand, a Swedish study found that individuals with pro-environmental values actually used more electricity that those without (Keiler-Arvedson, 1994).

The theory of cognitive dissonance is also cited in the literature as an explanation for environmentally responsible behaviour. Based on the work of Festinger (1957), the
theory states that people will try and maintain consistency or consonances between cognitions they feel are related. Cognitive dissonance occurs when an individual is made aware of an inconsistency between two cognitions. This dissonance would arise for example when an individual's actions were inconsistent with his or her attitudes. In such a situation the individual is compelled to reduce this feeling of dissonance by changing either the underlying attitude or the behaviour.

In an experiment to explore water conservation behaviour, Dickerson et al. (1992) found that students were more likely to engage in water conservation if they were reminded of their attitudes, and subsequently found themselves engaging in behaviour that might contradict these attitudes. In contrast, Stern (1992) contends that people who change energy conserving behaviour, such as turning off lights, do not achieve an associated change in attitudes about energy use.

The literature reviewed supports the contention that neither attitudinal or rational choice models are singularly effective in explaining behaviour. In addition, the effectiveness of understanding behaviour via other individual constructs such as values and cognitive dissonance was briefly considered. In the end however, the literature will confirm that a multi-construct explanation of environmentally responsible behaviour is the most widely supported.

In a meta-analysis of the literature Hines et al. (1987) surmise that "[t]he prediction of responsible environmental behaviour is not a simple process. It appears to involve a number of variables, none of which are likely to operate without interacting with others." (p. 6). The variety of factors, and their complex relationship to one another is illustrated
effectively by the researchers in their proposed model of responsible environmental behaviour, shown in figure 1.

Thus, it seems reasonable to postulate that not only are there a host of factors that could affect behaviour, but that any of these factors could be the principal motivating factor, or alternatively, that none play a role in influencing behaviour. As such, it is my contention that considering a wide range of factors will yield a clearer picture of the motivation for pro-sustainability behaviour.

**Taking a Broader Approach**

Aside from the shortcomings of using attitudes or expected outcomes as the explanation for behaviour the preceding discussion highlights the fact that these deficiencies are further exacerbated by the very nature of complex social issues. According to one researcher (Robinson, 1991) “[t]he problems with both rational-economic and attitudinal models of energy-using activities appears to be that they are too simple to grasp the real-world complexities of such activities.” (p. 635). He argues that energy conservation programs should consider a broader range of factors because such issues are often fraught with uncertainty, abstraction and ambiguity.
Applying this thinking to a re-examination of the meta-analysis of Hines et al. (1987), in particular the variables they uncovered as correlating with environmentally responsible behaviour allows for the development of a more holistic set of design criteria. Their meta-analysis considered 128 studies, the majority of which explore the correlation between the variable and a reported likelihood to engage in environmentally responsible behaviour. Table 1 indicates the correlation between the variables, shown in the first column, and the reported likelihood of action, seen in the second column. The third column indicates how many times that variable was cited in the 128 studies reviewed.

Although the authors noted that attitudinal constructs were cited most frequently, they reported that attitudes did not have the highest correlation with behaviour intentions. Verbal commitment had the highest correlation, while the second highest was with the locus of control variable. Locus of control, defined as "represent[ing] an individual’s perception of whether or not he or she has the ability to bring about change through his or her own behaviour" (Hines et al., 1987: p. 4), is considered by many researchers to be a crucial component in the motivation of environmental behaviour. (See for instance, Maddux et al. 1986; Axelrod and Lehman, 1993) After attitudes, personal responsibility is the next highest-ranking factor.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Corrected correlation coefficient</th>
<th>Number of values based on*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verbal commitment</td>
<td>.491</td>
<td>6</td>
</tr>
<tr>
<td>Locus of control</td>
<td>.365</td>
<td>14</td>
</tr>
<tr>
<td>Attitude</td>
<td>.347</td>
<td>51</td>
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<tr>
<td>Personal responsibility</td>
<td>.328</td>
<td>6</td>
</tr>
<tr>
<td>Knowledge</td>
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<td>17</td>
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<tr>
<td>Education level</td>
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<tr>
<td>Income</td>
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<td>Economic orientation</td>
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</tr>
<tr>
<td>Gender</td>
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<td>4</td>
</tr>
</tbody>
</table>

* Several studies reported data on more than one variable

Table 1. Summary of Meta-analysis Findings for Descriptive Studies. Adapted from Hines et al., 1987.
While it might be difficult to conceive of a computer simulation that could directly induce a verbal commitment, it is realistic to imagine that a simulation could help a user increase either their feeling of competence about sustainability issues, or their sense of personal responsibility. In the context of the meta-analysis of Hines et al. (1987), knowledge was broadly defined as something that "entailed not only knowledge of environmental problems and their consequences, but may also have pertained to knowledge of how to take action on a particular environmental problem" (p. 3). Thus, it is my supposition that a properly contrived simulation can broadly increase knowledge, and in so doing directly address the top five factors highlighted by Hines et al. (1987).

The key is to enable people to assimilate the information they receive more effectively. John Hiles (1996) argues that the difficulty people have in making sense of complex issues can be attributed, at least in part, to their inability to form a coherent mental model of the problem. As a result, information about the issue serves only to further confuse and frustrate, as opposed to increase understanding. Consequently, people tend to feel alienated by large, complex systems such as science, technology or politics, a frustration that is often manifested as a negative generalization, such as 'all politicians are corrupt'.

Hiles (1996) likens the situation to trying to cope with static or noise, which, as is the case with television for instance, only makes the picture less clear, and more difficult to

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1 John Hiles is currently the Chief Information Officer of Thinking Tools, a company that evolved from the Business Division of Maxis Corporation, the developers of SimCity. SimCity, a computer simulation that is discussed in a later section, was a fundamental inspiration for the development of QUEST.
understand. He contends that people who don’t have a good mental model of an issue cannot reconcile additional information with their conception of the issue. As a result the additional information is treated as static, and is either misinterpreted or ignored altogether. It is my contention that helping people overcome this sense of frustration and enabling them to form a mental model is a task ideally suited to a well-designed computer simulation.

The remaining indicators, namely education, income, economic orientation, age and gender, are demographic in nature. These factors deal with the make-up of the audience and, although they will not directly influence the design of the simulation, as we shall see these situational factors are vital to the simulation’s overall effectiveness.

NEW INSIGHTS: FROM INFORMATION TO UNDERSTANDING

Understanding the process by which information presented by a computer simulation is transformed into knowledge is crucial to developing an effective learning tool. Fortunately, some researchers recognize the misconception that presenting information is not the same as imparting knowledge.

“Though few would argue against the importance of information, the problem of communicating – of transforming information to knowledge- is often disregarded. These models assume that information need only be presented and that... the important informational variable is simply the amount of information the individual is given” (Kearney, 1994: pp. 420-421)

Historically, a lack of information was thought to be indicative of the difficulty people had in understanding complex social issues. In contrast, Postman (1992) argues
that the problem is more accurately characterized as trying to cope with the plethora of information available. It may well be noted when looking back on this decade that the concept of information technology came to be thought of as being synonymous with the management of rather than the delivery of information. Postman (1992) contends that information has effectively become the garbage of the nineties.

"From millions of sources all over the globe, through every possible channel and medium... information pours in. Behind it... is an even greater volume of information waiting to be retrieved. Information has become a form of garbage, not only incapable of answering the most fundamental human questions but barely useful in providing coherent direction to the solution of even mundane problems." (pp. 69-70).

In the field of sustainability research, Tinker (1996) surmises that "[t]here may already be too much public awareness of sustainable development. What is needed is more public understanding." (p. 1). He notes that "building more sustainable societies require[s] pragmatism, compromise and above all a real understanding of the way economic, social and ecological systems tick" (p. 1).

Kearney (1994), in her writing on helping people understand global change, reinforces the supposition that simply presenting information about complex issues has not been useful. "Information aimed at encouraging conservation behaviour and ameliorating environmental problems associated with global change has been largely ineffective." (p. 419).
She notes that the acquisition of knowledge, the process of transforming information to understanding, is quite complicated. The human brain is very selective about what it stores, and how it stores it. Anything that is perceived as uninteresting, confusing or irrelevant is not likely to be stored at all. Additionally, any information that is retained is likely to be filtered in some way by the person's own beliefs, ideas and experiences (Kearney, 1994).

Developing tools that help people make sense of complex seemingly unrelated issues is an important step. A properly contrived computer simulation has the power to present a vast amount of information that is condensed, yet still coherent and understandable. Furthermore, by using powerful multimedia tools such as graphics, video and sound, critical information can be framed so as to highlight key facts, salient points and unexpected linkages. It gives users the opportunity to form their own mental model of how the complex system functions, and enables them to relate these issues to their own personal experiences.

**Effective Communication**

The literature contains numerous examples extolling the virtues of effective communication techniques. For instance, Stern (1992) notes that

"[w]ith information, what matters is not only how much is made available, but how it is conveyed. Social psychologists and marketing professionals know that information is more likely to change behaviour when it is specific, vivid and personalized." (p. 1227)
He recognizes that energy efficiency programs failed because they simply made information available without considering how to make people pay attention to the message. Similarly, Costanzo et al. (1986) were able to demonstrate that ineffective communication manifests itself as a lack of understanding about conservation issues. Figure 2 depicts their measure of claimed familiarity vs. actual understanding of several conservation programs. They recommended that conservation programs adopt effective communication techniques to become more penetrating.

In fact, Gonzales et al. (1988) were able to improve the effectiveness of a home energy audit program by training the auditors in four principles of effective communication: vividness, personalization of statistics, including commitment through personal involvement and information framing. Their research concluded that individuals were more likely to engage in energy saving practices when visited by auditors who received the training.

Much of the literature reviewed in this section is based upon the work of Borgida and Nisbett (1977). They are attributed with recognizing that information is most effective if it is:

1. Vivid,
2. Concrete and
3. Highly personalized.

Similarly, Kearney (1994) suggests that there are a number of characteristics for making communication about complex social issues effective:

1. It must be interesting,
2. It must present abstract information in such a way that the reader can imagine it,
3. It must relate to the reader's existing knowledge and
4. It must present global issues on a human scale.

In addition, Andrey et al. (1996) noted that "[d]espite the abundance of expert knowledge on these topics, and the many public communications about global warming, there has been little associated change in human behaviour." (p. A-50). In response, they have developed a set of communication guidelines for dealing with global climate change issues:

1. Identify and characterize the intended audiences
2. Work on improving the credibility of the communicators
3. Develop communication partnerships
4. Break down complex messages into components and build the knowledge base one step at a time.
5. Be proactive/candid/open about uncertainty
6. Use analogues, parables, comparisons, examples and indices in appropriate ways to enhance understanding
7. Focus on actions. Concentrate on what is practical for different groups.

2 Although referring to text, Kearney notes her characteristics apply to other communication modes.
Ameliorating these lists will provide a solid foundation for the simulation's design criteria. Before doing so however, it would be prudent to explore some of the concerns the use of computer based learning tools has raised.

**Computers Are Not Infallible**

Long a powerful tool in the workplace, computers are becoming increasingly common in the home, where they are capable of, among other things, connecting users with the seemingly boundless world of the Internet. Yet, despite their seemingly limitless potential, there is a need for tempered enthusiasm.

A technology bias disadvantages an individual or group due to their lack of understanding or comfort with the technology. For example, according to a 1994 survey 1/4 of all U.S. adults have never so much as used a computer, programmed a VCR or even learned how to adjust the push buttons on their car radios (Harper, 1994). Clearly a computer based learning tool needs to recognize that not everyone is comfortable with this technology.

The power of computer games as an educational tool is well documented (See, for instance, Malone and Lepper, 1987a; Klawe and Phillips, 1995;), although not without criticisms. For instance, according to Grundy (1995), although capable of creating a powerful learning environment, computer games do not appear to offer any serious advantages over traditional methods. Given the costs involved, she raises some questions about the viability of this technology in a classroom setting.

Another study points out that a careful balance is required between the fun and learning elements in order to ensure that students, who may be initially attracted by a
gimmick, stay interested in the long term, so that real learning can take place (Malone and Lepper, 1987b). Additionally, Postman (1992) raises concerns about the emphasis computer learning places on individual problem solving skills.

"In introducing the personal computer to the classroom, we shall be breaking a four-hundred-year-old truce between the gregariousness and openness fostered by orality and the introspection and isolation fostered by the printed word. Teachers, while emphasizing print, have allowed orality its place in the classroom, and have therefore achieved a kind of pedagogical peace between these two forms of learning. Now comes the computer, carrying anew the banner of private learning and individual problem-solving." (p. 17)

Other researchers agree, and caution that the use of computer tools needs to be considered in light of the entire learning process. Klawe and Phillips (1995) note that the learning process was often enhanced when students used non-computer materials to augment their computer work. They point out the designers of computer educational tools often include all the necessary tools for learning with their software, such as a dictionary with a word processor, but they caution that "making computer use more efficient for learners can sometimes result in less effective learning" (p. 212).

Finally, Rappin et al. (1997) recognize that a simulation needs to find a balance between simply presenting information versus allowing the user to participate in the simulation creation process. Just presenting information is not effective, yet trying to encourage the user to perform too complex a task is likely to be equally unsuccessful. They note that "[o]ur hypothesis is that merely watching a simulation is not enough to
trigger learning, the student must have some hand in creating the model that drives the simulation” (p. 479).

The preceding discussions highlights the fact that computer based education is a potentially powerful yet still somewhat controversial technique. Striking a balance between learning that is made fun and the ability to appeal in the long term is crucial. So too is recognizing that computer based learning tools should be used in conjunction with other tools that emphasize group learning techniques.
3.0 DESIGN CRITERIA

…it is not detailed complexity but rather comprehensible simplification that gives rise to understanding. And it is on understanding alone that a critical assessment of model credibility must ultimately be based (Holling, 1978: p. 98)

Although the intent of this section is to develop a set of design criteria, this is not the first set of design criteria that has been developed as part of the process of creating QUEST. Refinement of these design criteria has been part of an ongoing, iterative learning process, which has involved using feedback from earlier versions of QUEST to clarify and reshape the objectives of future versions.

Thus, this section considers the rationale for choosing the criteria in addition to considering the criteria themselves by drawing not only on the material discussed thus far, but by incorporating what was learned from previous versions of QUEST.

KEY LESSONS

This thesis began by exploring theoretical and empirical behaviour research literature as a means of developing a set of design criteria for a computer simulation about sustainability. The intent at the outset was to better understand the relationship between information, in particular information presented as part of a computer simulation, and action, namely pro-sustainability behaviour. Rather than indicate what role a computer simulation might play however, the literature review led to the conclusion that a wide range of factors affect the motivations for any behaviour, and that the situation is further complicated in the case of complex social issues. For instance, failures of energy conservation programs based on a single socio-psychological construct support the
supposition that attempts to directly influence behaviour would likely be unsuccessful (Costanzo et al., 1986; Gonzales, 1988; Robinson, 1991; Stern, 1992).

It became apparent that using a computer simulation in an attempt to directly affect behaviour was not only unrealistic, but did not address a crucial, yet often overlooked element, the difference between presenting information and imparting knowledge. In fact, it is clear that the appropriate role for a computer simulation should be to help foster public understanding, a crucial, and often times forgotten component in the process of global change (Kearney, 1994; Andrey et al., 1996; Tinker, 1996).

Thus, refocusing on some of the early literature, particularly the material on energy conservation, enabled the thesis’s objective to be recast from exploring the link between information and action to investigating how best to attain understanding from information. As a result of reframing the problem, a host of new literature was uncovered that underscored both the importance and difficulty in transforming information into knowledge or understanding (Stern, 1992; Kearney, 1994; Hiles, 1996).

This in turn led to the literature on effective communication, which, it became apparent, was fundamental to the process of creating public understanding about an issue. Examples were uncovered from the energy conservation literature as well as writings on the process of global change. Additionally, thinking about the role information plays led to the recognition of additional issues including information-overload (Postman, 1992), as well as the potential pitfalls of using computers as educational tools (Malone and Lepper, 1987b; Klawe and Phillips, 1995).
GETTING THE BIGGER PICTURE: INTERNAL AND EXTERNAL CRITERIA

To this stage two things have become apparent. First, throughout much of the literature reviewed, a number of key factors transcend traditional disciplinary boundaries and appear repeatedly. Second, these key factors can be characterized as pertaining either to the development of the tool itself, or alternatively to materials and presentations that should be developed in support of the learning process. For this reason the design criteria will be broken into two categories: internal encompasses those criteria which are to be directly incorporated into the software, while external accommodate those criteria which should be developed to augment the use of the simulation. Deciding what the criteria are will depend upon both their citation frequency and the importance they were given in the literature reviewed.

The distinction between internal and external criteria is partially grounded in the literature on the use of computers as educational tools. A number of researchers cautioned that computers have the ability to hinder the learning process if not properly utilized. In particular, the need to use computers as one of many tools in the learning process was strongly made by a number of researchers. It is crucial to recognize a computer-based learning tool is part of a larger process, and as such, its development should include materials and techniques that support this fact rather than discourage it (Klawe and Phillips, 1995; Rappin et al., 1997).

At the heart of a simulation attempting to increase understanding about sustainability is the discipline of computer modeling. Literature from this field, or more precisely what it is lacking, lends additional support to this rationale. I have already noted that the literature on the educational use of computers recommends balancing between allowing
the computer to do too much vs. requiring the student to learn too much about simulations (Rappin et al., 1997). In the computer modeling literature the corollary to this situation revolves around balancing simplicity and complexity.

Computer modelers often compare the merits of a ‘top down’ approach, which implies considering a problem as the disaggregation of a single issue, with a ‘bottom up’ approach, which requires aggregating a number of individual issues together (See Costanza et al., 1993, for a more detailed discussion). As shown in figure 3, this tension exists in a two-dimensional space, with aggregation on the y-axis, and scientific understanding on the x-axis.

It is my contention that there has been little attention paid to a crucial third dimension, public understanding, shown on the z-axis. Debates in the literature about the merits of realism and generality fail to note that most models produce results that are too complex to be understood by anyone but perhaps the designers. As noted by Meadows and Robinson (1985), this is not a new problem but rather a disturbing trend in modeling.

As modelers we are, of course, pro-modeling. However, one of our main reasons for writing this book is a deep concern that the modeling profession is acquiring some attributes that will prevent it from contributing as much to social decision making as we believe it can contribute. The attributes we like and dislike will be apparent from our comments throughout the book. We value simplicity,
transparency, and enduring general insights, and we are repelled by complexity, jargon, secrecy and elitism (pp.13-14).

Ironically, it is arguably the ability to help people connect inputs and outputs that makes a computer model a powerful tool. As Tinker (1996) points out, knowing the answer is not as important as knowing what questions to ask as we try to move from awareness to understanding of sustainability. In order to avoid the pitfalls of traditional modeling, this project needs to create a tool that directly engages the public, while simultaneously being cognizant of the fact that the simulation is only part of a larger learning process. Thus, the need to address not only internal factors, but also external ones is a crucial element.

**INTERNAL CRITERIA**

Internal criteria can be defined as those which can be incorporated directly into the software, and includes anything that makes the actual software more engaging and thought provoking.

The rationale for selecting the criteria was based upon the fact that all of these factors were cited more than once in the literature reviewed, and spanned a number of disciplinary lines. For instance, Stern (1992), Kearney (1994) and Andrey *et al.* (1996) all underscored the importance of effective communication, from which we get a sense of the need for credibility, vividness, concreteness and personal relevance.

Both Kearney (1994) and Andrey *et al.* (1996) respectively, in compiling a list of effective communication techniques, recognize the value of using stories and analogues to
help deliver the message. They both note that this technique helps people overcome the difficulties of forming mental models.

Additionally, Andrey et al. (1996) raise an important point when they note the importance of dealing with uncertainty. In the case of sustainability, there is considerable uncertainty about the implications of our decisions, and this fact should be clearly made, as opposed to being hidden in the base assumptions of the simulation.

From the preceding sections I suggest the following list of internal criteria, which includes:

1. credibility
2. vividness
3. concreteness, use of stories
4. honesty about uncertainty
5. personal relevance

**EXTERNAL CRITERIA**

Although it is important that the simulation be built on a strong foundation using only this tool as a means of fostering sustainability ignores an opportunity to make it more effective by including it as part of a larger process. Throughout the literature review a number of factors were highlighted as being significant, yet it is not likely that these factors could be directly addressed by the simulation. These external criteria should be used to guide the development of workshops, forums as well as additional supporting material.

In the discussions about the use of computers I noted that Postman (1992) had strong reservations about the overuse of and the implications of using computers. His arguments
underscore the importance of keeping the proper perspective on computer learning and
information overflow. The simulation development process needs to recognize
technology issues, including an awareness of technology biases as well as the
implications of using computer tools for education. Ignoring these factors could result in
the message not been effectively delivered.

Ajzen, expanding upon the Theory of Reasoned Action (Ajzen and Fishbein, 1980),
recognizes the importance of external factors in his Theory of Planned Behaviour (1985)
by including an additional factor, perceived behavioural control. Inclusion of external
factors reinforce the significance researchers assign to an individual’s perceived ability to
take action. For example, Hines et al. (1987) include personal responsibility, verbal
commitment and locus of control as contributors in their model of environmentally-
responsible behaviour.

In the process of designing and using QUEST, it will be important to recognize the
following external criteria:

1. technology issues
2. locus of control
3. personal responsibility
4. verbal commitment

Revisiting the research on effective communication provides a framework for
exploring how QUEST embodies these design criteria. Aronson (1995) notes that in
order to communicate effectively, it is crucial to consider three key elements: the source
of the information, the message and its delivery and finally the audience. The key, he
says is determining “[w]ho says what to whom” (p. 79).
In the next section I will use this framework to explore how QUEST's development was guided by these criteria. In essence, the key to creating an effective simulation is to create a core application that considers the 5 internal design criteria, and to wrap this core in a process that understands the importance of the 4 external factors. Figure 4 illustrates the spirit of this approach, as well as emphasizing the relative importance of both the internal and external criteria.

Figure 4. The relationship between the internal and external Design Criteria.
4.0 IMPLEMENTATION

"Why do we want computer programs to simulate reality when we don’t want reality to be like reality?" Morning Smile, Globe and Mail, December 14, 1994

Developing a computer simulation to increase understanding about sustainability poses some interesting problems, but also offers some unique opportunities. As I have already noted, the development of QUEST has been a recursive process, allowing early versions of the software to help shape not only future versions of the software, but, based on public reaction, to actually define what objectives are possible and desirable.

It is the combination of this recursive development process and the design criteria introduced in the previous section that comprise the foundations of the Interface-Driven Modeling approach. Additionally, as I noted in the introduction QUEST has also benefited from SERF, and employs two fundamental design philosophies from that endeavour, namely Backcasting (Robinson, 1988) and the Design Approach to Modeling (Gault et al., 1987; Hoffman and McInnis, 1988).

Components of these three fundamental design philosophies, Backcasting, the Design Approach and Interface-Driven Modeling are all found in the following discussion of the implementation of the design criteria in QUEST.
A BRIEF OVERVIEW OF QUEST

QUEST is a computer based scenario generation and evaluation system designed to encourage thinking about sustainability in a regional context. Through QUEST users explore different possible future scenarios, focusing on the social, economic and environmental characteristics. By adopting the look and user-friendliness of a computer game, QUEST actively involves the user in the scenario creation and evaluation process by making the experience both easy and enjoyable.

The initial version of QUEST is being developed for the Lower Fraser Basin in British Columbia, Canada by the Sustainable Development Research Institute (SDRI) at the University of British Columbia (UBC). The Lower Fraser Basin includes the city of Vancouver, the surrounding municipalities that comprise the Greater Vancouver Regional District (GVRD) and the Fraser Valley, an area of significant agricultural importance. High population and economic growth are projected for the region and the ensuing environmental, social and economic impacts of this growth are potentially severe.

3 This description of QUEST is adapted from “QUEST: A Brief Description”, published by the Sustainable Development Research Institute at the University of British Columbia. The full version is available from the Institute. For additional information about QUEST, see the following publications.


Moving towards sustainability in this region will necessarily involve difficult choices and, thus, an understanding of complex trade-offs.

The purpose of QUEST is to encourage thinking about sustainability by actually placing a user in the position of making decisions that impinge upon regional development and subsequently displaying the consequences of these decisions. The range of policy choices, or user inputs, in QUEST represent the most significant issues for the region being modeled. For the Lower Fraser Basin these include making choices about the future patterns of population, economic activity, transportation, housing, consumption, land use, industry, social services and others. The consequences of these decisions include welfare of the population, quality of the environment, health of the economic and social systems, and the ability to maintain these in the long run. By requiring the user to wrestle with tradeoffs among an interrelated set of choices and the often counterintuitive consequences of these choices, it is hoped that QUEST will foster a better understanding of sustainability and how it might be achieved.

Figure 5 on the following page highlights QUEST's key components. The process of creating and exploring a forty-year future scenario in QUEST has four main steps: Invent-a-Future, Choose Policies, View Consequences, and Scenario De-briefing.

For the following discussion of design criteria it is important to understand that at the most basic level, QUEST is a series of models that attempt to simulate various key systems in the study region. For instance, there is a transportation model, which determines, among other things, modal mix and emission levels. There is also an economic input-output model that simulates the economy of the region. In addition, there
are a number of ecological models including ones for air quality, water quality and natural habitat. Beneath the user interface of QUEST, which allows the user to input their choices and see the consequences of these decisions, this series of sub-models calculates the results of the user’s choices.

Figure 5 Conceptual Framework of QUEST for the Lower Fraser Basin.
INTERNAL FACTORS

The following sections illustrate how various design approaches, functions and features of QUEST have been developed in recognition of the design criteria. This first section focuses on the incorporation into QUEST of the internal design criteria detailed in the previous section.

Credibility

The issue of credibility was underscored in both the energy efficiency literature (Constanzo et al., 1986), and the effective communication literature (Aronson, 1995, Andrey and Hachey, 1995). In QUEST, the issue of credibility is dealt with in three ways. The first is via the scientific foundation of the models that are used to calculate the results. During the development of QUEST it became evident that in order to ensure the models were producing plausible results, the models would need to be vetted by various experts in order to validate the approach.

For instance, the transportation sub-model is based upon work done by the Greater Vancouver Regional District (GVRD), whose mandate includes transportation planning and modeling. As a result of a working relationship with the GVRD, we have developed a transportation model that is based partially on their work in the region. This model also incorporates the work of Newman and Kenworthy (1989), which characterizes people’s transportation habits as a function of the type of neighbourhood in which they live.

Second, the models rely on data, such as population statistics, the sources of which contribute directly to QUEST’s credibility. In order to ensure reliable results, the QUEST
development team turned to organizations who specialize in the collection of the data used in the models such as the GVRD, Statistics Canada (StatsCan), as well as the research community at UBC.

Finally, in order to assure the users of QUEST about the credibility of both the data and the models, the team felt it important to explicitly make this point. As such, accompanying QUEST is a thorough package of documentation, which explains all of the sub-models, both in terms of fundamental science and function, and indicates sources of key baseline data. This information is accessible partially via QUEST's help system, and more thoroughly via a set of documentation that is distributed as part of the QUEST CD-ROM.

However, it is important to recognize that using credible data and underlying models does not overshadow the need to present the information effectively. Indeed, the balance between models and the interface in the IDM approach makes it easier for QUEST to demonstrate credibility by making available the means to communicate this fact to the user.

Vividness

The significance of vivid information was noted in the energy conservation literature (Gonzales et al., 1988; Stern, 1992) as well as by Kearney (1994), in her set of effective communication criteria. A key to QUEST's success is its ability to communicate in a comprehensible manner to a wide audience, which is brought about by its dynamic, game like interface. QUEST accomplishes this by enlivening the information and relationships that characterize sustainability. The result has been to create an experience for the user
that is rooted in the various academic fundamentals that underlie research on sustainability while at the same time being captivating and stimulating.

The key to implementing this objective was moving away from the traditional large, academic modeling exercises towards a more game-like approach. As Lee (1973) notes, the former often times failed to reach an audience because the models were too large and complex. The problem lies in the fact that models rather than educating people about the issues at hand, often only helped modelers learn about the challenges of such an undertaking (See figure 6). Unfortunately, large, complex models all too often appear to users as black boxes, seeming to take a number of inputs and transform them into a series of outputs. The steps involved in creating the outputs and, more importantly, the relationships that exist between the various inputs and outputs are not obvious, or are presented in a mundane, uninteresting way.

In contrast, QUEST was made more vivid by focusing the initial development work on the user-interface rather than on the underlying models. This IDM approach resulted in a simulation that has focused on usability from the outset. For instance, by employing powerful information presentation techniques such as dynamic mapping, QUEST is capable of geographically depicting an evolving user scenario. Figure 7 on the following page shows an example of the map comparison screen, which shows two maps of the study area, each superimposed on a satellite image of the region. This technique allows
the user to see changes in key issues such as land use, and connect these changes to the place in which they live. In addition to dynamic mapping, QUEST employs colourful graphing tools and real photographs to help make the presentation more vivid.

Figure 7. An example of the Map Comparison Screen, which allows user to compare geographic results.

The inspiration for these dynamic display tools comes from the successful computer game SimCity (Wright, 1989), which allows users to explore the intricacies of urban planning. To the credit of its designers, SimCity inspired millions of users to spend many hours trying to create the best city design (Burgess, 1993). One of the keys to the success of SimCity was its ability to enliven the data and concepts of urban planning through the use of a simple, yet highly effective user interface. QUEST employs a similar approach, creating a user interface that is vivid and dynamic, which has the effect of holding
people's interest, while simultaneously allowing them to grasp underlying issues and complexities.

Another feature of QUEST that helps to create vivid scenarios is the newspaper analogy employed in the View Consequences section. The main screen in this section resembles the front page of a newspaper, and is intended to report on environmental, social and economic conditions at the end of each decade. Much like an actual newspaper, this screen contains headlines, indicators and an index to more detailed information contained in various other sections. On this page users find headlines generated by QUEST that highlight the most dramatic changes for the decade (i.e. air pollution emissions rise by 35%) and a graphical display of the progress on nine key indicators chosen by the user in the Personal Priorities section of Invent-a-Future. The Personal Priorities concept will be explored more fully in a later section as part of the discussion of personal relevance.

Finally, upon completing a scenario, users are taken to the Scenario Debriefing section, which enables them to better understand the link between various inputs and outputs. This is accomplished through a series of screens that allow explicit exploration of which specific policy choices made in the Choose Policies phase influenced a particular outcome. For example, a user could discover that decisions about housing density, fuel mix and transportation modal split all contribute to air quality. The intent is to make clear the connection between the inputs, made in the form of policy choices, and the outputs, revealed through the scenario consequences. This is particularly important when attempting to communicate to people the complex and often counter-intuitive
nature of the relationships that exist between the many human and natural systems that coexist in an ecosystem.

**Concreteness and Stories**

The concept of presenting information that is concrete, not abstract was found throughout the literature. For instance, Gonzales and Aronson (1988) observed that energy auditors trained to make use of effective communication techniques were more successful at convincing customers to apply for retrofit programs. They compared the effectiveness of simply telling someone they have cracks around their doors and windows to using the analogy that their house had a hole in the wall the size of a football. They discovered that people could more easily visualize the problems of football-sized hole than they could a number of supposed cracks.

In QUEST, a scenario is made concrete by presenting information that users can easily grasp. For instance, when detailing the severity of poor air quality, QUEST indicates how many people would be treated for respiratory ailments rather than citing the concentration of specific pollutants. Similarly, in trying to help users understand the implications of changing land use, the dynamic mapping feature introduced above allows users to see the effects of urban sprawl, rather than receive only numerical or graphical indications of changes.

Along with concreteness, several researchers have suggested the use of parables or stories as a means of communicating about complex social issues. For example Halford and Sheehan (1991) suggest that a combination of more accurate mental models and better analogies will help people to cope with complex social issues. Similarly, Kearney
(1994) posits that stories could provide an effective means of communicating about global change issues, since they are compatible with how people process information.

QUEST reinforces the supposition that analogies are an effective means of reaching users since the software incorporates the storytelling concept at a fundamental level. QUEST is designed to help users craft scenarios, or stories, describing desirable futures, and explore these scenarios in order to understand the implications. The root of this approach can be traced to SERF, and the technique of Backcasting (Robinson, 1988), which encourages consideration of desirable futures rather than probable ones.

Additionally, design philosophies and presentation techniques are employed to enhance the user's ability to create a mental model of the complexities and intricacies of sustainability. For instance, results are presented in a manner that emphasizes the general trend rather than focusing on a specific number. QUEST makes use of a number of display options including graphs and maps to indicate to the user the state of the region. Furthermore, this information is grouped into categories, so that related data is presented on the same screen, which tends to allow the user to draw general conclusions rather than specific ones.

In addition to making the QUEST experience vivid, the newspaper metaphor described in the previous section embodies the story telling approach. By employing a conventional newspaper interface as both a way of summarizing the scenario, and allowing for review of other information, QUEST helps to frame the scenario in a way that is concrete by employing a familiar story telling medium.
Two of the components of the Invent-A-Future section of QUEST, World Views and Politics also strengthen QUEST's ability to be concrete and craft stories. World Views, which is described thoroughly in the next section as part of the discussion about uncertainty, enables QUEST to engage users in the fundamental components of scenario building. This is accomplished by explicitly requiring users to input their view of ecological resilience, technological innovation and social adaptability, representing the three core components of sustainability. By eliciting their feelings about the social, ecological and economic well being of the region and using this information to shape the entire scenario, or story, as it evolves, QUEST draws the user into the scenario building process.

Politics requires users to indicate how they believe public policy should be implemented. They indicate what mixture of carrots, symbolic of economic approaches such as taxes, sticks, which are analogous to rules and regulations, and information, intended to represent voluntary change they would expect to use to bring about change. Thinking about how policies need to be implemented makes the scenario more concrete by forcing users to ponder the real-world implications of the choices they make within QUEST. In addition, by comparing the initial mix of carrots, sticks and information made during Invent-A-Future, with the actual implementation method selected for each policy choice made, the difficulty of implementing policy change and sticking to convictions will be reinforced. This feature often results in users feeling the effects of cognitive dissonance since the politics mix chosen at the outset rarely coincides with the actual choices made during each decade. This feeling serves to further reinforce the concreteness of the scenario building process that QUEST entails.
Finally, future developments will see the additions of photographs and possibly video from the region, to help users understand the significance of key indicators. The intent is to create a number of tools aimed at helping users understand the frequently complex metrics and descriptions associated with sustainability research.

Honesty about Uncertainty

The importance of addressing uncertainty when communicating about complex social issues is recognized by Andrey et al. (1996). Robinson and Tinker (1997) note that coping with uncertainty is fundamental for the success of sustainability.

One of the main obstacles to developing a common conceptual framework for ecological, economic and social problems is that there is little consensus among experts in each discipline on how the ecological, economic and social systems relate to one another. The three main groups of disciplines provide us with three very different views of the world, which are difficult if not impossible to reconcile into a single mental image. (p. 73)

There are two components to the difficulties Robinson and Tinker (1997) are referring to. First, particularly in the case of ecological sciences, there is a wide range of views on the implications of such key issues as climate change. Second, as the authors note, there are problems associated with trying to develop a clear course of action when dealing with an interdisciplinary problem.

The software makes an attempt to recognize uncertainty at a fundamental level through the World View function. World Views are intended to help users recognize that there are many contentious issues associated with sustainability. In fact, many of the
disciplines that continue to explore sustainability are fraught with uncertainty, contention and misunderstanding. Consider for instance the ongoing debate about the implications of climate change and greenhouse gas emissions. In order to reinforce the fact that sustainability modeling contains uncertainties, QUEST asks the user to input their notion of how the world works. The user is required to position themselves on 3 axes, indicating their conviction about the nature of fundamental components of sustainability.

The first axis requires the user to decide if the region's ecological resilience is low, medium or high. This choice directly affects the severity of the impacts of human activity modeled by QUEST. While some people believe the consequences of continued growth will be manifested by ecological disaster, others feel that the ecosystem has the capacity to assimilate an increased level of waste. *World Views* explicitly highlights these contrasting positions, and enables the user, rather than the model, to determine which one drives the simulation.

The second axis forces users to consider the potential of economic growth by requiring them to decide if technological innovation should be low, medium or high. This second question forces one to estimate the degree to which continued economic progress will provide technological solutions to growth-related problems. The result of this choice is an increase or decrease in the effectiveness of various technological fixes. For instance, a scenario with high technological innovation would see a greater positive effect of fuel switching or emission reductions.

The third axis necessitates taking a position on the question of social adaptability. Again from choices of low, medium and high, this question requires the user to consider
how likely and willing people will be to adapt to the sort of changes required to achieve a particular scenario. As with the technological innovation question, this input influences the effectiveness of various policy choices in QUEST. For example, the social adaptability setting within the scenario will directly influence the effectiveness of a policy designed to increase vehicle occupancy. The vehicle occupancy achieved in a scenario with a low social adaptability setting will be lower than one in which social adaptability is high, assuming the same policy choices in each.

It is my contention that there is uncertainty at a fundamental level when considering sustainability. Rather than mask this fact, QUEST brings the issue to the forefront by forcing the user to indicate their beliefs about how the world works. After the user has made choices on these three axes, they have determined the state of the world that exists in their own scenario. The effect of choosing a World View is to change the relationship between key variables within QUEST. By making fundamental changes to the relationship between inputs and outputs, users are effectively creating different worlds in which they create their scenarios.

The power of World Views is that it forces users to confront the uncertainty issue directly, while subsequently presenting them with a means of evaluating the consequences of their beliefs. By allowing users to revisit their scenarios with a different set of World View settings, it is possible to demonstrate that a scenario that is desirable in one World View, might be quite unappealing in another. Again, this technique underscores the value of the IDM approach, which encourages openness and frankness on the part of the modeler to communicate to the user areas of uncertainty. Contrast this with a traditional
model that would likely deal with such uncertainty via an implicit assumption. In this instance the user is not made aware of the uncertainty that exists at a fundamental level when dealing with sustainability, nor is she encouraged to think about the effect this might have on her scenario.

**Personal Relevance**

An attribute that is repeatedly cited in both the behaviour and effective communication literature is personal relevance. In order for a message to be stimulating the receiver needs to be able to place the information in a personal context. Borgida and Nisbett (1977) noted that information that is vivid, concrete and highly personalized is most effective.

Making the information personally relevant is one of the principal differences between a straight game approach such as SimCity, which invites urban planning in a fictitious setting⁴, and QUEST, which allows users to apply real data to the place in which they actually live. By employing real data from the base year of 1990, QUEST allows residents of British Columbia’s Vancouver area to explore the consequences of changing populations, economic activities and lifestyles. These consequences are presented in terms of maps and graphs, which enable the user to relate QUEST’s outcomes to their daily lives.

In addition, the choice of both the spatial and temporal scales in QUEST tends to increase the feeling of personal relevance. The scenario spans a time period of 40 years, 

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⁴ SimCity does allow users to create scenarios for actual cities, such as San Francisco and Tokyo.
which for most adults allows them to see the dramatic changes that will characterize their children's adult life. The spatial scale is large enough to help users see connections between key issues such as transportation and air quality, yet is small enough that they feel in touch with the simulation.

QUEST allows for further personalization through the use of *World Views* (introduced in the previous section) and *Personal Priorities*, both part of the initial *Invent a Future* section. *Personal Priorities* enable users to decide which of the many indicators QUEST calculates are most important by asking them to choose three indicators for each of an ecological, social and economic category. They are also asked to weight the indicators, as well choose a polarity, which reflects their beliefs about whether increases in a particular indicator is desirable or not. To ensure the users have the maximum flexibility, they are allowed to include any indicator in any of the three categories. Thus, it is possible for a user to place an indicator such as population density in both the ecological and economic categories.

These indicators are used in the *Consequences* section of QUEST to give the user an immediate sense of the general state of their scenario, as seen in Figure 8. The dark coloured bars (shown in red in QUEST) highlight where things are worsening, while the light coloured bars (shown in green in QUEST) show where the
situation is improving. In addition, the width of the bars indicates to what degree things are getting better or worse relative to the previous decade, while the height of the bars reflects the user's weight of the particular indicators. Additionally, users are able to inform QUEST which direction of change should be viewed as positive, and which should be negative. The intent is to give the user, by allowing them to compare the amount of green with the amount of red, a quick snapshot of the general condition of their scenario.

Finally, the cognitive dissonance that often results from the comparison of the initial Politics mix to the actual choices made further reinforces the personal relevance of a scenario. When users are confronted with the fact that their actions, in the form of policy implementation strategies, don't agree with their own values, they are often times forced to reconsider these values. This type of personal introspection tends to make the scenario exploring process very personal, since it connects with people at a fundamental level.

**EXTERNAL FACTORS**

Up to this point in time the focus of the QUEST development team has been on the creation of the software itself, while, for the most part, the development of support materials and workshops is only just beginning. As such, discussions of environmental considerations are, perhaps, somewhat premature. However, some of these issues have at least been identified, based upon the hundreds of workshops and presentations in which QUEST has been demonstrated to date. The following discussions, although brief, highlight key issues that I feel the development team needs to consider as the
development focus shifts from the actual software to its use. The development team recognizes that finishing the software does not end the process of developing QUEST.

As noted throughout the thesis it is important to consider the setting in which QUEST is used. This includes understanding the audience composition, recognizing the importance of how and where the software is used, being cognizant of the potential problems computer technology may create and considering what additional materials are needed to support the process. As the literature pointed out, although external to the software, these issues can play a crucial role in making QUEST more effective.

It is intended, for instance, that QUEST be used primarily as part of a larger, workshop experience, such as a town hall meeting. In such a setting QUEST would be used as a tool to help steer the conversation and display scenario information. However, I feel it is crucial that QUEST not be relied upon as the only source of information. In order to help stakeholders feel that they can become involved, there needs to be some discussion of existing regional and local action plans and programs, as well as any other initiatives underway. This would help users to address the issues of personal responsibility and locus of control by helping them understand how they might become more involved. Additionally, by making information available via other mediums, it will be possible to engage those individuals who are not comfortable with computer technology.

In fact, the power of using QUEST in a group setting has been demonstrated on a large number of occasions. One of the most interesting phenomenon discovered in a
group setting is the ability QUEST has to focus a group with different issues on a single issue, and help them to understand the issue from different perspectives.

There are plans to include QUEST as part of the Canadian portion of Urban Lifestyles, Sustainability and Integrated Environmental Assessment (ULYSSES), a European based project aimed at bridging the gap between environmental science and public understanding (Ravetz, 1997). This project uses a series of computer models in controlled focus groups to help the public understand the links between lifestyle choices and climate change. QUEST will make a significant contribution to the process in Canada as it is planned to be part of the Vancouver ULYSSES project. Equally important will be what the researchers learn about the use of computer models to improve public understanding about a complex social issue.

In summary, it is crucial that any process designed to use QUEST recognizes the potential pitfalls of using computer based learning tools, and attempts to avoid them, by recognizing that the software is only one of many techniques available.
5.0 CONCLUSIONS AND NEXT STEPS

This thesis began by asking how behavioural research could be exploited to improve the effectiveness of a computer simulation. After reviewing the literature it became apparent that role best suited to QUEST was moving people from awareness towards an understanding of the challenges posed by sustainability.

The development of a powerful user interface has been a fundamental component of this process. In fact, one of the most important results of creating QUEST has been the evolution of an approach to modeling that emphasizes the value of a thought-provoking, engaging user interface. Employing this technique, which we have come to refer to as Interface-Driven Modeling, has resulted in the crafting of a tool that overcomes a number of shortcomings of more traditional computer-based models, and creates an atmosphere that fosters public understanding.

Although traditional large, socio-economic models may pay too little attention to public education and accessibility, QUEST needs to be cautious of not allowing the pendulum to swing too far the other way, and ignore the need for real modeling. Having a powerful user interface does not exempt QUEST from basing results on valid, vetted science. Throughout the entire development process there has been a constant tension between the need to create a true-to-life representation of the issues at hand, with a desire to make the simulation compelling and thought provoking, in other words, fun-to-use. This tension accurately summarizes the fundamental philosophy of the Interface-Driven Modeling approach.
Additionally, it is important to recognize that QUEST is not the only tool available. Developing a series of workshops and forums using QUEST, based on existing initiatives aimed at empowering regional stakeholders would be one means of integrating QUEST into the existing public education process. In essence, QUEST is not just a piece of software, but is an entire process designed to encourage discussions, highlight alternatives, and seed a dynamic group-based learning process.

While the need for Interface-Driven Modeling was spawned from the SSP project and the SERF experience, the combination of QUEST's heuristic development process and the theoretically based design criteria I have developed has made it an effective, powerful approach. Yet, even as the software nears completion, there is a sense that although the tool itself may be ready, the focus of the development team needs to shift, in order to create the proper environment for using the software.

For instance, the results of projects such as ULYSSES will be used to steer future QUEST development, emphasizing the point that this version of QUEST is not the final version, but rather it is only part of a continual evolution. Not only will such endeavours improve future scenario evaluation tools such as QUEST, but they will also serve to increase our understanding of the importance of embracing holistic and innovative approaches to managing regional and global change.

Creating a simulation whose information is simultaneously clearly presented and relevant, demonstrates consequences credibly and honestly, and evokes a feeling of purpose and a means to get involved was the challenge facing the QUEST development team. Not surprisingly, these same challenges are indicative of the difficulties that
regional stakeholders of the Lower Fraser Basin face in striving for sustainability. I for one am confident that the QUEST process will become a powerful ally for those interested in increasing public understanding about these issues.
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