Framing futures:

Visualizing perspectives on social-ecological systems change

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Thesis

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Propositions

1. Both analytic understanding and experiential engagement must be shared between actors across social-ecological systems to create system wide action for change (this thesis).

2. Media designers and artists should be a core audience for science communicators (this thesis).

3. In any group of people individual perspectives offer more insights into the future than a group perspective shaped by consensus.

4. It is crucial for the western science community to understand how the research industries of emerging global powers frame ideas about scientific truth and knowledge.

5. Technological innovation is the Deus Ex Machina of futurologists.

6. Environmental scientists are mostly blind to humanity's staggering complexity; anthropologists are overwhelmed by it. This makes them ideal partners in research and life.

7. Individuals who make the effort to appreciate music they have always hated but that other people adore develop more capacity for empathy than the musically close-minded.

8. To increase their chances of long-term love, smart singles should meet as many people as possible and take things very, very slowly with all of them.

These propositions are part of the PhD thesis 'Framing futures: Visualizing perspectives on social-ecological systems change' *by Joost Mattheus Vervoort, to be defended on November 29th at the Aula, Wageningen.*

Contents

Contents i

1 Introduction 1
1.1 General introduction 2
1.2 Project context 4
1.3 The objective of this thesis 4
1.4 Communicating about complexity in social-ecological systems: challenges 4
1.5 Practical preconditions 5
1.6 Research approach and scope 6
1.7 Disciplinary perspectives and interdisciplinary collaboration 7
1.8 Case studies 8
1.9 Research questions 8
1.10 Thesis outline and reading guide 9

2 Stepping into Futures: Exploring the potential of interactive media for participatory scenarios on social-ecological systems 13
2.1 Introduction 15
2.2 Interactive media: broadening the communication channel 17
2.3 Criteria for participatory scenario communication 18
2.4 Overview: interactive media in science communication 22
2.5 Evaluating benefits and drawbacks 28
2.6 A strategy developed in the context of practical case studies 31
2.7 Conclusions 36

3 The System Perspectives Scope: stakeholders framing social-ecological systems change in terms of space, time and system dynamics 39
3.1 Introduction 41
3.2 Introducing the System Perspectives Scope 42
3.3 Applying the toolbox in two case studies 48
3.4 Analysis of results 50
3.5 Discussion 57
3.6 Conclusions and recommendations 63

4 Exploring scales and cross-scale dynamics from the perspectives of change agents in social-ecological systems 65

4.1 Introduction 67
4.2 Objectives 72
4.3 Methods 73
4.4 Results and analysis 75
4.5 General discussion 82
4.6 Conclusions 87

5 Combining analytic and experiential communication in participatory scenarios 89

5.1 Objectives 93
5.2 Case study: Oxfordshire 94
5.3 Analytical and experiential communication tools 95
5.4 Workshop preparation and setup 97
5.5 Measurements and analysis 98
5.6 Results 100
5.7 Discussion 106
5.8 Conclusions and recommendations 113

6 A sense of change: media designers and artists communicating about complexity in social-ecological systems 115

6.1 Introduction 117
6.2 Objectives 119
6.3 Collaborative design workshops 120
6.4 Design concepts 122
6.5 Discussion 130
6.6 Conclusions 137

7 Synthesis 139

7.1 Introduction 140
7.2 Taking on the challenges of communicating about complexity in social-ecological systems: lessons learned 141
7.3 Tools in an analytic framework: complementaries and gaps 144
7.4 The focus on individual perspectives in the context of futures exploration . 145
7.5 Alternative research strategies 147
7.6 Up-scaling the impact of complexity-conscious communication 148
7.7 Communicators in context: contributors, participants and audiences 149
7.8 Multi-level lessons in communication: TransForum 150
7.9 Conclusions and recommendations 151

8 Bibliography 153

A Guidelines for interactive media design from Landscape Visualization, Serious Gaming and Visual Analytics 169

B Overview of workshop concepts 171

C Other concepts from the final selection 175

D Glossary 181

E Nederlandse samenvatting 185

F Acknowledgements 189

Curriculum vitae 193

Chapter 1
Introduction

Follow me, the wise man said, but he walked behind.

-Leonard Cohen, Teachers, 1967

Chapter is based on:

J.M. Vervoort, Kasper Kok, P-J Beers, R. van Lammeren, A. Veldkamp, in preparation. *Exploring interactive visualization strategies for communication about social-ecological systems change*

1.1 General introduction

We live in an increasingly interdependent world, characterized by accelerating social and environmental change (Gallopin 2002). The reality of this interdependence expresses itself in climate change, global threats to food security, economic crises and widespread degradation of ecosystems (Millennium Ecosystems Assessment 2005). These conditions challenge the limits of human understanding and scopes of concern because links between causes and consequences across systems, levels and domains are complex and uncertain (Levin 1999; Stern 2000).

New perspectives on complex systems

The realization of the complexity and uncertainty that characterizes linked human and natural systems, or *social-ecological systems* (Folke 2006) across all scales and levels has proliferated throughout the sciences in recent decades (Kok and Veldkamp 2011). An increasing understanding in different disciplines of the characteristics of such complex systems has led to new models of knowledge development (Gibbons et al. 1994; Hermans et al. 2010) and governance (Cash 2006; Buizer et al. 2011). Faith in the power of mono-disciplinary expertise to achieve complete understanding of a system is starting to be replaced by the recognition that deep uncertainty characterizes complex systems. A wide range of societal perspectives is needed to begin to address uncertainty (van der Sluijs 2005). Collaboration across system levels and dimensions is crucial to the ability of societal actors to make system-wide sustainable changes (Rotmans 2005; Cash 2006; Buizer et al. 2011).

The role of communication in the framing of societal understanding, engagement and action

Communication technologies and strategies are central to the development of knowledge and action in the face of complexity and uncertainty. Theories and definitions of what 'communication' is in different contexts abound (Craig 1999). In this thesis, we use the transactional communication model as our basic framework for communication (Barnlund 2008). Following this model, we see communication as a simultaneous receiving and sending of information by groups and individuals. Importantly, how this information is shared and received depends highly on the form and of the communication used, which we see as ranging from style of writing in some instances, body language, images, communication platforms and other attributes of communication form.

While the transactional model is useful to describe communication dynamics, we use the constitutive model to describe the effects of communication that communication is not merely an exchange of information but that it reflects and creates individual and shared perceived realities (Craig 1999).

Through various media, the framing of societal perspectives in the form of images, mental models and discourses can play a key role in guiding the directions of change in social-ecological systems (Ravetz 2006, Beers et al. 2010, Apeldoorn et al. 2011).

Societal images act as gathering concepts that simplify complexity to metaphors with affectively strong associations, such as 'frankenfoods' (Johnson-Laird 1983) or 'climategate' (Barrouillet et al. 2000). They play up certain elements of issues while obscuring many others (Lakoff and Johnson 1980; Beers et al. 2010). Similarly, the mental models that societal actors maintain as ways to frame, structure and make sense of the world also highlight and obscure system dynamics and relationships (Johnson-Laird 1983; Barrouillet et al. 2000). Another perspective on the societal role of ideas and conceptualizations is that of discourses. On the level of social interactions, discourses frame and shape what is discussed and considered important, and what light is shed on different issues (Hermans et al. 2010).

Seen through the constitutive model of communication, images, mental models and discourses represent perspectives on how the complexity of the world is mapped in human communication, with analytic as well as affective associations. All are generally framed by competing societal interests and are generally too simple to capture the complexity of systems such as social-ecological systems (Holling and Gunderson 2002; Beers et al. 2010). Conflicting images, mental models and discourses can play up or omit crucial information about the future and can block or facilitate the seizing of opportunities for systems change (Pritchard and Sanderson 2002). They provide simple and risk-averse frames that tend to focus on single system levels or domains (Holling and Gunderson 2002).

This thesis: the potential of interactive visualization

As described by the transactional model of communication, the content of communication is inextricably tied to its mode and format (Barnlund 2008). Dominant media formats and modes of communication are restrictive in terms of their ability to capture perspectives on complex systems change. However, new forms are emerging.

This thesis focuses on the potential of interactive visualization to help move beyond these limitations of the forms societal communication about complexity in social-ecological systems (Beers et al. 2010). Visualization, the visual representation of content, is exceptionally suited to capture both the analytic and affective dimensions of human communication (Sheppard 2005). Interactive visualization allows for the sharing and interacting with content as per the constitutive model, and thereby captures the full potential of communication in creating and sharing realities.

Interactive visuals, especially when linked to other modalities, have proven to be powerful means for the generation of affective engagement (Al-Kodmany 2002; Sheppard 2005; Freeman 2010; van Lammeren et al. 2010). Finally, interactive media offer many ways to increase the accessibility of different types of content (Gooding 2008). However, there is very little precedent for the use of interactive visualization tools to specifically exchange and communicate a range of perspectives on social-ecological systems.

1.2 Project context

The research in this PhD thesis is part of the TransForum agro-ecological knowledge innovation network. TransForum functioned as an innovation institute for agricultural development in the Netherlands. It was set up as a six year project that ended in early 2011. Its goal was triggering transitions towards sustainable agricultural development (Veldkamp et al. 2008). A wide range of practical and theoretical projects related to agro-ecological innovation were brought to life by TransForum (TransForum 2010). These projects incorporated very different images and mental models of sustainable agriculture. Specific attention was given to this plurality of perspectives through the scientific research theme 'images of sustainable development', of which Beers et al. (2010) provide an overview as well as the role of framing and images in agricultural transitions. The work that resulted in this Ph.D. thesis was part of that theme.

1.3 The objective of this thesis

The overarching objective of the research in this PhD thesis is:

To harness the potential of interactive visualization for the elicitation and communication of societal perspectives on social-ecological systems change.

Because this objective delineates research that draws from many different disciplines and has no direct tradition to build on, it brings up a number of new, specific challenges that must be identified before research questions can be introduced.

1.4 Communicating about complexity in social-ecological systems: challenges

The research in this PhD thesis focuses on two fundamental challenges for the use of interactive visualization in the communication of complexity in social-ecological systems.

Challenge 1: In order to elicit and share analytic perspectives on complexity in social-ecological systems, consciousness among societal actors of complex systems characteristics is essential.

Social-ecological systems exhibit the characteristics and behaviors of complex systems (Levin 1999). This has many consequences for the development of shared societal understanding about the dynamics of these systems:

- Complex systems are highly connected across different system levels and scales, and therefore changes in sub-systems can have large repercussions, just like high level changes can have impacts on the smallest levels (Cash et al. 2006).

- Feedbacks are crucial in cross-level and cross-scale interactions because they can amplify and propagate changes to create non-linear effects with system-wide consequences.
- Social-ecological systems consist of interacting social and biophysical systems, and non-linear effects can extend from the biophysical to the social and vice versa, with different outcomes (Westley et al. 2002).
- The characteristics of complex systems refute claims about full system knowledge. Instead, complex systems are not only characterized by predictable uncertainties but also by deep uncertainties where measurement is not possible (van der Sluijs 2005), and uncertainties that may have previously been regarded as manageable but that have since left the possibility of control (Ramrez and Ravetz 2011).

Challenge 2: The need to elicit and share analytic perspectives on the complexity and uncertainty inherent in social-ecological systems has to be combined with the need for societal engagement as a precondition for action.

This challenge is crucial because engagement is a precondition for societal actors to take action towards change (Sheppard 2005). Without engagement, communications about social-ecological systems change remain uninvolved and intellectual and fail to stimulate individuals to draw on their true resources. But the complexity inherent in social and environmental change can be disengaging, and even intimidating:

- Individual' affective engagement with a given issue is generally strongest when that issue is perceived as clearly and directly related to individual or communal experiences, identities and aspirations (Xiang and Clarke 2003). Because causes and effects in complex systems are often indirect and multiple in origin and result, fostering engagement with these processes is a challenge (Levin 1999).
- Also, the uncertainty that characterizes complex social-ecological systems makes it hard for individuals to develop clear ideas about the future that would lead to emotional investment (Marx et al. 2007).
- This challenge is compounded by the fact that many competing images associated with social-ecological systems exist that grossly oversimplify system dynamics but that have strong affective associations (Beers et al. 2010).

1.5 Practical preconditions

The previous section's challenges have been used to design the research questions that formed the basis for the work in this Ph.D. thesis. In all our designs and experiments, however, we have been conscious of several practical preconditions for successful communications:

- *Accessibility to a diversity of societal actors:* Because of the realization that perfect knowledge of complex systems is not possible in conditions of deep uncertainty, it is essential that connections are made between different, complementary perspectives (Gibbons et al. 1994). From the knowledge development perspective, people from different positions in social-ecological systems maintain different images and mental models and can provide insights that allow us to better understand complexity in these systems (Berkes and Folke 2002). From the engagement perspective, the involvement and engagement of a range of societal actors is key to creating systems change (Ostrom 2009). Communication strategies should help share fundamentally different perspectives on the dynamics and structures of social-ecological systems.

- *Flexibility to capture different perspectives, systems and case studies:* Complex systems theory is a conceptual framework that can be applied to a wide range of systems, perspectives and case studies. Communication strategies and tools that aim to capture a range of perspectives on social-ecological systems change should have the flexibility for different societal actors to express these perspectives in ways that are true to their understanding.

- *Feasibility to be developed, used and adapted:* The reality of science communication projects and participatory knowledge development platforms is that these settings are often directed or facilitated by small groups of experts. The communication of interactive media could be nearly unlimited when endless resources and manpower would be available. But this is generally not reality. To understand the trade-offs and choices that have to be made in the development and deployment of feasible communication tools, the research in this Ph.D. thesis focuses on realistic feasibility.

1.6 Research approach and scope

Three tenets have shaped the research in this Ph.D. thesis: interdisciplinary synergy, research by design and participatory research. Firstly, our approach to communicating about social-ecological systems change was to combine the strengths of a range of science domains and design traditions to transcend the limitations of individual fields. Secondly, we studied the strengths and weaknesses of interactive visualization by designing and developing tools from the ground up. Finally, we developed and deployed these tools not in a lab setting but in real contexts of social-ecological systems management and governance, working with key actors in these systems. While this approach is limited compared to the rigour for testing that could be achieved in a more controlled environment, it has allowed us to understand the strengths and weaknesses of tools and strategies in the contexts for which they were meant, and for stakeholders in these contexts to provide feedback on their usefulness.

1.7 Disciplinary perspectives and interdisciplinary collaboration

The research team behind the work in this Ph.D. thesis approached the challenges of communicating about social-ecological systems change from an interdisciplinary background. In terms of disciplinary perspectives on social-ecological complexity, our initial perspective was rooted in ecology, physical geography, land use change, agricultural systems and environmental management and policy. More specifically, the social-ecological systems perspective (Gunderson and Holling 2002) and broader complex systems theory (Lansing 2003; Levin 2003) served as our starting point. In this context, the post-normal science perspective (Hermans et al. 2010) and mode-2 scientific practice (Gibbons et al. 1994) have informed our views and methods. In terms of science communication, we started out from a mix of backgrounds in scenarios communication (Xiang and Clarke 2003), landscape and geo-visualization (Bishop and Lange 2005) and participatory modelling (Voinov and Bousquet).

The research in this Ph.D. required us to bridge to other fields such as cognitive and visual psychology, communication and education science, design and aesthetics and to collaborate with experts in these fields. In terms of science communication strategies, we explored visual analytics (Thomas and Cook 2007), information and knowledge visualization (Card and Mackinlay 1996; Eppler and Burkhard 2005), serious gaming (Squire 2005), social media (Gooding 2008), group interactions (Johnson-Laird 1983) and art and design (Barrouillet et al. 2000).

Practice context: exploring futures in multi-stakeholder settings

The research in this Ph.D. thesis has been conducted in multi-stakeholder and community settings where the focus is on issues that touch broad sections of society (e.g. global environmental change). We have chosen to research our methods and tools directly in this type of context because it is here that challenging complexities and uncertainties are encountered and the value of the explication of analytic and experiential perspectives becomes most clear.

In this, the research relates in a number of ways to multi-stakeholder scenario development. Scenarios are descriptions of possible futures that reflect different perspectives on past, present, and future developments (Gallopin 2002, van Notten et al. 2003). In single- and multi-stakeholder settings, scenarios can be used to explore future uncertainties. In multi-stakeholder settings specifically, scenarios focus on the future can be used as a relatively open space where perspectives can be shared and collaborative ties, commitments and ideas can be forged (Wilkinson and Eidinow 2008, Kahane 2010). Other methods such as visioning and back-casting focus more directly on strategizing toward desired futures (Robinson et al.).

In this practice context, this thesis takes a different approach by mostly focusing on individual scenarios and visions to create assemblages of individual perspectives rather than group perspectives. The principal reasoning behind this approach is that it enables us to examine more directly the different perspectives that come together in multi-stakeholder and community settings. This approach enables us to say more about the ability of different tools to elicit perspectives. Importantly, it focuses on a step that is normally skipped in scenarios development and visioning, because these processes jump to the development of content with entire groups. We will discuss the potential of a focus on individual perspectives in the context of the explorations of futures in with communities and multi-stakeholder groups.

1.8 Case studies

The research in each of the chapters in this thesis has involved broad regional communities, communities of specialists and selected key individuals, depending on the objectives of the studies.

- In the United Kingdom, we worked with sustainable development communities in the county of Oxfordshire (Chapters 2, 3, 5), both during workshops and on-line. There are a large number of sustainable development initiatives in this county with strong links to policy makers and research at multiple system levels. A running relationship of the research team with key actors in this region has made long-term collaborative work possible, and enabled us to reach a wide demographic.

- Because the research in this PhD thesis was part of the TransForum network, the Dutch agricultural context in which TransForum operated made for an ideal case. The focus of TransForum was on system-wide action and innovation and cross-level, cross-sector and cross-disciplinary knowledge development, which matched perfectly with our objectives. Furthermore, the research team had easy access to the organization and its partners. We worked with a number of key agents of change Dutch agriculture connected to TransForum (Chapter 4).

- We collaborated with groups of artists and designers at Dutch arts education institutes. These groups were made up of a range of nationalities up to 23 different nationalities in one workshop group. This provided us with a range of cultural perspectives in the collaborative visualization work done in these workshops (Chapter 6).

- As part of a European-level network and series of seminars, environmental scientists in the METIER network consisting of a collection of European nationalities and institutes cooperated as participants in our evaluation of an on-line interactive visualization tool (Chapter 5).

1.9 Research questions

On the basis of our overall objective and the challenges that this objective raises, we formulated a series of research questions, each of which provides the basis for a chapter in this thesis.

First, we required a broad exploration of the state of the art:

- What is the current state of the art in different science communication fields relevant to our objective, how do these fields deal with the challenges of communicating about social-ecological systems change, and how could strengths be combined and weaknesses overcome (Chapter 2)?

Then, we focused on our first challenge: facilitating the elicitation and sharing of different analytic perspectives on social-ecological systems change. We explored two complementary strategies:

- How can basic analytic perspectives of a wide range of societal actors on social-ecological systems be elicited in an accessible, flexible and generalizable fashion using interactive visualization (Chapter 3)?
- How can interactive visualization help capture in-depth, extensive views of how key actors structure their perspectives on social-ecological systems (Chapter 4)?

The second challenge, combining the elicitation of analytic perspectives with generating experiential engagement was also approached using two complementary strategies guided by the following questions:

- How can tools focused specifically on the elicitation of analytic perspectives be combined with tools focused specifically on experiential engagement to generate complementary benefits (Chapter 5)?
- How can analytic understanding of and experiential engagement with social-ecological systems change be integrated fully to facilitate a new type of engaged and strategic knowledge development (Chapter 6)?

1.10 Thesis outline and reading guide

Figure 1.1 shows the structure of this Ph.D. thesis. The thesis is structured based on the two main challenges for communicating about complexity in social-ecological systems, and further organized using the above research questions. Using these questions, each chapter provides a slightly different view on the challenges to relate them to the specific research context.

Chapters 3 to 6 all present one or more different tools. All four studies in both lines of research make different choices with regard to crucial preconditions of accessibility, flexibility and feasibility. Chapter 7 provides a discussion of the project in its entirety, overall conclusions, and recommendations for future research.

First, in chapter 2, we provide an overview of multi-media communication strategies currently used in several science communication fields: scenario communication, landscape

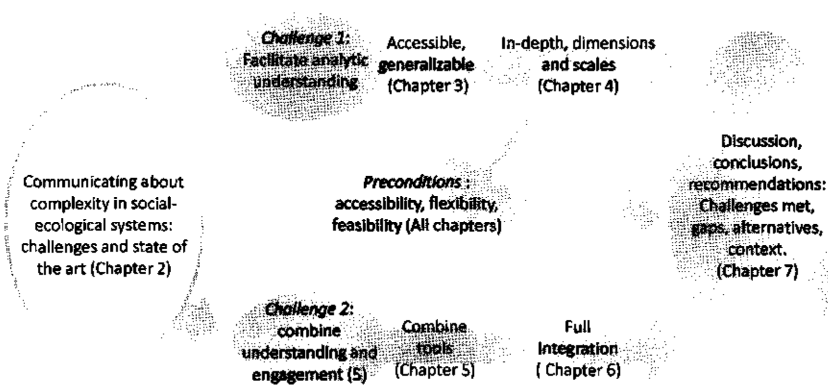


Figure 1.1: Thesis outline and structure. The thesis is structured based on the two challenges discussed in this chapter, and the two research questions per challenge that provide different strategies. The preconditions of accessibility, flexibility and feasibility help to shape these strategies.

visualization, serious gaming and visual analytics. These strategies are evaluated on their *potential for the communication of complex dynamics in social-ecological systems.* The criteria we use for this evaluation combine the challenges from this chapter in a slightly different structure, and go into them in more detail. Our starting point in terms of the type of content of the communication is participatory scenario development. This goal provides the evaluation with a more specific focus than communication about complexity in social-ecological systems in general. Based on the results of this evaluation, we propose guidelines for the development of a communication framework that aims to integrate the most valuable characteristics of these science communication strategies. Elements of this framework will be developed into tools and used for more specific purposes in subsequent chapters.

Chapter 3 presents the first of the two complementary tools developed and evaluated for the elicitation and communication of analytic perspectives on social-ecological systems change. This method, the System Perspectives Scope, is a web-based, interactive visual formalism that allows users to explicitly express their perspectives on the dimensions and dynamics of present and future environmental issues. The design strategy aimed for accessibility and flexibility as well as generalizability and comparability of outputs. Using the insights that this method produces, participatory process designers can tailor their planning, scenario or modelling process to fit stakeholders' priorities in the dimensions and dynamics they find most relevant. Conversely, it allows for the recognition of issues, levels and dynamics that are not considered by the stakeholders. These 'gaps' in stakeholder perspectives can be used in participatory processes to stimulate stakeholders to focus on issues they had not considered in terms of these levels and dynamics. The System Perspectives Scope also brings signification relationships to light between different elements of participants' perspectives.

Chapter 4 presents the results of a different approach to the elicitation of analytic perspectives on social-ecological systems change. Instead of focusing on a quick, accessible and highly comparable approach, the Scale Repertoire is based on extensive one-to-one facilitation. The tool elicits in-depth and rich information about the fundamental ways in which key societal actors frame and structure their understanding of social-ecological systems change. Through the Scale Repertoire, the unique insights on cross-scale dynamics maintained by change agents in social-ecological system innovation were captured. These conceptual insights, born from practice, have much to offer current interdisciplinary explorations of scale and scale dynamics, as well as insights for practical governance where cross-scale dynamics play a prominent role.

In the next section of the thesis, we focus on challenge 2: combining the elicitation and communication of analytic perspectives with generating experiential engagement with social-ecological systems change. Again, two different, complementary strategies are used. In chapter 5, we focus on the psychological differences between processes of analytic understanding and experiential engagement, and evaluate how the complementary benefits of these processes can be combined. In community workshops in Oxfordshire, we combined the System Perspectives Scope from chapter 3 with a live version of the Scenario-Communities tool based on the design framework in chapter 2. The combination of these methods proved to be synergetic: participants reported being engaged and challenged to imagine personal, experiential perspectives of the future by creating new scenario storylines through the Scenario-Communities method, while using the System Perspectives Scope to explicate their analytic perspectives on the social-ecological systems they were a part of. Links between the analytic and experiential content were found. The study results indicated that moving from a mode of experiential engagement to a mode of analytic understanding is the most intuitive and effective.

In contrast to the use of separate methods in chapter 5, in chapter 6 we explore how the facilitation of analytic understanding and experiential engagement can be fully integrated in a single interactive concept. To do this, we explore the potential of communication strategies that lie beyond the various traditions of science communication that provided the inspiration for the tools discussed in the previous chapters. In this chapter, we present the results of a collaboration with groups of interactive media designers and artists. We put the challenge of combining analytic understanding of and experiential engagement with social-ecological systems complexity to these groups. The results of this challenge took the form of a large number of communication concepts, either in the shape of first designs or fully-fledged installations and visualizations. These concepts were selected first by the workshop participants and then by panels of communication and complex systems science experts in terms of how well they tackle the challenges of communicating about social-ecological systems change. A number of games, interactive group concepts and social media storytelling concepts emerged as having the highest potential to deal with these challenges. We discuss these concepts and the directions and recommendations they provide for future developments.

In chapter 7, the synthesis, we discuss the conclusions and recommendations that can be drawn from the research in this thesis. We start by summarizing the chapters' individual conclusions, and then explore how our different tools and strategies have helped us take on and combine the twin challenges of facilitating analytic understanding of, and experiential engagement with, social-ecological systems change. We discuss a number of lessons learnt from taking on these challenges. The practical design of the tools based on the preconditions of accessibility, flexibility and feasibility has led to a number of lessons as well. Then, we discuss the complementaries between the different tools in the thesis, and where gaps lie that could be explored by future research. Building on this analysis, we identify alternative overall research strategies that could be taken, again to point towards future work. We also discuss the up-scaling of the potential impact of complexity-conscious communication tools. Then, we step back to discuss the societal contexts of science communication and the consciousness of the different possible roles of the science communicator. Finally, we end with a number of overall conclusions and recommendations.

Chapter 2

Stepping into Futures: Exploring the potential of interactive media for participatory scenarios on social-ecological systems

Someone turn the lights on.

-Cursed, Old Money, 2005

Chapter is based on:

J.M. Vervoort, K. Kok, R. van Lammeren, A. Veldkamp, 2010. *Stepping into Futures: exploring the potential of interactive media for participatory scenarios on social-ecological systems*. Futures 42,6.

Abstract In this chapter, we present a strategy for the development of interactive media scenarios to help communicate uncertainties and complexities in coupled human and natural systems. Insights arising from complex systems theory advocate the need for more adaptive perspectives on natural resources management. For the collaborative exploration of future complexities and uncertainties, participatory scenario development has proven to be a powerful approach. A range of communication strategies with benefits for conveying complexity, however, has not yet been adopted by scenario developers. We present a framework of criteria with which we structurally analyse the benefits of interactive media communication. First, we consider requirements of feasibility, flexibility and stakeholder contributions. Then, we synthesize criteria for communication on social-ecological systems. Finally, we set criteria for communicative clarity and engagement. Using this framework, we review several science communication fields, including landscape visualization, serious gaming and visual analytics. We then develop a strategy for interactive media communication in participatory scenario development, including two work-in-progress examples. This strategy employs mixed media, microgames and accessible stakeholder contributions in a geo-web context, and is suitable for participatory work in live settings as well as on-line, from a local to a global scale.

2.1 Introduction

In recent years, an urgent need for a paradigm shift in natural resources management has arisen (Gallopin 2002). Policies based on an engineering perspective on natural systems have created dramatic examples of ecosystems collapse that show the dangers of simplified understanding and the illusion of full knowledge (Holling and Gunderson 2002). More subtle, inclusive and humble perspectives have since gained a foothold across various scientific disciplines, based on the view that human and natural systems are fundamentally connected as *Social-Ecological Systems* (SES) (Folke 2006). Their analysis through complex systems theory (Levin 1999) has spawned many new insights. However, the messages resulting from these insights are far from straightforward. The complex systems' perspective encourages policy makers to consider non-linear effects and sudden shifts, to take multiple scales of organization into account, to use complementary knowledge from different types of expertise (Yorque et al. 2002), and to be 'at once bold and careful' (Lempert 2007). However, these messages from complex systems theory arise from a world of conceptual metaphors based on scientific systems thinking, presupposing a background that is unfamiliar for a wide range of societal actors (Anderies 2008). There is a risk that the arguments for more adaptive natural resources management are lost in translation (Beers et al. 2006; Hoogstra and Schanz 2009).

In this chapter, we explore the potential of *interactive media* to aid communication on natural resources management from a complex systems perspective. Because humans are able to process information much more effectively in visual form than though any other communication channel, visualization can reduce the need for information simplification, as well as decrease risks of miscommunication (Tufte 1990). Also, interactive visual communication can make what is communicated more vivid and engaging (Sheppard 2005).

The potential of interactive media to facilitate education and dialogue in this mode of thinking is only beginning to be explored. A number of scientific communication niches with specific interests and strategies exist, and beyond them, there is a world of interactive media applications that is as yet mostly untapped by science communicators. Meanwhile, generations of 'digital immigrants', people that learned to make use of computers at a later age, are being succeeded by generations of 'digital natives' who have grown up interacting with the digital world and for whom this world is second nature (Prensky 2001).

Here, we choose to link the potential of interactive media to an approach to social-ecological complexity that has already shown great promise in terms of communication: *participatory scenario development* (Martens and Rotmans 2005). We define scenarios as *descriptions of possible futures that reflect different perspectives on past, present, and future developments* (Gallopin 2002; van Notten et al. 2003). Participatory scenario development involves a wide range of societal actors in the co-construction of scenarios. These stakeholders exchange insights and perspectives on future uncertainties and complexities. In terms of communication, the scenario method itself has a number of cognitive and affective benefits (Xiang and Clarke 2003). We propose that linking these benefits with the potential inherent in visualization will create a compounding effect that will aid in dialogues on

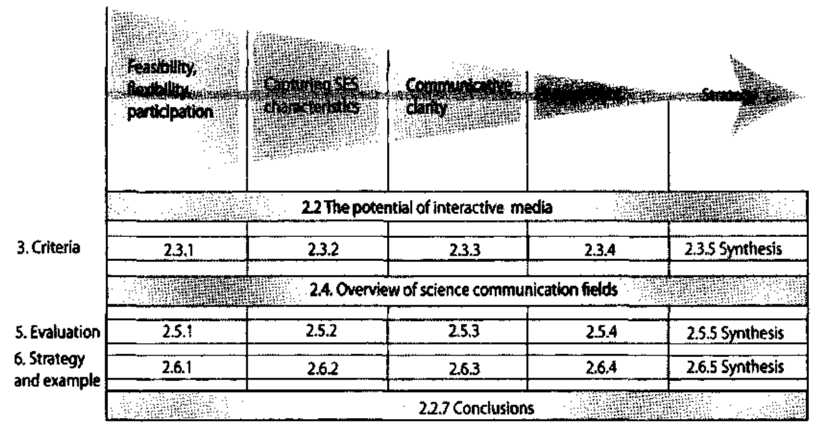


Figure 2.1: The chapter sections as structured by a succession of criteria. Each step in the criteria succession (the arrow) narrows down choices, until we end up with a specific strategy for the use of interactive media in scenario communication. For section 2.3, 2.5 and 2.6, paragraphs correspond to steps in the criteria succession.

adaptive natural resources management.

The objective of this chapter is to provide a *guiding framework* for scenario developers to navigate through the spectrum of interactive media possibilities offered by different science communication disciplines. The first sections (2.2, 2.3, 2.4, 2.5) function as an exploration of the potential and challenges of interactive media scenarios. Within this exploration, sections 2.4 and 2.5 serve as a *review* of several research domains in interactive media communication. In section 2.6, we build on this review to advocate a specific *strategy* for scenario developers, which is accompanied by two example projects based on this strategy.

The arrow in figure 2.1 provides the backbone for our analysis, as well as for the chapter's structure. It stands for a succession of criteria that we will consider in turn. Each step in the succession narrows down the choices The first step consists of a combination of basic requirements: feasibility, flexibility and the participatory character of the approach. We need to consider these requirements first for any method to be useful for participatory scenario development at al. When these requirements are met, we focus on a method's ability to represent the content: social-ecological systems change. Then, the clarity of these communications becomes the next step for consideration. Finally, the power to engage audiences prompts the final choice for one method over others.

We use this criteria succession several times throughout the paper, particularly in section 2.3, 2.5, and 2.6. We start, however, with an overview of the communicative benefits of interactive media (section 2.2). We argue that these substantial benefits are essential to keep in mind while exploring requirements, limitations and possibilities in interactive scenario communication. Then, we introduce the criteria linked to each step in the criteria succession (section 2.3). Next, we provide an overview of a spectrum of science communication fields (section 2.4). Returning to the criteria succession, we compare these fields in an evaluation (section 2.5). Based on this evaluation, we propose a strategy that follows these criteria, accompanied by two projects that the authors are currently developing (section 2.6).

2.2 Interactive media: broadening the communication channel

Visualization

Visualization is the main focus for most research on new media communication. We define visualization as 'any communication that uses visual structures to represent objects, concepts and relationships' (Pylyshyn 2003). In this broad definition, everything from a data table to a virtual reality environment is visualization. Sheppard (2001) describes visual communication as having three types of potential effects: cognitive, affective, and behavioural. Concerning visualization as an aid for cognition, Thomas and Cook (2007) and Tufte (1990) give us some clear benefits. Firstly, visual representations can *increase the information available* to a user at any one time, in terms of presentation, and following this, in terms of *memory retention*. The perceptual system can take over a part of the *workload* from what would otherwise have to be handled by cognitive inference, and therefore more information can be taken in. This benefit is amplified by the human capacity to handle *parallel information* when it is presented visually. Also, the strategic presentation of visual information can *clarify patterns* of value, relationships and trends, further reducing cognitive workload and *search time* for users. And unlike speech or written text, information presented visually allows for different personal *viewing styles* and patterns of examination and re-examination (Tufte 1990). Visual imagery can also trigger *emotional responses* instantly, because humans are set up for the visual recognition of, and subsequent response to attractive, puzzling or threatening elements in their environment (Nicholson-Cole 2005; Sheppard 2005). Therefore, visualization has the power to amplify the attention given to what is being communicated, as well as further improving memory retention through this link with emotional engagement (Eppler et al. 2008).

Interactivity

Levels of engagement with visual imagery can be further enhanced when an interactive format is used (Thomas and Cook 2007). Direct interactivity demands a higher level of engagement from users. Interactive features also give users more control to follow through on ideas about what is visualized, allowing them to change perspectives and revisit observations. Users can both receive and give feedbacks on their interpretations and choices. This way, interactivity has the benefit of helping users focus on elements of the visualization that are salient to them. A fluid interaction with an interface that gives clear feedbacks can improve the user's general experience as well (Csikszentmihalyi 1990).

Multiple modalities

Most research on scientific communication has focused on communication through visual imagery. However, there is potential for the combination of multiple modalities of perception (e.g. auditory, tactile) to increase the bandwidth of human-computer interactions. Humans are able to handle a combination of inputs from these different modalities (Sharma et al. 1998; Oviatt 1999). In this regard, our attention goes mainly to audiovisual communication as it is the most accessible combination of modalities. In research on combined audiovisual communication, it has been demonstrated that more input can be dealt with by the user when different perspectives on the same information are presented through audio, image and text simultaneously (Hecht et al. 2006). Additionally, when auditory and visual input with different content are presented in a harmonious, coherent way, there is little interference between visual and auditory perception (Roach et al. 2006).

On-line media: web 2.0 and beyond

All this potential of interactive media will amount to very little if it fails to contact key audiences. There is much potential in the use of on-line media to expand the reach of participatory processes in scenario development beyond the small group of stakeholders and the limited time of a workshop. It might sometimes be preferable to select key stakeholders and reap the benefits in engagement and immersion that more high-tech formats can provide (Al-Kodmany 2002). Our goal here is to focus on widely applicable communication strategies, thus keeping technical requirements to a minimum. Moreover, whatever value is generated within a scenario exercise will be harder to convey to the world at large if the communication is confined to a limited time and number of attendees. Finally, the web has become a more and more participatory affair: a wide range of techniques for user-generated interactions and content-mix-ups, known collectively as 'web 2.0' (Gooding 2008), have come to dominate on-line space. In the next sections, we will show how, through pervasive gaming methods (Jegers 2007), web 2.0 strategies can also be used to achieve a kind of immersion that circumvents the boundaries of other forms of communication.

2.3 Criteria for participatory scenario communication

In this section, we explore the criteria succession shown in figure 2.1. Practical considerations, SES science and scenario development all pose challenges that have to be faced when the aim is to develop communicative and engaging interactive media scenarios. These challenges have consequences both for the scenario content and the media strategy used.

Feasibility, flexibility and participation

Communication is so central to our lives that its technologies are naturally driven by strong commercial, political and scientific interests (Eppler et al. 2008). The fast-paced developments that result from these drivers provide so many possibilities that with sufficient resources, the sky is essentially the limit for interactive media. The commercial game industry is an example of this: the highest-grossing games, developed with budgets in the millions, feature staggering graphics, virtual environments of enormous size and complexity, and extensive support structures (Squire 2005). However, the reality in scenario development is that far less resources are generally available for communication facilitation, whether scenarios are developed by scientists working with local initiatives or for collaborative efforts on a global level. In order to take this limitation into account, we first need to evaluate the feasibility of communication strategies from the perspective of small research projects, consisting of a relatively small number of scientists and technicians. This perspective forces us to first consider which interactive media strategies we can translate to such a project scale.

This scope has consequences for two other prerequisites: flexibility and the co-construction of content with stakeholders. If a method cannot be used in a variety of SES scenario contexts, it will have very little relevance. And because of our focus on *participatory* scenarios, we are explicitly interested in an approach that allows for content co-creation and dialogue with stakeholders rather than one-way communication. We see possibilities for synergy between the feasibility of constructing or adapting a tool with limited resources, requirements for its flexibility and the possibilities for stakeholder contributions to the content and insights. As we will demonstrate in sections 2.5 and 2.6, new, creative uses of technologies are available to make this synergy a reality.

Capturing social-ecological systems characteristics

When developed in a participatory fashion, scenarios can be a basis for the sharing of knowledge and the building of consensus in the face of future complexities and uncertainties (Biggs et al. 2007; Kok et al. 2007). Constructing scenarios from a SES perspective can help create a sense of the role of complexity and uncertainty in human and natural systems. Instilling this understanding can in turn help recognize the need for adaptive management perspectives.

An example of a scenario exercise that aims to capture SES dynamics in social-ecological systems is the Millennium Ecosystem Assessment (MA) (Millennium Ecosystems Assessment 2005). The MA is an extensive UN-funded assessment of the consequences of changes in ecosystems for global human well-being and biodiversity. Part of the assessment is a set of scenarios that has resilience (Folke 2006) as its core perspective on SES. The MA documents and related papers (Bennett et al. 2003; Cumming and Peterson 2005) discuss the importance of including ecological processes and feedbacks in scenarios. However, they also point out that very few scenario sets have included them so far, instead limiting themselves to environmental impacts.

Extending the philosophy of the Millennium Assessment, we propose that both the scenario content and the interactive media strategy used should be able to convey a true sense of SES dynamics. Characterizations of complex systems exist for a number of contexts (Holland 1998), (Grus et al. in press). We choose to examine complex systems from the social-ecological resilience perspective and synthesize what we see as the most basic requirements for interactive media scenarios to able to communicate on SES dynamics:

1. *The capacity to show the connectedness of social and ecological systems and their driving forces:* the SES perspective is first and foremost a product of systems thinking. System elements, their relationships and feedbacks should be represented in an accessible way (Westley et al. 2002).

2. *The capacity to portray non-linear change:* To provide a real sense of changes, discontinuities and surprises in social-ecological systems, we have to be able to show the interplay of their dynamics rather than static snapshots or linear storylines (Holling and Gunderson 2002). Van Notten et al. (2005) provide an overview of the role of surprise and discontinuity in recent scenario development, and observe that true discontinuities and surprises are often avoided in scenario exercises.

3. *The capacity to portray multiple levels on scales of time, space and organization:* Without the capacity for a multi-scale perspective and the depiction of cross-level interactions, our ability to depict fundamental change in social-ecological systems will remain incomplete (Holling et al. 2002). Biggs et al. (2007) investigate the value of multi-level scenarios and argue that these are better able to capture system dynamics and maintain value through different scales of organization. Kok et al. (2007) point out that the level of coherence between levels in a scenario should be carefully considered.

4. *The capacity to incorporate and exchange different perspectives and types of expertise:* From the perspective of resilience, natural resources management often suffers from fatal blind spots to crucial system interactions. When an effort is made to connect different sources of expertise to a dialogue, there is a better chance that traps can be avoided. (Berkes and Folke 2002). Kasemir et al. (2000) show that stakeholders, when given the chance, may choose to express deliberate ambiguity of messages in their scenario content.

All of these four elements of system descriptions from the SES perspective present challenges for human understanding and communication: 1. Systems thinking is by no means a cognitive strategy that pervades all of society (Senge and Sterman 1992). 2. People do not generally make non-linear future projections (van Notten et al. 2005) 3. Multi-scale thinking does not come naturally to human beings (Dorner 1996). 4. People are to a large degree bound to their implicit perspectives and world views (Rorty 1989). This is the compound challenge we have to face when considering new ways to communicate on complex systems thinking.

Communicative clarity

Xiang and Clarke (Xiang and Clarke 2003) provide a set of credentials for scenarios that help us set the challenges for interactive scenarios in terms of clarity as well as engagement. Instrumental for communicative clarity, a main function of scenarios is captured by a concept from cognitive psychology known as *chunking*: the grouping of smaller, less meaningful units of information into larger, more meaningful and cognitively ergonomic chunks (Miller 1956). In the case of scenarios, this means that ideas about elements of future developments are integrated into coherent alternative storylines, giving them focus and internal logic. *Coherence* plays a large part in keeping scenarios intelligible and imaginable. Conversely, scenarios should represent a *diversity of perspectives* to provide comprehensive insight. However, comprehensiveness should be balanced with the need for coherence and clarity. Coherence also needs to be balanced with *comprehensiveness*, which allows for greater realism but can work against clarity. Human cognitive procedures used for judgements are often determined by what information is most readily available and requires minimal mental adjustment from the status quo (Tversky and Kahneman 1974). To help break from this pattern, the scenario approach links drivers, relationships and consequences that were previously lost in the selection of information, or falling outside the scope of considered possibilities, to *stretch* participants' thinking (2003). Both stretching and chunking functions serve to let scenarios have a bridging function between different stakeholders and different sources of knowledge. To further enhance this process, good scenarios should be both *plausible* yet *unexpected*, stimulating creativity while retaining credibility (Schwartz 1991). Also, *qualitative* and *quantitative* methods can be used in tandem to contribute to clarity: numbers can be clarified by storylines and vice versa. Finally, a good scenario set should take questions of cognitive ergonomics into account in its design decisions, such as the number and time span of the scenarios and whether they follow a single or multiple themes (Xiang and Clarke 2003).

Engagement

As focused on practical feasibility, scientific soundness and clarity as a scenario exercise may be, it will have very little impact if it does not engage and stimulate stakeholders to participate. Many of the aforementioned benefits and requirements of the scenario approach serve not only clarity, but also engagement. When scenarios are both plausible and surprising, coherent and comprehensive, this increases their power to draw participants in. Concreteness, detail and specifics also add to engagement, especially when presented in a *sensorially direct* way, which is where interactive media come in. Interactive media can also be instrumental in creating a basic *vividness* for the scenario content: people relate the inferential weight of information directly to its vividness (Nisbett and Ross 1980). Contributing directly to vividness are *imaginability* of the content, *relevance* to the participants' personal interests and a *close proximity* in terms of either or both space and time to their circumstances. The last criterion poses a particular challenge for scenarios with a longer time-line.

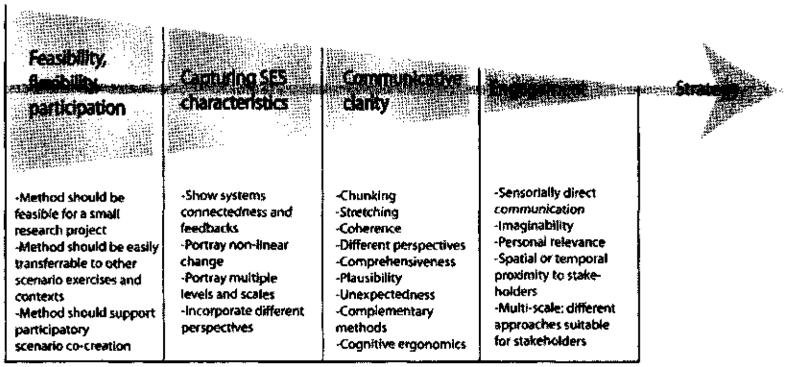


Figure 2.2: Synthesis: scenario criteria. The arrow represents our criteria succession leading up to choosing a strategy for interactive media scenarios. Each section connected to the arrow summarizes the challenges discussed in this section. We advocate considering the challenges in each step in turn, as one set of challenges has to be overcome to consider the next.

If multi-scale scenarios are actually meant for stakeholders on the different scales included, care should be taken to recognize the different relevant issues for stakeholders on each scale (Biggs et al. 2007). We can expand this notion by stating that communication methods on different scales should also fit their audience, and this has consequences for the appropriateness of communication on multiple scales in a single interactive method.

Scenario criteria synthesis

Sections 3.1 to 3.4 have explored the challenges for scenario communication focused on SES. Figure 2.2 summarizes these challenges. Again, the arrow represents the criteria succession leading to a specific strategy. We propose that scenario developers consider and deal with the challenges in each step in turn. Feasibility, flexibility and the capacity for participation form the basic requirements. Then, scenario developers have to consider what is needed to capture SES characteristics as represented by the criteria we propose. Finally, interactive media should build on the functions that scenarios have in terms of communicative clarity and engagement.

2.4 Overview: interactive media in science communication

In section 2.2, a case has been made for the potential of interactive media for participatory scenario communication. In the following section we investigate several fields of science communication, their strategies, benefits and drawbacks, in the light of the requirements of participatory scenarios. We do not pretend to capture the full spectrum of media communication research. We define research domains fairly broadly to include promising lines of research that may be on the fringes these domains.

We explore the following fields of science communication:

- *Scenario communication:* scenarios are our starting point, and scenario developers have themselves done their share of scenario communication, though as we will show, these strategies only cover a part of the interactive media communication spectrum.
- *Landscape visualization* (Sheppard 2001; Al-Kodmany 2002; MacFarlane et al. 2005)focuses on the accurate visualization of landscapes and environments. This domain has much in common with scenario development, but there are also crucial differences, mainly related to the planning perspective that makes up much of this field, and the lack of emphasis on processes of change.
- *Serious gaming* (Wachovich et al. 2002; Giasolli et al. 2006; Breslin et al. 2007; Slager et al. 2007), the study of how the communicative power of games can be harnessed for educational purposes, is a field of study with a wide range of applications, and some of them bear relevance to scenario thinking. Serious games developers focus on affective engagement as well as cognitive understanding of the games' educational contents.
- *Visual analytics:* Visual analytics focuses on the visualization of and intuitive interaction with large, complex collections of information. This field contains valuable insights on the relationships of perception, cognition, analysis and interactivity (Mazza 2004; Andrienko and Andrienko 2007; Thomas and Cook 2007).

Figure 2.3 sketches the general scope of each of these research domains. The main body of scenario communication focuses on relatively abstract, conceptual communication (graphs and diagrams, with land use change maps and snapshot images at the more realistic end). Yet, research from landscape visualization has shown that realism in communicative content is a benefit in getting audiences both cognitively involved and emotionally engaged (Bishop 1994; Appleton et al. 2002; Appleton and Lovett 2003). Additionally, visual analytics as well as serious gaming demonstrate the added value of dynamic communication and interactivity, both for engagement and learning. On this dynamic side of the scale, serious gaming focuses mostly on experiential/environmental communication, while visual analytics deals with abstract representations.

Interactive media communication in scenario development

To provide a point of reference, we start with the state of the art in communication within scenario development. Scenarios dealing with social-ecological systems are often developed through complementary strategies, using both qualitative techniques like storylines,

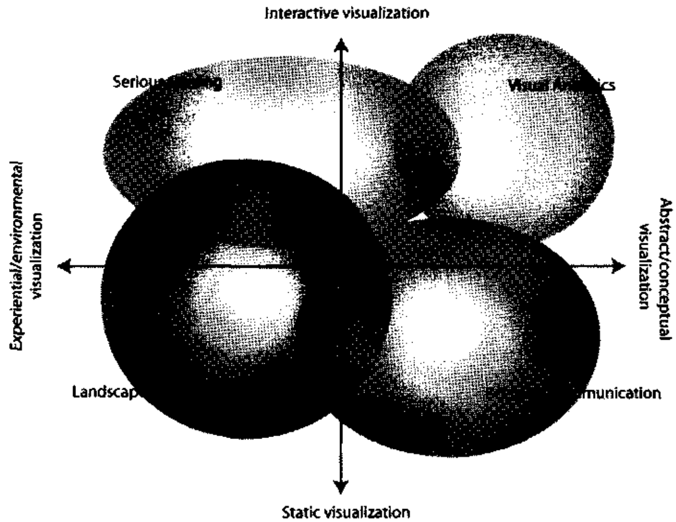


Figure 2.3: An indicative sketch of research domains in science communication. This image adapts the Zube (1987) landscape visualization classification to characterize these domains. Experiential vs. conceptual visualization are based on Sheppard (2001).

and quantitative techniques like models. This is particularly common with scenarios on a continental or global scale (Millennium Ecosystems Assessment 2005; UNEP 2007; Volkery and Ribeiro 2007). Output from quantitative models is typically in the form of graphs and maps. A communicatively powerful version of this numerical output comes in the form of dynamically changing maps, showing e.g. land use change happening over the scenarios time span (Verburg et al. 1999; Volkery and Ribeiro 2007). Output from the qualitative approach consists mostly of storylines, sometimes accompanied by images. In both components, visual communication plays a relatively minor role. In the Millennium Assessment (Millennium Ecosystems Assessment 2005), for instance, the section containing the qualitative storylines is accompanied by nothing but small drawings. The Global Scenario Group (Gallopin 2002) and GEO4 (UNEP 2007) scenarios have similar images representing each scenario. An interesting exception is the PRELUDE (Volkery and Ribeiro 2007) scenario set, which is presented on-line in a multi-media package that includes a combination of small animated films, thematic music and voice-overs, as well as different fiction approaches such as fictional stakeholder meetings and e-mail exchanges, alongside a library of quantitative information and land use change animations.

The story-and-simulation (SAS) approach (Alcamo 2008) tries to bridge the gap between quantitative and qualitative approaches by an iterative process of output exchange between the two. Fuzzy Cognitive Mapping (Kok and van Delden 2008) and Causal Loop

Diagrams (Sendzimir 2007) are methods that have strong potential to help scenario developers, due to their relatively accessible, semi-quantitative approach, and are now being integrated with the SAS method (Vliet et al. in press). Beside their bridging function, these methods have strong communicative potential in their own right.

Considering this common approach, we are especially interested in evaluations of the communicative effectiveness of scenario sets in terms of their format and presentation. Evaluations have, however, largely been limited to their content (van Notten et al. 2003; Xiang and Clarke 2003). Scenario sets that capitalize on interactive media are still a minority.

Landscape visualization

Landscape visualization (Sheppard 2001), (Brink et al. 2007) is a catch term that describes only a part of the more comprehensive field of geo-visualization. We choose to focus on this designation here because it captures the work in geo-visualization that deals most with audience engagement and interactivity. We can delineate landscape visualization as the part of digital geographic visualization that deals with 3D visuals (Sheppard 2005). We furthermore include insights from other, connected geo-visualization sub-domains such as Participatory Spatial Planning in this category (Al-Kodmany 2000; Jansen et al. 2007). The book 'Visualization for landscape and environmental planning' serves as a good introduction in landscape visualization (Bishop and Lange 2005).

Ghadirian and Bishop (2008) discuss Appleton's (2001) division of landscape visualization based on the techniques used: image draping, photo-realistic rendering, and virtual worlds, adding augmented reality (virtual images superimposed over and enriching reality) in their own research. Image draping and virtual worlds feature more user freedom, but often at the expense of the realism achieved with rendering tools like Visual Nature Studio (Schroth et al. 2006; Appleton 2007), though the use of commercial game engines in visualization is making this less of a trade-off (Herwig and Paar 2002; Paar and Rekittke 2005; Salter et al. 2008). An example of landscape visualization linked to a process model is the SIEVE project (Stock et al. 2008). In this project, the developers are working towards a direct translation of management choices made in an environmental process model to one of several scenarios in the form of landscape visualizations of different land cover types. Another work-in-progress example of this attempt to link process models to spatial visualization is the IPODLAS project (Isenegger et al. 2005). Similarly, a model links agent-based modelling to visualization of alpine tourism scenarios (Walz et al. 2008). With the development of mobile media platforms, the use of multi-platform visualization in landscape visualization shows additional promise (Stock et al. 2007).

Recently, web-based tools have opened up new possibilities for extended and asynchronous stakeholder contributions (Lammeren and Bergsma 2006; Seeger 2008). A fairly recent development that is rapidly changing the range of options for participatory landscape visualization and spatial planning is the introduction of geo-web tools. These 'virtual globes' like Google Maps and Google Earth (Brodersen 2006; Compieta et al. 2007; Clough and Read 2008; Cutler 2008; Sheppard and Cizek 2008), NASA World Wind (NASA 2006) and Microsoft Virtual Earth (Microsoft 2008) offer a geographical way to organize online data. With Google Earth, users can move into the third dimension, and even the fourth for some information put in time animations, for instance showing ecological and climatic change (Singh et al. 2008). Also, in Google Earth, expansions can be made with relatively little skill in web-design, and tools like Google Sketch-Up (Google 2008) allow users to make easy 3D components to enrich the virtual world. Because of the high exposure and rapid rate of development of these tools, they offer new possibilities for geo-visualization and indeed for interactive scenario communication that go beyond benefits in access. Craglia et al. (2010) propose a number of future research avenues for web-based interactive geo-visualization.

Accelerating technological developments in landscape visualization have run ahead of research to assess their effectiveness (Orland et al. 2001; Brink et al. 2007), (Mahdjoubi and Wiltshire 2001; Sheppard 2001). McFarlane et al. (2005) have described that this strong focus on the technical side of the equation has resulted in visualization tools that are running ahead of theory to guide them, and so become 'hammers looking for a nail' (Hacklay 2002).

Serious gaming

Serious gaming can be defined as a computer-based contest with an artificial intelligence or other players that uses game enjoyment for training purposes (Greitzer et al. 2007). Serious gaming and its associated concepts of e-learning, edutainment and game-based learning form a rapidly growing field of interest for training programs in governmental, commercial and scientific sectors (Susi et al. 2007). Serious gaming borrows its techniques from the fast-moving commercial gaming industry, where gamers immersion and engagement in the games have consequences for the success of the project. The commercial gaming industry has surpassed the film industry in financial size and cultural influence (Association 2004). To get a sense of the potential scale of a successful application of serious gaming, America's Army, a freely downloadable serious war game created for the U.S. government, has been downloaded 17 million times and has a community of around 4 million registered players (Susi et al. 2007). Considering that so many people worldwide willingly spend their time on computer games, educational bodies have been researching how to harness this intrinsic motivation for engagement with training purposes.

When serious games deal with sustainability issues, their use of scenarios starts to overlap with the approaches in traditional scenario development. Games like Floodranger (Discovery Software and View the World), Splash (Desdemona), VGAS (Artlab 2004) and Fishu@lis (Artlab 2004) have focused on scenarios that get their players to experience the complexities of human interactions with environmental issues on a household, regional, or in the case of the World Water game (Delft Hydraulics), global scale. Now, with the increasing possibilities offered by broadband internet, games can be run online, lowering the participation threshold that much more: Red Redemptions games Operation: Climate Change and Climate Challenge (Miller 2007; Red Redemption 2007; Red Redemption 2007) are excellent examples of how to bank on this benefit, using fairly simple yet clear imagery and game dynamics to draw in large audiences 128 000 players in the case of Climate

Challenge. At the same time, in virtual social environments such as Second Life (Linden Research 2008), volunteers have started bottom-up initiatives on sustainable development (Miller 2007).

Finally, another recent genre of games has recently been connected to serious gaming: alternate reality gaming (ARG), also known as or overlapping with pervasive or ubiquitous gaming (see Nieuwdorp (2007) for a discussion on definitions). The game realities of alternate reality games extend across platforms, even using the physical world as an interaction arena to engage players in a suspension of disbelief. This is best summed up in the motto of the genre's first mainstream title, the Beast: 'this is not a game' (Steward 2008). Recognizing the potential to harness players' enthusiasm to focus on sustainability issues, serious ARGs have been developed, drawing on an additional potential pool of players because of the plausibility and relevance of their focus. The best example of this is World Without Oil (Writerguy 2007), where thousands of players worldwide joined in a 'what-if' interaction concerning an early peak oil crisis in 2007. Players were responsible for a large part of the project's content. Other examples of serious games with ARG elements include AECO (DVTG Adventure Ecology Team 2007) and Tomorrow Calling (Wolff 2008).

Visual analytics

Visual analytics is the science of analytical reasoning supported by a highly interactive visual interface (Thomas and Cook 2007), (Thomson et al. 2005), (Andrienko and Andrienko 2007). In a comprehensive research agenda, Thomas and Cook (2007) discuss the current state of Visual Analytics as well as guidelines and avenues for future research in this field. Their focus is mainly on Visual Analytics tools driven by United States homeland security and emergency response systems, and stress its relevance for these types of application. Similarly, Andrienko et al. (2003) set up a catalogue of Visual Analytics systems and show a wide range of strategies according to queries on time, space and target identity. These authors point out that many of these strategies are in need of further development and evaluation when held against their requirements.

Visual Analytics is a young field, and we believe that the rigour and depth of its theoretic underpinning is as yet more useful for interactive scenario communication than specific applications. Chen et al. (Chen and Benford 2007) conclude that many visual analytics tools have been limited in their combining of space, time and attribute components, and have not yet fully been able to facilitate human pattern recognition and interpretation. But the focus that Visual Analytics research has on information representation, analysis and interpretation complements the insights from serious gaming concerning engagement and emotional affectation. Additionally, resilience scientists already make use of heuristic models such as the adaptive cycle, the panarchy model, and the ball-and-cup visualizations (Gunderson and Holling 2002) that can be said to fall within the wider domain of information and knowledge visualization.

2.5 Evaluating benefits and drawbacks

Here, we use the criteria formulated in section 2.3 to evaluate the potential of the different science communication domains we introduced. We follow the criteria succession (figure 2.1) to structure our evaluation.

Feasibility, flexibility and participation

For a small budget project, feasibility is a major issue: strategies should either make use of pre-existing standards, or when built from the ground up, be relatively easy to construct. Landscape visualization tools provide relatively easy ways to translate geospatial data to 3D environments (Appleton et al. 2002). The problem with these tools is that they are relatively limited in any capacities beyond the basic visualization of landscapes. Using manipulated photography is simpler, and can generate sufficient realism (Dockerty et al. 2006), but also lacks in flexibility. Conversely, from the serious gaming perspective, the problem is reversed. The diversity of communication strategies that exist within commercial gaming and to a smaller degree in the serious gaming world offer a world of opportunities to handle the challenges that our resilience communication criteria offer. But these techniques have to be built from scratch. Certain types of commercial game setups lend themselves relatively well for straightforward adaptations, as Herwig and Paar (2002) show by using a game engine for the visualization of environments. But when we want to make use of more complex game characteristics such as artificial intelligences and intricate interaction procedures, the amount of resources needed to mimic these elements increases steeply. High profile games involve hundreds of developers (Squire 2005). Visual Analytics platforms show a similar mix of potential and development difficulty to serious games, but generally lack the ability to include narratives (Andrienko et al. 2003).

Paired to the feasibility of an approach is the required flexibility of the resulting tool. We are looking for participation tools that are ideally as widely applicable as the low-tech workshop techniques that currently make up the participatory scenario developer's arsenal. Meanwhile, we still want to harness the potential interactive media offers in terms of communication bandwidth (Al-Kodmany 2002). The least complex landscape visualization methods offer us a degree of flexibility because of their standardized conversion of geospatial information. Again, the feasibility problems that serious games and visual analytics present also affect their flexibility and transferability.

Finally, our emphasis on using interactive media as a platform for dialogue and stakeholder contributions rather than unilateral communication links into feasibility and flexibility issues, because the content of the communication should be controlled as much by the participants as by the developer. This is where traditional landscape visualization falls short. Conversely, interactivity is highly integrated in serious gaming. With the onset of online gaming and the creative communities that have risen up with it, players have been making active contributions to the games content, often greatly extending the scope of experience (Van Doorselaer and Coppens 2003). The challenge is that in commercial games, communities are often tech-savvy and committed enough for very sophisticated contributions, whereas with serious games, the intended participants will often not match this profile (Susi et al. 2007).

Capturing social-ecological systems characteristics

When reviewing landscape visualization in the light of the SES communication criteria, we conclude that methods in this field generally lack the capacity to represent systems change in a continuous fashion. A notable exception is the work of Stock et al., whose work on linkages to dynamic models point to future development in that direction (2008). Other challenges in capturing SES generally tend to fall beyond the scope of landscape visualization. Non-visible or non-environmental system components such as fast socio-economic interactions, when present at all, are integrated in a static fashion. And maintaining the domain's high standard of realism will be challenging when there is a need for *fundamentally different* representations of multiple scales of space, time and organization.

In contrast, digital games are essentially communication arenas with internal rules and temporal dynamics that can lead to complexity both as emergence and as conscious design (Westera et al. 2008), including the capacity to incorporate surprises and transformations of the environment. As such, they are particularly suited to be linked to dynamic scientific models in order to give participants understanding of spatial-temporal dynamics. The analogue between games internal models and research models is discussed by Sawyer (Sawyer 2002), who advocate conscious linking up between the two to bank on the experience in the gaming community with artificial intelligence, design for accessibility and engagement. This analogue holds for dealing with qualitatively different representations of temporal, spatial and organizational levels. But commercial games that reach this level of complexity are generally developed on much larger budgets than serious gaming projects, and therefore much of this broad potential for complex system dynamics still remains untapped (Westera et al. 2008).

Visual analytics focuses on the usage of multiple scales and perspectives, as well as interactive temporal dynamics to make complex information more accessible. The focus in this field is more on the exploration of meaningful patterns in raw, unstructured data, and is focused on primary discovery rather than on the communication of insights in a scenario context (Thomas and Cook 2007). Visual Analytics does have potential for the first analysis of information on complex systems. One can imagine a future situation where even at this stage, interactive visual facilitation would be transparent enough for sense-making by non-experts. In terms of scenarios, however, strategies employed in Visual Analytics can serve as complementary to the more accessible communications in landscape visualization and serious gaming rather than as a standalone basis.

Communicative clarity

Realism is a large part of the focus of landscape visualization. Because of the work on translating GIS and model data directly into landscape visualization tools, this focus is combined with an emphasis on accuracy with regard to available data. This is especially relevant when visualizations become more life-like, because their relation with underlying processes becomes less clear when increased realism muddles the original information (Orland 1994).

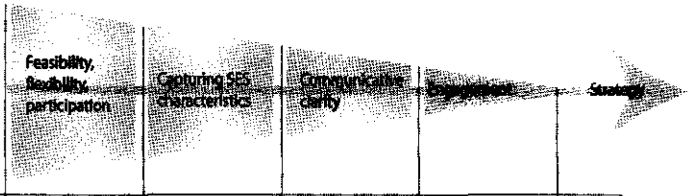
With serious games, the focus is less on representational realism and accuracy and more on the transparency and clarity of the communication, though training games that are set up to prepare people for specific tasks do make realism their priority (Breslin et al. 2007). Visual Analytics deals with abstract information and is therefore not concerned with realism, but all the more with accuracy, clarity and reliability, in a way that can be complementary to the environmental approach of landscape visualization (Brath et al. 2005), (Tory and Mller 2004).

Engagement

Serious gaming, landscape visualization, and visual analytics are used for very different user interaction goals. Landscape visualization is often used in a workshop setting, though there are also examples of on-line platforms for a large number of participants (Dykes 2000). The geo-web revolution plays an instrumental role in geo-visualization's move towards on-line interaction and participation. Generalizing, though, we can say that in landscape visualization participants take the role of visitors in a virtual environment. Interaction is generally limited to moving around and possibly commenting. In comparison, serious games are built on a much higher degree of interaction. The participants act as the protagonists or even the directors of virtual worlds, not only interacting with the game world but also with other agents controlled by the computer or by humans (Wachovich et al. 2002). Squire (2005) finds that commercial games, as well as serious games built by producers with a commercial gaming background, often have very sophisticated ways to deal with learning curves and cognitive ergonomics. These games let the players get familiar with expanding perspectives and increasingly complex interactions in an intuitive fashion. To achieve this, many games work with a situational scenario-based approach, focused on creating the appropriate experiential context for learning. In this regard, again, serious gaming offers the most possibilities and the most difficulties in execution. Visual Analytics, finally, distinguishes itself from other information visualization genres mainly because of its focus on human interactions with the information platform and with other experts (Thomas and Cook 2007). Again, these interactions are too specific and too abstract to serve as a basis for scenario communication in a narrative sense, and serve better as complementary strategies to a mix of landscape visualization and serious gaming benefits.

Review synthesis

See figure 2.4 for a summary of this review section. Again, we structure the benefits and drawbacks of different fields according to the criteria succession. The scores in each box roughly represent our evaluation of each communication domain per step. Landscape visualization and serious gaming have complementary benefits and weaknesses, each ending up with 9 points. The structure of the criteria succession again shows that the benefits of serious gaming are offset by practical considerations. Landscape visualization is generally



Landscape visualization	2 Some tools easy to implement, contributions in geo-web tools	1 Links to process dynamics still in development	3 Strong focus on representational power	2 Varied, but users are generally viewers or visitors	8 Total
Serious gaming	1 Much resources needed to reach standard of commercial games	3 Strong links between game models and scientific models	2 Powerful technology, no conscious focus on accuracy, validity	3 The field's main focus: long experience in commercial gaming	9 Total
Visual analytics	1 Difficult to transfer to new purposes	2 Conscious focus but temporal dimension needs development	2 Focus on accuracy and clarity, but abstract	2 Interactivity and analytical flow, not emotional engagement	7 Total

Figure 2.4: Summary of the review. The scorings provide a rough summary of how suited each communication domain is to deal with each challenge, with totals for each evaluated research domain. 1=unsuited, 2=moderately suited, 3= well suited. The texts give a quick sketch of benefits or drawbacks considering each step.

deficient in its ability to capture SES dynamics. In both cases, we have to consider that each step should be dealt with in turn. If scenario developers want to benefit from the advantage serious games can have in their ability to convey SES characteristics, the problems with feasibility and flexibility have to be overcome. Conversely, when purely focusing on landscape visualization, feasibility and flexibility are its advantages. But scenario developers will then run into the limited capacity of landscape visualizations to convey SES characteristics. For both domains, true stakeholder participation that goes as far as stakeholder-produced content is not common. Visual Analytics has less practical value for scenario developers overall, its main usefulness being the theoretical underpinnings of the field (Heuer 1999), (Card et al. 1983).

2.6 A strategy developed in the context of practical case studies

Given the dilemmas and limitations brought up in section 2.5, scenario developers will have to come up with creative strategies for interactive media to deal with practical challenges, the requirements of complex systems thinking, and the need for communication that is at once clear and engaging. This section proposes such a strategy. We illustrate this strategy with two incarnations of a developing project: Scenario Communities. This project is part of the research theme 'Images of Sustainable Agriculture' within the TransForum program for agro-ecological innovation (Veldkamp et al. 2008). In Chapter 5 of this thesis, the authors use a live version of Scenario Communities in workshops for a case study in Oxfordshire, United Kingdom.

Feasibility, flexibility and participation

We propose to tackle requirements of feasibility and flexibility by keeping the communication platform simple and making creative use of existing communication structures (Arias 1996; Al-Kodmany 2000; Al-Kodmany 2001; Al Kodmany 2002) The participatory character of web 2.0 technologies allows us to see the interactive media evaluated in section 2.5 in a new light. We advocate taking advantage of these developments by adopting a web-based, mixed media (Gooding 2008) approach: simple web 2.0-based interaction structures, linked to a geo-web platform, serve as a support structure to nest more high-tech components. This leads us to a strategy with three levels of functionality:

- Level 1 deals with the communication of initial scenarios that set the context and inspire participants to contribute.
- Level 2 consists of web 2.0 methods that allow participants to contribute to the scenarios.
- Level 3 provides a spatial-temporal background through on-line geo-web tools.

For the communication of basic context scenarios (level 1), simple solutions include short animations or landscape visualizations in video form, and small, nested interaction arenas or 'micro-games' that let users explore vital elements of the virtual environment. This way, developers use the benefits of landscape visualization and serious gaming technology without having to construct the entire world. Considering participation (level 2), a mash-up approach allows participants to provide contributions similar to the context scenarios. Web-video sites like Youtube (Youtube 2008) allow participants to add their own video sequences. Relatively accessible 3-d construction tools like Google Sketchup for Google Earth (Google 2008) lower the threshold for the creation of virtual environments considerably. These kinds of contributions may still be out of reach for many audiences, but we can combine their more low-tech contributions (in the form of text and images, for instance) with video and virtual environment contributions from more tech-savvy individuals. To create a spatial-temporal context (level 3), we see the rise of geo-web platforms as an excellent opportunity to latch onto. These applications are characterized by widespread use, worldwide support communities, and an open character that invites outside contributions (Jansen et al. 2007), (Sidlar and Rinner 2009), (Hopfer and MacEachren 2007). Google Maps (Google 2008) and Google Earth (Google 2008) serve as readily accessible varieties of geovisualization and 3-D landscape visualization, respectively (Sheppard and Cizek 2008). The feasibility of using these platforms as a basis is complemented by their flexibility.

Considerations of feasibility, flexibility and stakeholder participation have led to choices in the Scenario Communities project that follow the strategy described here. In our current development, we use a web 2.0-based website linked to Google Maps, later to be integrated with Google Earth. Within this shell, storylines are currently presented as a succession of short animations, and interactive games in future versions. Participants can respond to these storylines by creating their own stories from particular perspectives in Google Maps and Google Earth, using text, images, sound and video. The website also allows participants to comment on each other's storylines. The basic geo-web interaction platform that supports the animations and micro-games can be very flexibly used for other projects, and offers much room for stakeholder contributions and the exchange of perspectives.

Capturing social-ecological systems characteristics

We saw that serious games arguably have the most potential to deal with complex multi-scale dynamics in a narrative context, but as we discussed, present the most challenges in terms of feasibility. In the context of our three-level strategy, small-scale game environments specifically tailored to let participants get a feel for SES dynamics in specific cases, nested in accessible support structures, are a viable solution to this dilemma. Much of the learning benefits of games, however, stem from the fact that they immerse players in a consistent world with rules and allow gamers to deal with increasingly complex problems within this virtual environment (Jegers 2007). The power of games to provide a coherent experience of non-linear temporal dynamics could be endangered by our nested multi-media strategy. This approach does, however, allow for qualitatively different experiences on multiple temporal, spatial and organizational scales, turning a concession to feasibility into an advantage.

In our live version of Scenario Communities in Oxfordshire (chapter 5 of this thesis), we used a series of drawn animations for the communication of context scenarios (level 1). Drawn animations allow us to incorporate non-visual elements of the storylines alongside depictions of change in the visual environment. This way, links and feedbacks in social-ecological systems can be visualized. In future versions, system dynamics can be more directly represented by replacing the animations with a series of micro-games.

Using these media, we aim to convey system feedbacks and non-linearity on two levels of communication. First, the order in which the story lines are presented: we use a combination of back-casting and middle-casting (van Notten et al. 2003). Participants are presented with the end states of scenario storylines (currently in the form of an animation, in future versions in the form of micro-games). Participants respond to these end states using level 2 functionality. Then, participants start out in the recent past to build their storylines, working up to the end state again. The combination of back-casting and middle-casting aims to instil a sense of system dynamics in the participants by starting out in the past, while already having to think towards a scenario outcome that diverts from business as usual. Within the scenario storylines presented as animations or games, a number of surprises and non-linear effects are communicated. Two spatial scales form the focus scales in the project: the regional (province) scale of the context scenarios and the local/personal scale of individual storylines by participants. These spatial scales are represented in Google Maps (level 3). Beyond these scales, the context scenarios have been designed to show effects caused by and affecting other spatial, temporal and organizational scales. This inclusion of cross-scale effects is reinforced by using the Millennium Assessment scenarios as a larger context.

Communicative clarity

We propose scene-based landscape visualization and gaming techniques to produce doors and windows into a more realistic representation of SES scenarios (level 1). We follow Westera et al. (Westera et al. 2008) who recommend that for serious games, credibility is attainable through content as much as through representation. Furthermore, they claim that through strong content and realistic game dynamics it is possible to reduce the need for complex representational design. This philosophy should be extended to the design of participation functionality (level 2). Additionally, such geo-web applications as Google Earth are themselves quickly becoming more and more capable of realistic information representation while keeping their flexibility and accessibility (level 3).

Though containing less realism than most computer-generated graphics, the drawn animations used in the Oxfordshire case (chapter 5) are not limited to physical landscapes in their content and can therefore create a coherent whole out of the scenario storyline elements. In planned versions, the interactive element added allows participants to experiment, creating a number of perspectives on the storyline. This may add to increased clarity, though it could also make the communication overly complex in comparison to the animations.

Engagement

We advocate a game design mindset as an overall perspective to deal with interactivity, engagement and cognitive understanding (Dickey 2005; Kilii 2005). Again, Westera et al. (2008) discuss that strong content and game dynamics can account for user engagement at least as well as visual realism (level 1). ARGs have shown us that with creative approaches to content, a different kind of engagement can be created, especially when connected to a high capacity for creative input from participants (level 2) (Kim et al. 2008). This way of interactive media development is synergetic: the communication remains feasible and flexible, and uses its focus on content and participant input as a strength to foster engagement. Though not yet on par with some of the more high-tech landscape visualization tools, geo-web tools offer a sense of locality and environmental context (level 3). This functional level will help create a sense of immediacy and personal relevance (Sheppard 2005), (Al-Kodmany 2002).

The animations used in Scenario-communities are designed for liveliness and relevance using strong visuals and sound, and micro-games case allow for a direct, gaming type of engagement. Following the strategy, we work with the kind of engagement created by ARGs: participants' active contributions to the content stimulate a form of engagement based on a sense of investment in the scenarios.

	Feasibility, flexibility, participation	Capturing SES characteristics	Communicative clarity	Engagement
LEVEL 1: *Context visualization (animations, micro-games)*	Small elements to visualise, complementary benefits	Integrated animation shows change, links Games give sense of dynamics	Coherent, comprehensive visualization Cross-platform consistency	Animations focus on imaginability, vividness Direct interactivity
LEVEL 2: *Personal web 2.0 storylines*	Space for different levels of commitment and computer skills	Non-linear time structuring Interaction with scenarios	Chronological structure, complementary media	ARG: engagement through investment Sharing perspectives
LEVEL 3: *Geo-web support structure*	Based on existing structures, familiar, flexible, connectable	Multi-scale Room for spatio-temporal visuals in geo-web context	Natural geospatial structuring of storylines	Geospatial context provides proximity and directness, exploration

Strategy

Figure 2.5: The strategy proposed in this section consists of three levels. 1. context visualization providing overall scenarios as a starting point for users. We use either animations and micro-games. 2. personal web 2.0 storylines created by participants. 3. geo-web support structure provides geographical and temporal context. These elements all have their benefits when considered in the light of the criteria succession, as summarized in the boxes.

Strategy synthesis

See figure 2.5 for a synthesis of our strategy's benefits, based on the three functional levels introduced in section 2.6, Figure 2.6 shows how the three levels in the strategy interact. Both methods communicating the context scenarios (level 1) are able to capture SES characteristics, represent temporal change and fluidly incorporate different social-ecological elements. Both clarity and engagement benefit from the limited number of elements communicated per animation/micro-game, as well as the lively audio-visuals that are used. Web 2.0-based storyline creation by participants (level 2) is accessible, flexible, and easy to implement. It allows participants to actively contribute and respond to discontinuities and challenges presented by SES dynamics in the scenarios. By providing new inspiration and possibilities to respond per time step, clarity is maintained. We stimulate engagement by participants getting invested in their contributions and interactions with others. Finally, the geo-web context (level 3) provides a sense of locality and structure, as well as a clear and fluid cross-scale environment, all this in an on-line world that is already up and running.

Experience in creative work with stakeholder groups has made clear that the benefits of face-to-face cooperation are numerous (Kasemir 2000; Kok et al. 2006). Our strategy would provide benefits both in a live scenario workshop as well as through on-line participation. We propose that in practice, the particular benefits of live participation and on-line participation be used to complement each other. Live workshops could provide opportunities for direct group learning and generate momentum, while the on-line format could enrich the work, maintain interest and include far more participants.

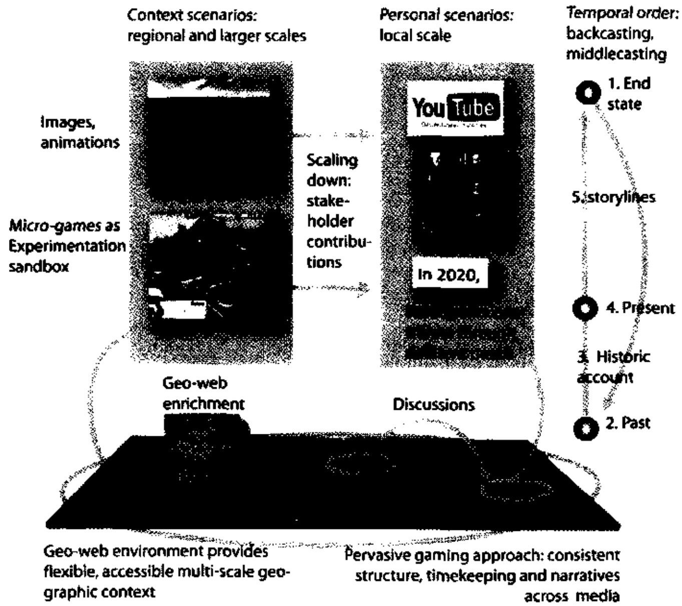


Figure 2.6: The structure of the three-level strategy for interactive scenario communication. Again, level 1 provides context scenarios as a starting point. Level 2 builds on web 2.0 techniques to let participants build personal storylines. Level 3 forms the geographical and temporal context. Rules, dynamics and narratives are consistent across platforms.

An important benefit of this strategy is its potential for up-scaling: because the geo-web support structure and environments are already available, all that is needed are context scenarios (animations and micro-games, level 1) that represent larger scale storylines. Considering that with scenarios on a national or global scale, reaching intended audiences through live events becomes much harder, this scale flexibility is an essential benefit.

See Appendix 1 for further, more detailed guidelines for interactive media synthesized from the science communication fields discussed in this chapter.

2.7 Conclusions

If we want to foster more adaptive perspectives in society, we must create space to incorporate future complexities and uncertainties in our communication. In this chapter, we explored the potential in interactive media to help us deal with that communication challenge. Our evaluation of landscape visualization, serious gaming and visual analytics shows that these offer much potential for the enhancement of participatory scenario communication on SES that is as of yet unused in mainstream scenario development. Serious gaming and landscape visualization offer more practical handles than visual analytics and both provide benefits that are complementary. Web 2.0 technologies provide the key to mix approaches in these domains in a way that deals with the challenges identified using our criteria succession in this chapter (section 2.2).

These conclusions have led to a strategy for an interactive media scenario method consisting of three integrated functional levels:

- Level 1: Toned-down versions of landscape visualization (animations) and serious gaming (micro-games).
- Level 2: Web 2.0 technologies that allow for the creation of personal stakeholder storylines.
- Level 3: A geo-web environment that structures the context scenarios and the personal scenarios in time and space in an accessible, engaging fashion.

We have successfully used a live version of Scenario-Communities (see chapter 5 of this thesis). We propose that this on-line interactive media strategy be used in a complementary fashion in both live workshops and on-line interactions. This strategy has a scale flexibility that makes it suitable for different scales, from local to global scenarios.

Chapter 3

The System Perspectives Scope: stakeholders framing social-ecological systems change in terms of space, time and system dynamics

Lull our budding concerns to sleep.

-Terzij de Horde, The Roots of Doomsday Anxiety, 2010

Chapter is based on:
J.M. Vervoort, M.A. Hoogstra, K.Kok, R. van Lammeren, A.K. Bregt, R. Janssen, 2010. *The participatory framing of environmental change concerns in terms of space, time and systems dynamics.* To be submitted to Human Ecology Review.

Abstract This chapter introduces and evaluates the System Perspectives Scope, an interactive, visual toolbox designed to elicit and compare stakeholder perspectives on the dimensions and dynamics of social-ecological systems change. The toolbox consists of three tools: 1. Scale Perspectives, a tool aimed at eliciting stakeholders' perspectives on the spatial and temporal levels at which social-ecological systems change issues play out; 2. Myths of Nature, focusing on stakeholders' basic assumptions about the interactions of human and natural systems; and 3. The Circles Test, a tool used to capture stakeholders' understanding of the links between past, present and future and their engagement with the future.

The System Perspectives Scope was applied in two contrasting European case studies to evaluate its ability to produce relevant results for sharing and comparing stakeholder perspectives, and further steps in participatory planning, modelling and scenario development. The Scale Perspectives outputs showed that participants had highly different, multi-level perspectives on the key temporal and spatial scales for land use management. Myths of Nature captured different perspectives on social-ecological systems dynamics. The Circles Test captured participants' time orientation and engagement with the future. Significantly, Scale Perspectives outputs were related to Myths of Nature and concepts of time links that warrant further research. The main problem of the toolbox is that the tools produce very basic results. We discussed how elaboration of the tools and more information from participants could help overcome this limitation. Outputs from the individual tools and combined results indicate the potential of the System Perspectives Scope with regard to the goals of eliciting and comparing perspectives and generating input for participatory processes. More generally, the results of this study show the need for participatory processes where the focus levels and system perspectives are co-defined by stakeholders, and that are conscious of different stakeholders' assumptions about systems change.

3.1 Introduction

In the management of complex, interacting human and natural systems, one-sided attempts by scientists and policy-makers to implement new plans, methods and technologies have met with numerous difficulties (Millennium Ecosystems Assessment 2005). There are two main reasons for these difficulties:

- Firstly, top-down procedures have met strong resistance from local stakeholders that would potentially be affected by their execution (Pritchard and Sanderson 2002).
- Secondly, by working from a single perspective, policy-makers remained blind to the complexity inherent in the interactions in and between human and natural systems (Cash et al. 2003; Scheffer et al. 2003).

As a response to these difficulties, two interacting developments have taken place in land use and natural resources management. Firstly, many government bodies, businesses and researchers have adopted participatory strategies (Schwartz 1991; Gibbons 1999; Al-Kodmany 2000). Secondly, the complex systems science perspective has become more prevalent in science and, to a lesser extent, in policy (Gunderson and Holling 2002). Seen from this perspective, interacting human and natural systems, or *social-ecological systems* (Folke 2006), are neither predictable nor chaotic, but rather evolve through an interplay of changing subsystems. These sub-systems interact across space and time, and thus, spatial and temporal scales as well as various social scales play a key role in the understanding of this complexity (Cash et al. 2006). In this study, we define a scale as a measure for a dimension (e.g. geographic space, time), and define the positions on a scale (e.g. local, global) as *levels* (Gibson et al. 2000). To develop adaptive ways to deal with the complexities and uncertainties of social-ecological systems, managers and policy-makers will have to examine the roles of cross-scale and cross-level interactions (Kinzig et al. 2006).

Scales, however, are always a human-constructed form of measurement. Therefore, a multiplicity of perspectives exists on what levels are most important, and concerning what levels problems should be acted upon (Scott 1998; Wilbanks and Kates 1999; Cumming et al. 2006). This multiplicity of frames and perspectives becomes crucial when we move from theory to practice, and look at societies actually attempting to adaptively manage problems in complex social-ecological systems. These attempts will, cooperatively or otherwise, involve many different types of stakeholders. These stakeholders will have different concerns and perspectives on the problems at hand (Van Asselt and Rijkens-Klomp 2002). And these concerns will implicitly be framed in terms of time, space, and other scales (Cash et al. 2006).

Examples of participatory processes that work from the complex systems perspective can be found in participatory planning and decision making (Arias 1996; Lynam et al. 2007) participatory scenario development (Kok et al. 2007; Soliva 2007), and participatory model building (Ozesmi and Ozesmi 2004; Vliet et al. 2010). However, these participatory processes do not generally start with explicit knowledge about stakeholders perspectives on the key functional levels associated social-ecological change issues. Similarly, individual ideas about the dynamics of interacting human and natural systems are not made explicit at the framing of the participatory process.

The *System Perspectives Scope* (SPS) introduced in this chapter is an interactive, visual toolbox that can be used to elicit stakeholder perspectives on social-ecological systems change through visual exercises explicitly built on the paradigm of complex systems science. The toolbox can be used on paper or in an on-line format, and can be used to quickly explore the perspectives of large groups of participants. Its design focuses on clarity, accessibility flexibility. The SPS combines a new tool, Scale Perspectives, first proposed and used in this study, with two pre-existing tools, Myths of Nature and the Circles Test. Through these three tools, the SPS provides information on stakeholders' key social-ecological change issues, the functional levels they see as being most important for these issues, and how these perspectives relate to both their views on social-ecological system dynamics and their concepts of time. In this, the SPS is a toolbox for the eliciting and sharing of analytic perspectives on social-ecological systems change. The output of the toolbox can be used directly in the choice for focus levels in multi-level models, scenarios and plans. They can also serve to decide which world-views should be catered to by scenario storylines, planning visions and models, and which should be challenged.

1. To introduce the SPS as a new exploratory toolbox to elicit, compare and combine different analytic perspectives on social-ecological change (figure 3.2).

2. To report on a first application of the SPS in two qualitatively different case studies, and evaluate the usefulness of the outcomes to frame stakeholder perspectives in terms of focus levels and system views for participatory processes such as scenario development, participatory modelling and planning (sections 3.3 to 3.6).

3.2 Introducing the System Perspectives Scope

The SPS allows science communicators to elicit a coherent view of stakeholder perspectives based on systems complexity through its three components:

1. Scale Perspectives allows many stakeholders in participatory processes to voice their most important land and resource use *issues* for the future, and moreover to explicitly frame these issues in terms of *temporal and spatial scales*.

2. Myths of Nature, based on Holling (1979), captures stakeholder views on the *dynamics* of natural systems, to connect concepts of system behaviour to the stakeholder issues and levels identified.

3. The Circles Test, developed by Cottle (1967), provides underlying assumptions of the value of the future perspectives developed with the first two tests, in terms of stakeholders' concern for the future and their ideas about the *structure* of time in general.

The relationship of myths of nature to perspectives in the spatial dimension has been previously explored by Lima and Castro (2005), and their relationship to the temporal dimension, in the form of time orientations, has been studied by Hoogstra and Schanz (2008). However, these studies do not capture integrated perspectives on both time and space. By combining the new Scale Perspectives with the Circles Test and Myths of Nature, the SPS aims to do both in an integrated fashion by combining perspectives on the spatio-temporal extents of social-ecological change issues with their perceived dynamics and value.

SPS part 1: Scale Perspectives

Research and thought on the human experience of space and time has a long history, initially in philosophers such as Kant (1965/1781), Heidegger (1962) and Husserl (1964). Later, psychologies of time (Zimbardo and Boyd 1999) and space (Freundschuh and Egenhofer 1997) were developed more extensively. Of these, our chief interest is in psychological research dealing with these dimensions in relation to strategy development, planning and action. As a psychological underpinning of this study, we were inspired by Lewin's (1951) widely influential concept of a 'life space': a conceptualization of a person's perceptions of time and space in relation to personal concerns and potential actions. Issues on temporal and spatial levels that fall outside a person's life space will have very little relevance to an individual, but might be of relevance to others in a community.

Studies in the specific context of environmental management on the link between personal perspectives on time and space include the influential 'Limits to Growth' report by Meadows (1972), where it was posited that humans have a limited interest in and capacity for action when considering a geographic extent beyond their local communities and over long time periods. Participants in research by, among others, Boniecki (1980), Simons et al. (2004) and Hoogstra and Schanz (2009) showed a lack of engagement with events on a temporal extent beyond 10-15 years. In contrast to this spatial and temporal 'myopia', a 'hyperopia' has been found in both dimensions in terms of problem recognition (Uzzell 2000; Gifford et al. 2009): the longer term future was seen as more problematic than the shorter term by participants in these studies, and global concerns were seen as more problematic than local issues.

Scale Perspectives represents a new, visual way of dealing with stakeholders' perspectives on the relevant temporal and geographical levels for their most pressing social-ecological change issues. Psychological research has dealt with personal views of temporal and geographical scale (Uzzell 2000; Lima and Castro 2005; Gifford et al. 2009), but this research has not been operationalized to provide direct input for a planning/visioning/modelling context. And unlike previous methods, Scale Perspectives uses a direct visual mode of representation to capture an integrated view of the spatial and temporal levels where issues are relevant according to stakeholders. While the visualization of a scaled field has been used to depict personal concerns in terms of time and space (Meadows 1972), it has not been used as a tool for interaction before. Instead of being guided by focusing questions on specific levels, the participants are free to determine relevant levels themselves, in a fully integrated

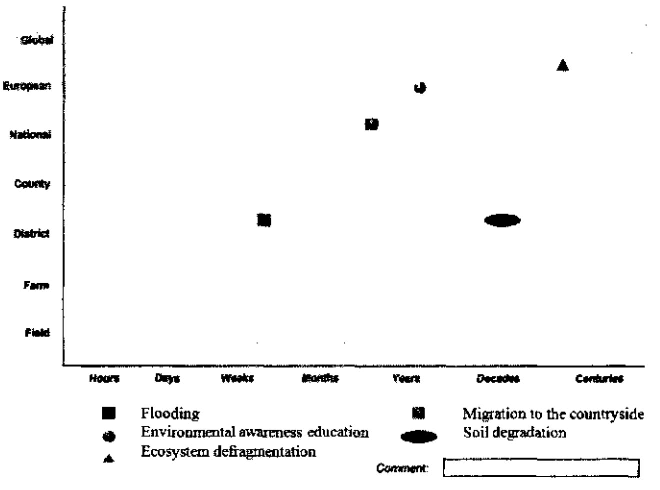


Figure 3.1: Scale Perspectives with an input example from a single participant. Users move their pre-selected issues to levels that reflect their perspectives within fixed scales of time and geographic space.

field of spatial and temporal dimensions.

Participants start out by providing the top social-ecological change issues they are most concerned about. In our application, we chose to limit the top issues to five to keep the test accessible in terms of cognitive load (Miller 1956). Participants list these issues themselves. In the next step, users are asked to place dots representing their issues on a field framed by fixed scales of time and space (figure 3.1). Each marker on the scales represents a new spatial or temporal level. The two scales create a field where a continuum exists between the spatial and temporal levels on each scale.

The level markers for the temporal scale are: hours, days, weeks, months, years, decades and centuries. The level markers for the spatial scale are: field, farm, district, county, national, European and global. We chose a jurisdictional scale to frame the spatial dimension of the test, rather than an ecological or geological scale, because we considered this to be most familiar to participants as well as being the most relevant scale for many of their issues. Given this space, participants are asked to place their issues on or between the temporal and spatial levels that they consider to be the levels where their issues play a key role. Thus, there is a cross-level effect at work in the re-framing of stakeholder issues in the field of scales: first, participants are asked to describe issues that *impact* their regional futures, then, they are asked to place these issues on the key levels where they *operate*. Participants are also given the opportunity to comment on the way they positioned their issues in the scale field.

We will evaluate the effectiveness of Scale Perspectives on its ability to inform participatory process designers using the following questions:

- *What issues are considered a priority by the participants?*
- *At what temporal and spatial levels are these issues seen to be most relevant, and which levels are not a part of the participants' focus?*
- *Is there a consensus or a diversity of perspectives regarding the scaling of particular issues?*
- *How can the outputs of Scale Perspectives be used in subsequent steps of a participatory process what are its limitations in this regard, and how can these be overcome?*

SPS part 2: Myths of Nature

Myths of Nature part is included in the SPS to link perspectives on key issues and their functional levels as defined by stakeholders to their ideas on system dynamics. Holling (1979; Holling 1986) and Timmerman (1986) found that different implicit myths exist among institutions and individuals about how ecosystems respond to (human) disturbance. Four different 'myths of nature' have been shown to inform natural resources management strategies. Schwarz and Thompson (1990) linked these myths of nature to Douglas' and Wildavskys (1982) four world views on social relationships in their Cultural Theory of Risk. The result is a division of world views that relates perceptions on the dynamics of natural systems with those of social systems. This link shows potential to be instrumental in successful scientific communication (Kahan 2010). Lima and Castro (2005) have linked these myths of nature to an exploration of people's positive or negative valuations of the environment on two spatial levels: the community level and the global level. For the temporal dimension, Hoogstra and Schanz (2008) have tested Myths of Nature in connection with time orientations. This preceding research, and the focus of Myths of Nature on system dynamics, provide a strong argument for their inclusion in the new context of the SPS. Following Hoogstra and Schanz (2008), the four myths of nature are represented visually in this part of the test see figure 3.2. We changed the names slightly to make the tests more accessible to our audience. The original names are in parentheses. They are:

1. *Nature forgiving (benign).* In this myth of nature, natural systems have a single equilibrium to which, when disturbed, they will invariably return when given time.
2. *Nature malleable (capricious).* In this myth of nature, natural systems have no intrinsic equilibrium, are always in flux, and change according to whatever disturbance or manipulation affects them, neither collapsing nor returning to any previous state;
3. *Nature resilient (perverse/tolerant).* In this myth of nature, natural systems can return to their equilibria after a certain degree of disturbance. However, once a threshold is passed, the system will undergo a radical change, and returning to the original state of balance will be very difficult

4. *Nature fragile (ephemeral).* In this myth of nature, the equilibria of natural systems are easily and irrevocably disturbed.

We evaluate the effectiveness of Myths of Nature on the basis of the following questions:

- *Can participants relate to this visual version of Myths of Nature sufficiently to allow them to express their views on the dynamics of natural systems?*
- *How can the outputs of Myths of Nature be used in subsequent steps of a participatory process what are its limitations in this regard, and how can these be overcome?*

SPS part 3: The Circles Test

The third part of the SPS is set up as a way to relate participants' perspectives on key issues and levels to their basic engagement with the future, which is connected to their sense of the structure of time. To do this, we focus on their *time orientation* (Zimbardo and Boyd 1999; Hoogstra and Schanz 2008). This psychological construct stands for a person's basic

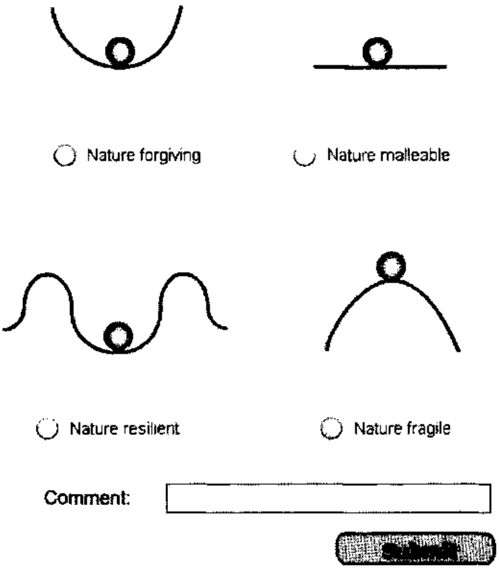


Figure 3.2: Myths of Nature with an input example. Each image depicts the dynamics of natural systems in response to change: the slope of the 2D 'landscape' shows where the balance will end up after the ball, representing the current system state, is displaced due to disturbance. Participants pick the myth of nature that most closely resembles their perspective.

structuring of their time experience: the relative importance placed on past, present and future. Other dimensions of this construct are the connectedness seen between these time zones, and the general character of the flow of time: linear or cyclical, for instance. Studies have linked time orientation to the temporal dimension of a person's life space, known as their time perspective. The temporal extent of the future considered by a participant is given less or more relevance depending on the value that person places on the future in general.

Tests have been developed to directly assess a person's time orientation (Nuttin 1964; Wohlford 1966; Cottle 1968; Wohlford 1968; Cottle 1971; Zimbardo and Boyd 1999). Out of these, we chose the Circles Test (Cottle 1967) because it fits our approach of visual communication dealing directly with analytic constructs in an interactive setup. It has been demonstrated to provide reliable and stable results in relation to other time perspective tests (Cottle 1967; Cottle 1975; Cottle 1976; Beiser 1987; Bruno and Maguire 1993; Bruno 1995; Brown and Herring 1998).

In the Circles Test (figure 3.3) three circles representing past, present, and future are presented to participants in random locations on an un-scaled space. Participants are asked to manipulate the sizes of these circles to represent the relative importance they personally attribute to each time zone in relation to the other types. They are also asked to place the circles in relation to each other to reflect how they see these time zones to be related. Three variables are derived from the Circles Test: relative size of the time zones (indicating importance attributed), the order and structure in which they are placed (indicating overall

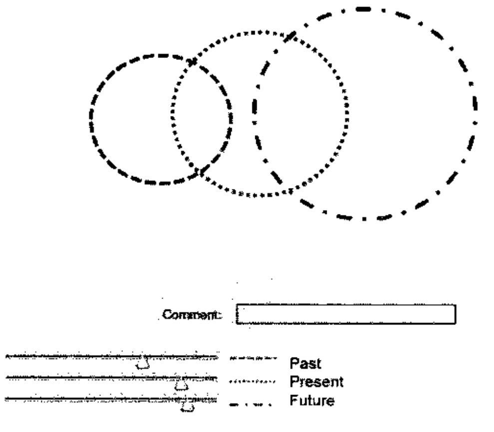


Figure 3.3: The Circles Test with an input example. Past, present and future are represented by the striped blue, dotted green and dot-stripe purple circles, respectively. The circle size reflects the relative importance this time zone has for the participant. The degree of overlap reflects how much he/she sees these parts as connected. The locations in the field where the time zone circles are placed reflect the participant's view on the flow of time.

concepts of time), and the amount of overlap between time zones (indicating their perceived connectedness). We evaluate these variables in the context of our cases by their capacity to answer the following questions:

- *How can the connectedness of time zones be used in a participatory process?*
- *How can the connectedness of time zones be used in a participatory process?*
- *How can the outputs of the Circles Test be used in subsequent steps of a participatory process what are its limitations in this regard, and how can these be overcome?*

3.3 Applying the toolbox in two case studies

To evaluate the capacity of the System Perspectives Scope to generate meaningful results, we applied the toolbox with 63 participants in two case studies, both communities focusing on social-ecological change issues. These two case studies were selected in very different contexts and on different geographical scales to test the SPS in contrasting contexts. One case study focused on sustainable development communities in Oxfordshire (United Kingdom) with a demographically diverse group of participants. The other is a European case study with PhD students working in environmental science the METIER (METhods for Interdisciplinary Environmental Research) network. This means that the SPS was used in two contrasting settings: a highly diverse group of participants that are bound to a single region (Oxfordshire), and a uniform group of highly educated participants, who are diverse in their geographic and cultural locations (METIER).

In Oxfordshire, we introduced the on-line version of the System Perspectives Scope as part of a multi-step participatory scenario development exercise. We developed qualitative scenario storyline with a number of regional government professionals and researchers of the University of Oxford. These scenario storyline were then translated to multi-media animations. We introduced the SPS to capture a wider range of stakeholders' perspectives on the future of the Oxfordshire region beyond what was possible in live workshops where the SPS was also used, as presented in chapter 5 of this thesis.

In the METIER case, the outcomes of the System Perspectives Scope were used in a subsequent meeting of the network to reflect on the group's spectrum of perspectives on social-ecological change in terms of scale, Myths of Nature and time orientation.

Participants

39 people participated in using the SPS in the Oxfordshire case. Of these, 34 gave all required input. The second column in table 3.1 shows the demographic composition of this group. In the METIER case, 24 people participated, of which 20 people gave all required input. The third column in table 3.1 shows the demographic composition of the METIER group. As can be seen, the Oxfordshire group is fairly evenly balanced on all demographic characteristics. In all respects, the METIER group is much more uniform. In Oxfordshire,

Table 3.1: Demographic composition of the groups of participants in the Oxfordshire and METIER case studies.

		Oxfordshire (n=34)	Metier (n=20)
Sector	NGO	15%	0%
	Research	6%	90%
	Education	26%	0%
	Government	6%	10%
	Sustainable development business	18%	0%
	Other business	12%	0%
	Other	18%	0%
Gender	Male	62%	75%
	female	38%	25%
Education	Elementary school	9%	0%
	High school	21%	0%
	Undergraduate	21%	5%
	Graduate	38%	75%
	Ph.D.	12%	20%
Age	Below 30	15%	60%
	30-39	12%	35%
	40-49	18%	5%
	50-59	21%	0%
	Above 60	29%	0%
Nationalities		1 (UK)	11 (European)

participants were active in business, education, NGO's, those branches of government dealing with sustainable development and research. METIER is an international network of Ph.D. researchers connected to a series of seven courses on environmental research, with an emphasis on remote sensing, spatio-temporal model construction and geo-visualization. However, this group of participants is spread over a much larger spatial extent, and spread out across nationalities.

Demographic questions

We included several demographic questions in the System Perspectives Scope, to link users' contributions to demographic information as well as to check for a bias in our groups of participants. Following Hoogstra and Schanz (2008) we collected the following data per participant: age (continuous); education (elementary school, high school, undergraduate, graduate, Ph.D.); work sector (NGO, research, education, sustainable development government, other government, sustainable development business, other business); gender; nationality.

Linking outcomes between tools

The following questions were chosen to explore the relationships of the outcomes from the new tool, Scales Perspectives, with the variables from the Circles Test, Myths of Nature and the demographic data, based on whether the following questions can be answered:

- *Do views of natural system dynamics in Myths of Nature relate to Scale Perspectives inputs?*
- *Do time orientations captured by the Circles Test relate to Scale Perspectives inputs?*
- *Do differences in demography relate to Scale Perspectives inputs?*
- *How can links between the outputs of different tools be used in a participatory process?*

User evaluation of the SPS

Because it is easy to lose on-line users due to an overload of tasks and information, we chose to present only the SPS toolbox elements and limit questionnaire elements for the on-line version to the option for users to comment on the different steps in the toolbox. While comments were positive, they were given sparingly and it can be argued that this lack of evaluation limits the interpretation of the case studies. However, we build on work with the SPS in a live setting, also with Oxfordshire sustainability-oriented communities, where user evaluations were mandatory (chapter 5). In these evaluations, users valued the SPS as a valuable way to capture their perspectives and that the toolbox 'encouraged holistic/system-wide considerations'. Users' main criticism of the SPS toolbox in the live setting was that they needed more time to explore their entries in the toolbox elements. In the on-line version used in this study, this time limit did not exist.

3.4 Analysis of results

This section reports the results from our use of the SPS toolbox in the Oxfordshire and METIER case studies, first reporting on the results of individual tools and then linking outputs between tools. Methods of analysis are described where applicable.

Results from Scale Perspectives

Figure 3.4 shows the reconstructed input field of Scale Perspectives with all entries from the 34 participants from the Oxfordshire case and 20 participants from the METIER case. Each participant entered five issues. The entries at the top of the spatial scale fall within the global level. Table 3.2 shows the percentages of entries divided over three spatial and three temporal ranges of levels to clarify the patterns.

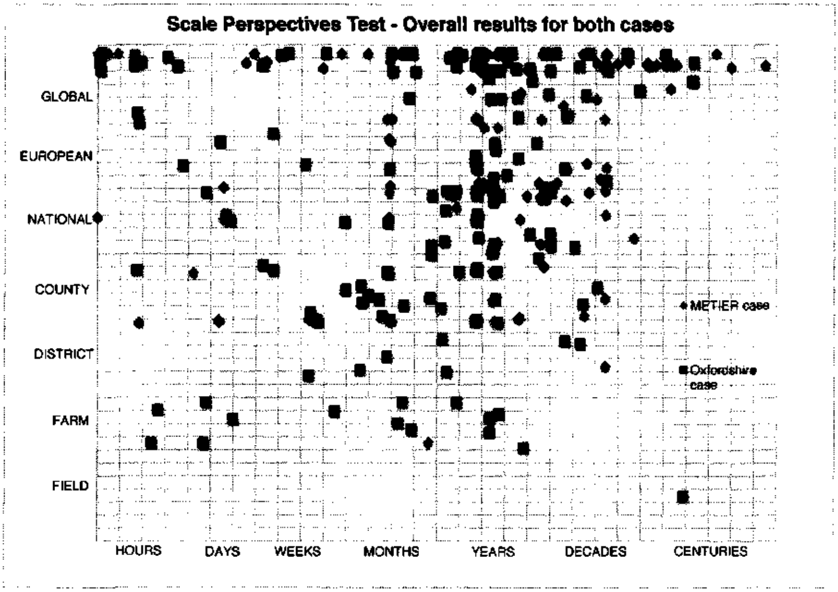


Figure 3.4: Overall results of Scale Perspectives for the Oxfordshire and METIER cases. This figure shows five entries per participant from in both cases. The squares are all entries from the Oxfordshire Case, the diamond shapes are all entries from the METIER case.

For the Oxfordshire group input, the highest number of entries, 29% of the total, fall in the national *global/decades centuries* spectrum. *District < national* and *national < global* are also highly populated with entries on the *months < decades* time spectrum. The *field < district* spatial scale contains the lowest number of entries; another combination of levels with low entries is the *district < national* spatial spectrum on the *hours < months* time spectrum.

For the METIER group, almost half (46.1%) of the entries fall within the national global and decades centuries range. On the same spatial level, the months < decades levels also contain a large number of entries (25.2%). The lower levels in Scale Perspectives received very low scores.

Table 3.3 shows the top five most frequently mentioned issues in Scale Perspectives for both case studies, in percentages of the total of entries per case. These top five issues make up about half of the total entries per case. Partly different, and partly similar issues are mentioned between the cases: climate change appears in both cases, and ecosystem/environmental degradation are similar; however, the relative frequencies of these issues are different. In both cases, the top five issues do not diverge from the overall pattern of

Table 3.2: Scale Perspectives entries for both case studies in percentages of the total entries, categorized in three ranges of temporal and spatial levels. Percentages in bold represent the ranges with the highest number of entries.

Oxfordshire	hours<months	months<decades	decades-centuries
national-global	9.5%	20.7%	**29.0%**
district<national	1.8%	20.1%	8.9%
field<district	3.0%	4.1%	3.0%
Metier	hours<months	months<decades	decades-centuries
national-global	4.3%	25.2%	**46.1%**
district<national	5.2%	5.2%	12.2%
field<district	0.0%	0.9%	0.9%

Table 3.3: The top five most mentioned issues in the entries of Scale Perspectives for both cases in percentages of the total entries per case. The bottom row for each case summarizes the total percentage of these top five entries of the total number of entries per case.

Oxfordshire			Metier	
Transportation	14%		Climate change	19%
Energy	13%		Environmental degradation	11%
Food	8%		Water management	8%
Climate change	7%		Economy	7%
Ecosystem degradation	6%		Public policies	7%
Total of top five issues	48%		Total of top five issues	52%

entries, showing the same empty spaces in the field of scales. Furthermore, each issue is spread out across levels, with no exception see figure 3.5 for the spread of issues in the Oxfordshire case. We found no significant differences of focus on spatial or temporal levels for the top five issues in both cases.

Results from Myths of Nature

For the Oxfordshire case, 38% of the participants chose the 'nature resilient' image, 56% of the participants chose the 'nature fragile' myth, and 6% chose the 'nature malleable' image. The 'nature forgiving' myth was not chosen. In the METIER case, participants only chose the 'nature resilient' myth (70%) or the 'nature fragile' myth (30%). Neither the 'nature malleable' nor the 'nature forgiving' myth was chosen.

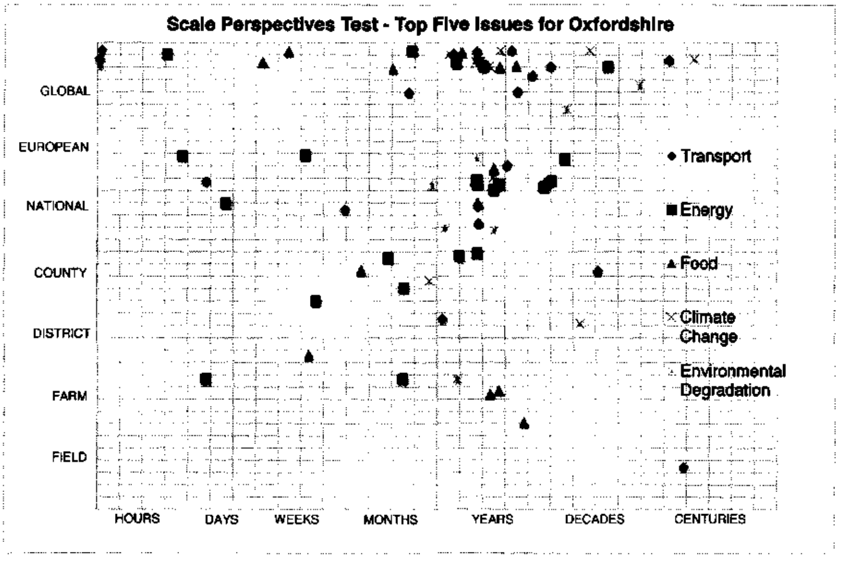


Figure 3.5: The top five most mentioned issues in Scale Perspectives results for the Oxfordshire case: 1. Transportation 2. Energy 3. Food 4. Climate change 5. Environmental degradation.

Results from the Circles Test

Table 3.4 shows the outcomes of the Circles Test in percentages for both case studies. Time structure shows the percentages of Circles Test participants that structured the order of the three time zones linearly, and the percentage that used other configurations. Based on our live tests, we found that users might create a cyclical structure to symbolize other relationships, such as a hierarchy. Therefore, we limited our divisions to 'linear', 'other than linear', and 'complete overlap'. 'Relative sizes' shows where the future time zone is equal, dominant or dominated in relation to the sizes of the other time zones. 'Overlap' shows the percentages of participants divided by percentages of overall overlap between the three time zones.

In both cases, the linear time structure is prevalent. The Oxfordshire group shows an even balance between linear and other structuring of the circles to represent the flow of time. The METIER case shows a higher prevalence of linear time structuring. A majority of participants in both cases entered the future time zone size either as equal or as smaller, or dominated, than the other time zones. There is a strong difference between the cases as well: the Oxfordshire group results show a dominance of the future time zone in 34,9% of the cases; conversely, in the METIER group results, this is only 4.3%. The results for the amount of overlap between the time zones shows that little overlap between past, present

Table 3.4: Outcomes of the Circles Test in percentages for both case studies, for the time structure displayed by the circles, the relative size of the future circle to the other circles, and the total overlap of circles.

Time structure	linear	not linear		
Oxfordshire	49.7%	50.3%		
Metier	67.0%	33.0%		
Relative sizes	no dominance	future dominant	future dominated	
Oxfordshire	47.0%	34.9%	18.1%	
Metier	65.0%	4.0%	30.0%	
Overlap	0.0%	<=33%	<=66%	<=100%
Oxfordshire	23.7%	37.9%	17.8%	20.7%
Metier	27.0%	50.0%	9.0%	14.0%

and future time zones is indicated in both cases. The results here are less different between the cases: for both groups, an overlap between 0% and 32% is most frequent.

Relating the results of the SPS components

We used Pearson's Chi Square (χ^2) test (p= 0.05) for an analysis of relationships in and between the SPS components. The Chi Square test creates contingency tables for groups from different categorical variables. Table 3.5 shows an overview of the Chi Square test results. The demographic diversity in the METIER case was too uniform to be used in statistical analysis, with the exception of the nationalities in this group; but for that characteristic, the diversity was too high to be analysed (11 countries for 20 participants). Therefore, only the demographic outcomes of the Oxfordshire group are linked to Scale Perspectives entries in table 3.5.

Scale Perspectives entries linked to Myths of Nature

For the Oxfordshire group, dividing Scale Perspectives Entries between the two most prevalent choices of Myths of Nature (nature resilient and nature fragile) a significant difference was found, both in the temporal dimension (χ^2 = 35.025, $p < 0.05$) and in the spatial dimension (χ^2 = 14.552, $p < 0.05$). Figure 3.6 shows this difference for the spatial and temporal dimensions. In the spatial dimension, 55% of all entries associated with 'nature fragile' are found on the *district* $<$ *national level*, while almost the same number of entries associated with 'nature resilient' (52%) can be found on the national global level. Entries on the *field* $<$ *district* level are few in both cases. In the temporal dimension, there is a different pattern.

Table 3.5: Results of the statistical analysis of differences in Scale Perspectives entries based on other test variables, using Pearson's Chi Square () with p = 0.05. Tested for both cases: different issues, Circles Test results, Myths of Nature results. Tested for Oxfordshire: demographic results. The asterisks indicate significant differences (p < 0.05)

Oxfordshire	Issues	Time structures	Relative sizes	Overlap	Myths of Nature
Spatial Temporal	χ^2= 5.0575 χ^2= 2.49	χ^2 = **6.667*** χ^2=**6.744***	χ^2=11.006 χ^2=7.751	χ^2 = **35.025*** χ^2= 7.685	χ^2=**14.064*** χ^2= **14.552***
Oxfordshire	Gender	Work Sector	Age Groups	Education	
Spatial Temporal	χ^2= 0.989 χ^2=2.628	χ^2=**19.613*** χ^2=10.432	χ^2=**13.478*** χ^2=4.120	χ^2=5.982 χ^2=**10.622***	
Metier	Issues	Time structures	Relative sizes	Overlap	Myths of Nature
Spatial Temporal	χ^2=1.978 χ^2= 6.001	χ^2=0.442 χ^2=3.190	χ^2=4.920 χ^2=1.860	χ^2=5.520 χ^2=3.787	χ^2=**6.070*** χ^2= 3.787

For the entries associated with 'nature resilient', there are more entries on the short term and the long term and only 18% on the middle term, while this middle term accounts for 40,5% of the entries associated with 'nature fragile'.

In the temporal dimension, 83% of the wider spread of the 'nature resilient' entries are caused by a multi-level placement of entries by individual persons rather than between persons. In the spatial dimension, individual persons placing entries at multiple levels accounts for 74.3% of the multi-level spread.

For the METIER group, a significant difference is suggested by the χ^2 (6.070, $p < 0.05$) for Scale Perspectives entries divided by the two chosen myths of nature on the spatial scale. This difference is mainly caused by the higher prevalence of entries linked to 'nature resilient' on the national global level (63%).

Scale Perspectives entries linked to Circles Test results

For the Circles Test results in Oxfordshire, the 'time structure' variable produced significantly different groups in Scale Perspectives entries in the geographic dimension (χ^2 = 6.667, $p < 0.05$) as well as in the temporal dimension (χ^2 = 6.744, $p < 0.05$). See figure 3.7 for the time structure plotted against scale perspective entries in the spatial and dimensions. The Scales Perspectives Test entries associated with a 'linear' time structure are more frequently placed on the district < national spatial level (52%) and the months < decades temporal level (52%), while the entries associated with a 'not linear' time structure are most frequently placed on the national global spatial level (50.2%) and the decades centuries temporal level (50.6%). Conversely, the METIER group shows no significant differences in either dimension. The Oxfordshire group Scale Perspectives entries divided by the relative sizes of time zones show a difference that only hints at significance for the spatial dimen-

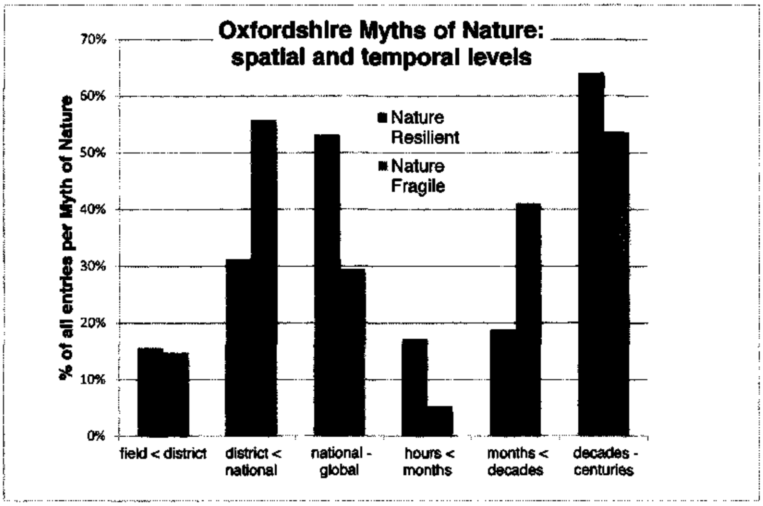


Figure 3.6: Oxfordshire Scale Perspectives entries ordered by spatial and temporal levels, and divided by the two most prevalent myths of nature associated with these entries, in percentages of the total entries per myth of nature.

sion ($\chi^2 = 11.006$, $p < 0.05$). No such relationships were found for the METIER case. For the Oxfordshire group, a significant, but inconsistent difference was found for the division of Scale Perspectives results by the amount of overlap in the time zones ($\chi^2 = 35.025$, $p < 0.05$) for the spatial dimension. The METIER data indicated no relationships of Scale Perspectives entries to the amount of overlap.

Scale Perspectives entries linked to demographics

In the Oxfordshire case, the work sector the participants operated in shows a significant difference in the Chi Square test ($\chi^2 = 19.613$, $p < 0.05$). However, 30% of cells had an expected case count below 5, and the recommended maximum is 20%. Entries divided by age groups showed a significant difference in the spatial dimension ($\chi^2 = 13.478$, $p < 0.05$). However, again there is a low expected count of entries on the lowest spatial level (25% of cells). There is a high number of entries placed in the national global level by those of ages 60 and above as compared to the other age classes. Significant differences were found for entries divided by education levels over the temporal dimension ($\chi^2 = 10.622$, $p < 0.05$), but not in the spatial dimension. Those with the highest education levels tended to distribute their issues more evenly across all levels on the temporal scale than those with lower education levels: owners of a graduate or Ph.D. degree located only 48% of their issues on the decades centuries temporal level, while those with an undergraduate or lower degree located 70% of their issues on this level.

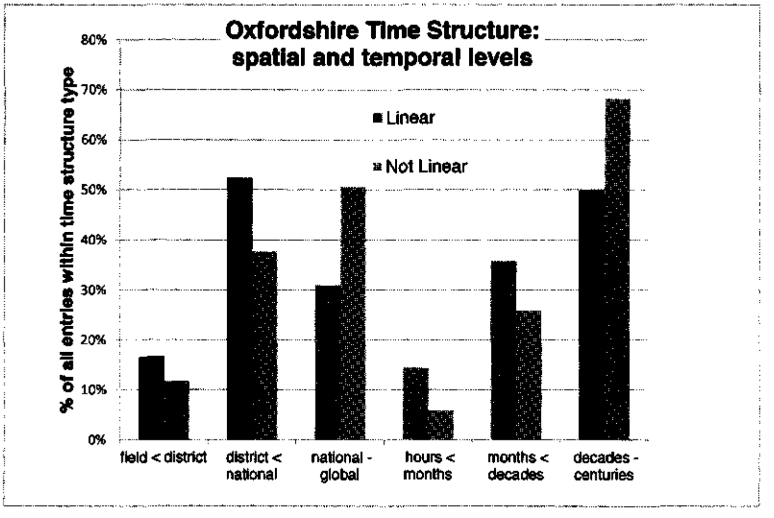


Figure 3.7: Oxfordshire Scale Perspectives entries associated with 'Linear' versus 'not linear' time structures in the Circles Test, in percentages of the total entries per time structuring, ordered along three levels in the spatial dimension.

3.5 Discussion

Our use of the SPS toolbox in Oxfordshire and the METIER network gives us two cases studies to be used in this chapter for a first analysis of the relevance of outputs as a method to elicit, compare and combine analytic perspectives on social-ecological systems change - and to provide inputs to following steps in participatory processes such as scenario development, modelling and planning. Using the research questions defined in previous sections, we will discuss the potential of the SPS, its limitations and gaps, and possible ways in which its application can be extended and limitations overcome.

Scale Perspectives

What issues are considered a priority by the stakeholders?

In both case studies, the top five most mentioned issues made up about half of the social-ecological change issues mentioned by the participants. This indicates that, overall, issues that were a concern to the majority of participants have been identified and dimensionalized, as well as a range of issues flagged by smaller groups or individuals. Top issues partly differed between the cases but it is valuable to note that climate change and environmental/ecological degradation were part of the top five mentioned issues in both cases.

For this first exploration of the SPS, the open character of this question was useful to discover this prevalence of top issues and the ways participants define them. A potential problem of the results is that the issues identified by participants range from the specific to the general. We hypothesize that the more general the issue, the less meaningful its dimensionalization in space and time will be. This concern argues for a requirement of more specification and elaboration from the participants on their input.

Scale Perspectives as used in our two case studies has generated a first overview and dimensionalization of issues relevant to stakeholders, and when applied on a large scale, this is useful information to then be picked up by smaller groups of stakeholders to frame their problem domain and focus, and to find out which issues are largely ignored. The benefit of Scale Perspectives as used in these cases is that the input is quick, clear and easily generated and interpreted. However, there is a problem with specificity that we will discuss in the last question.

At what temporal and spatial levels are these issues seen to be most relevant, and which levels are not a part of the participants' focus?

Participants in both cases have entered strongly multi-level perspectives, both in the temporal and the spatial dimension. A first observation based is that this outcome advocates the use of multi-level participatory processes in general. Results from both case studies show that clear patterns can be found in a prevalence for different spatial and temporal levels. The Oxfordshire group showed a preference for the highest spatial and temporal levels, but this preference was more extreme in the METIER group. We believe this difference reflects the difference between the case studies: the Oxfordshire group consisted of a demographically diverse group of participants in all respects, while the METIER group was made up of Ph.D. students and researchers, mostly male and in the same age group. Also, the Oxfordshire group had a regional focus, while the METIER group was spread out across Europe. In general, the focus of participants in both groups on the highest spatial levels in the test confirms the idea of environmental hyperopia. The same goes for a temporal hyperopia when the future is concerned in relationship to the present and past. These results maintain the tension between this hyperopia in problem recognition and the myopia associated with taking positive action (Boniecki 1980; Wilbanks and Kates 1999). Both cases show that several combinations of spatial and temporal levels are not considered relevant: the smallest spatial levels and shortest temporal levels are largely left empty. In Oxfordshire, the longest term for the intermediate spatial level (*district < national*) was also left largely empty. Temporal and environmental hyperopia may have affected the specificity of issues contributed by participants the more global and long-term the focus of the participants, the less specific their input will be.

Is there a consensus or a diversity of perspectives regarding the scaling of particular issues?

In both cases, entries for each of the top five issues were all widely spread across spatial and temporal levels. This indicates that while stakeholders can agree on the top issues, they may disagree on the spatial and temporal levels at which these issues are most relevant. This 'multiplicity of scale perspectives' (Cash et al. 2006) is often a source of scale mismatches. Therefore, specifically addressing this issue in the participatory process could be very beneficial for stakeholder cooperation in land use and natural resources management differences in scale perspectives could be negotiated, and it could be made clearer that each of these issues actually consists of processes on multiple levels of time and space.

How can the outputs of Scale Perspectives be used in subsequent steps of a participatory process what are its limitations in this regard, and how can these be overcome?

The above discussions provide a first use of the Scale Perspectives tool in a participatory process: raising consciousness of the temporal and spatial dimensions of social-ecological change issues, and furthermore generating awareness of the multiplicity of framing and perspectives that exist in terms of scaling issues. The results were used for this purpose in subsequent steps of both case studies.

Secondly, for participatory process designers, the spatial and temporal levels considered relevant by stakeholders provide a basis for multi-level content that is more likely to connect with the perspectives of those stakeholders. Also, gaps offer clues as to what elements of the social-ecological systems are downplayed in the perspectives of stakeholders. In the examples of the Oxfordshire and METIER cases, this combination of building on stakeholder perspectives and paying attention to blind spots can inform a participatory process that explicitly explores the cross-level links between stakeholders' concerns about global issues and policies on the regional to national level, and their links to the largely ignored local and shorter-term levels. The information provided by Scale Perspectives can then help determine the dimensions and focus domains of models, scenarios and strategies.

That said, the Scale Perspectives tool as used here in its most basic form has some limitations, as well as some simple ways in which it can be improved to have much more potential. We have flagged the issue of differences in specificity in participants' contributions, and how specificity is linked to spatial and temporal scale. Furthermore, links between different incarnations of an issue (e.g. local issues with drought and flooding and global climate change) remain implicit.

A solution to overcome these limitations is to explicitly ask participants to provide incarnations of a single issue at different temporal and spatial levels, and describe the links between these processes. This way, specificity as well as rich information are stimulated, and the Scale Perspectives tool increases its potential for generating scale consciousness. It also provides more information for the development of models, scenarios and plans, because participants are essentially creating a dimensionalized conceptual map. Our use of the SPS in chapter 5 of this thesis has taken this approach. The downside of this approach is that researchers steer the participants into cross-level thinking, whereas the more basic use of the tool in this study reveals more about the primary temporal and spatial focus of stakeholders.

Myths of Nature

Can participants relate to this visual version of Myths of Nature sufficiently to allow them to express their views on the dynamics of natural systems?

In the study by Hoogstra and Schanz (2008) as well as in the live trials of this study, participants indicated that they found the visual metaphors for Myths of Nature easy to understand. An indication of the validity of the results from this visual version of Myths of Nature is prevalence of choice for the 'nature resilient' myth as compared to the other myths, which is similar to other, text-based studies (Lima and Castro 2005). The advantage of using Myths of Nature to capture and reflect on different perspectives on social-ecological system dynamics is their clarity and their relative simplicity, as well as the ease with which results can be compared. A major disadvantage of the Myths of Nature approach is the strong pre-framing of stakeholder perspectives by offering them alternative models to choose from, rather than allowing them to make up their own issues. It could be argued that within the general model of basins of attraction, they do represent simple images of the main alternatives; however, it should be understood that this entire model is a pre-frame. Furthermore, the Myths of Nature, taken at face value, do not offer possibilities for more extensive and subtle models of system dynamics.

How can the outputs of Myths of Nature be used in subsequent steps of a participatory process what are its limitations in this regard, and how can these be overcome?

As with the Scale Perspectives results, a first use of the Myths of Nature is to provide participants with information to reflect on, in this case the different perspectives on social-ecological system dynamics that are present amongst themselves, and the consequences that this has for bridging between these perspectives.

Myths of Nature results are also applicable in a participatory process to build on and challenge the implicit assumptions of stakeholders on social-ecological system dynamics. In the Oxfordshire and METIER cases, different models, plans and scenarios can now be constructed that build on both the 'nature fragile' and 'nature resilient' myths of nature. This way, stakeholders who chose either myth will be able to relate to one part of the content as well as be challenged by the other representations. In planning and scenario development, strategies and policies can be tested under the assumptions of the different myths (ref Rotmans). In participatory model building, the different myths can be used to guide alternative versions of models with different valuations of interactions.

The problems of the Myths of Nature approach lie in the pre-framing of perspectives and over-simplification. The pre-framing issue is partly an unavoidable aspect of the stability landscape concept, but it can be consciously dealt with by presenting the Myths of Nature in context and making it very clear that these are models and not realities which, in fact, is supported by the basic concept of having these different perspectives. The simplicity of the Myths of Nature can be overcome by applying the tool differently to different aspects of social-ecological systems: different myths holding true different subsystems (e.g. natural systems have different myths than human systems). On the basis of the results from the current chapter, this extension of the Myths of Nature was made optional in our use of the SPS in chapter 5 of this thesis. Another extension would be to have participants define Myths of Nature for systems at different spatial and temporal levels which would be particularly valuable considering the significant connections found between participants' Myths of Nature and spatial and temporal focus in the Scales Test.

The Circles Test

How can the connectedness of time zones be used in a participatory process?

The Circles Test provides a visual representation that allows participants to express their views on the connectedness of past, present and future. The results for both cases indicate a relatively low sense of connectedness between the past, present and future time zones among our participants. These results can in themselves spur a discussion in a participatory process on the connectedness of events and developments in the past, present and future. In terms of participatory process design, the results warrant a focus on content that emphasizes historical development and the consequences of present choices for the future. For this purpose an obligatory explanation by the participants would again prove useful.

How can the general conceptualization of time structure be used in a participatory process?

In our live trials, we found that the classification of all circular positioning of the three time zones as a 'cyclical view of time flow' was not sensitive enough to capture other types of symbolic use of this composition. Our choice to limit the analysis of output to 'linear' and 'not linear' structuring limits the hypotheses and conclusions that can be drawn from this. Therefore, an obligatory textual explanation of the Circles Test input is recommended as an addition to the SPS. Given this limitation, the prevalence of a linear time orientation in both cases is an outcome that merits an explicit focus on non-linearity in the participatory process.

How can the emphasis on time zones by relative circle sizes be used to inform a participatory process?

The test captures different valuation of past, present and future, symbolized as the different relative size of each circle that represents a time zone. Between the two case studies, we found a higher dominance of the future time zone in the Oxfordshire group. This implies that Oxfordshire participants place more overall value on the future, which may be a function of the demographic diversity of this case. In both cases, though, the future time zone was more often neutral or dominated by the other time zones. For participatory process designers, this would indicate that special attention should be given to stimulating participants' engagement with future issues.

Linking the SPS components

Do choices for different views of natural system dynamics in Myths of Nature relate to different Scale Perspectives inputs?

In both cases, the two relevant Myths of Nature for our groups of participants, 'nature resilient' and 'nature fragile', show significant differences in their associated Scale Perspectives entries. In the Oxfordshire group's results, entries associated with the 'nature resilient' myth are found more on the highest spatial and temporal levels, while entries associated with the 'nature fragile' myth are found more on the middle spatial and temporal levels. For the METIER case, the same differences are seen between entries associated with these Myths of Nature in the spatial dimension. The 'nature resilient' myth, in its visual representation used in this study, could be seen as inherently multi-level in a functional, temporal sense (Hoogstra and Schanz 2008). Conversely, those participants that chose the 'nature fragile' myth might have a greater sense of urgency about their issues, and therefore focus on a district < national level and an intermediate months < decades time zone. These spatial and temporal levels are more likely to be associated with the planning levels that stakeholders in Oxfordshire come into contact with.

Do time orientations captured by the Circles Test relate to Scale Perspectives inputs?

A positive relationship between the relative sizes of time zones and the extent of time covered by entries in Scale Perspectives would be expected. However, either the data sample sizes were too small to detect this link, or the Circles Test requires control questions to determine the possibility of these concepts being linked for stakeholders. In terms of the structuring of time zones, the association of 'linear' time zone structures with intermediate spatial levels could indicate that these participants are working from a local planning perspective, while the association of 'other than linear' configurations, associated with higher spatial levels could indicate that these participants are considering spatial levels unsuited to a structured, linear view of time. Similarly, individuals with a linear time orientation could have a stronger focus on a middle-term, planning time-frame. Beyond this time-frame, time orientations that are other than linear might be more feasible. For the Oxfordshire group, the statistical analysis also shows a relationship between the degree of connectedness between the time zones in the Circles Test and different emphases on spatial levels. However, this relationship is erratic and without a clear trend.

Do differences in demography relate to different Scale Perspectives inputs?

Our data analysis of the Oxfordshire group showed some differences between Scale Perspectives entries based for each demographic characteristic. A significant difference between entries divided by work sectors is hinted at in the data, but this difference is spread evenly among all categories, and shows no clear trends. The age group of 60 and above shows more focus on the largest spatial scale than younger participants. This might be due to the wider geographic experience built up by this age group over their lives. Finally, those with the highest education levels placed their issues more evenly across temporal levels. This might indicate that higher education levels are linked with a multi-level perspective. However, suggestion is contrasted by the results from the Ph.D. students in the METIER group, who focus heavily on the largest temporal levels. Overall, these significant differences based on demography indicate that for participatory processes, different demographics represent different perspectives on relevant spatial and temporal scales for land use issues. This outcome reinforces the value of a diverse group of stakeholders if participatory processes should include different perspectives on key spatial and temporal levels.

How can links between the outputs of different tools be used in a participatory process?

While the above paragraphs discuss possible reasons for significant links between Scale Perspectives, Myths of Nature and Circle Test outputs, it would be very valuable to bring this discussion into the participatory process. Organizing group work on understanding the links between spatial and temporal focus on issues, different perspectives on system dynamics and engagement with past, present and future could be a strategy for developing a sophisticated systems understanding in the group of the relationships between social-ecological systems dynamics and the way these are framed by different stakeholders. Based on the results from this chapter's work in Oxfordshire, we discussed these links in the live workshops reported in chapter 5 of this thesis, but no systematic evaluation of stakeholder responses was done. This is a potentially valuable future research avenue for the SPS.

3.6 Conclusions and recommendations

Based on its first application in two case studies, the System Perspectives Scope shows potential for the capturing, comparing and combining of stakeholders' analytic perspectives on social-ecological change.

The Scale Perspectives tool could help generate consciousness about the multi-level processes involved in social-ecological systems change and the multiplicity of scale perspectives that frame these issues. The tool can also inform the choice of spatial and temporal focus levels in a multi-level participatory process, both based on the key levels defined by stakeholders as well as on their 'blind spots'. The limitations of the tool as used in these case studies can be overcome by an explicit focus on processes operating at different system levels.

The assumptions on social-ecological system dynamics elicited by Myths of Nature can be used to generate consciousness about basic differences in stakeholders' assumptions about social-ecological systems change. It can also serve as a basis for alternative sets of assumptions in models, scenarios and strategies - which can then offer both familiar as well as challenging world-views to stakeholders.

The Circles Test, if accompanied by participants' explanations, can warrant a focus on non-linearity and discontinuities and on the importance of past and present choices for the future. It can also indicate whether extra care should be taken to stimulate engagement with future issues among the participants.

All three tools in the toolbox have important limitations, largely because of their simplicity. These could be overcome by extending and elaborating on their execution, and by asking for more content from the participants.

Our two case studies indicated links between perspectives on system dynamics and focus levels in the temporal and spatial dimensions. Because the nature of these links is complex, this information is potentially more difficult to use directly to design content for participatory progress designers. However, exploring these relationships explicitly in a participatory process could lead to a sophisticated group understanding of the relationships between social-ecological systems dynamics and their framing through different perspectives. Finally, the linked results are significant in themselves and warrant a further exploration of the relationships between myths of nature, perspectives on temporal and spatial scales and general time orientations.

Chapter 4

Exploring scales and cross-scale dynamics from the perspectives of change agents in social-ecological systems

There lived, I know not when, never perhaps
-but the fact is he lived-
an unknown king
whose kingdom was
the strange Kingdom of Gaps.

-Alexander Search (Fernando Pessoa), The King of Gaps

Chapter is based on:
This chapter was based on J.M. Vervoort, L. Rutting, K.Kok, F. Hermans, A. Vedlkamp, A.K. Bregt, R. van Lammeren, submitted. *Exploring scales and cross-scale dynamics from the perspectives of change agents in social-ecological systems.* Submitted to Ecology and Society.

Abstract Issues of scale play a crucial role in the governance of social-ecological systems. Yet, attempts to bridge interdisciplinary perspectives on the role of scale have thus far largely been limited to the scientific arena. This study explores practice-based perspectives on scale and cross-scale dynamics. We proposed that: 1. key societal actors with experience in facilitating accepted change in social-ecological systems would describe the dynamics of these systems using a spectrum of scales; and that 2.This range of scales would allow these actors to capture cross-scale dynamics they saw as crucial. To test these propositions, we used an interview method aimed at eliciting perspectives on scale held by innovators in Dutch social-ecological systems. To make the scale framing of these change agents explicit, we extended the scale terminology, distinguishing between dimensions, scales and levels. Our results show that the participants used a wide range of scales to capture cross-scale dynamics they saw as crucial in the systems they were a part of. Their accounts also indicate that cross-scale consciousness contributed to the ability of these societal actors to effect change. The results of this case study show the value of eliciting practice-based perspectives on scale for theory development to understand differences in scale framing and to capture new dimensions, scales and cross-scale interactions that point to further research.

4.1 Introduction

Research on scales and cross-scale dynamics has the potential to bridge the divide between different disciplinary approaches to the study of interacting human and natural systems. The different conceptualizations of scales used in disciplines such as ecology, physical geography, human geography and sociology reveal a great deal about the ways knowledge and research are structured in these disciplines (Gibson et al. 2000; Sayre 2005; Buizer et al. 2011). Connecting different concepts of scale has many practical implications, as it can help develop a more comprehensive understanding of cross-scale dynamics in and between human and natural systems and can increase consciousness of the role of scale in environmental policy and management.

The study of system dynamics of spatial and temporal scales has been crucial to systems-oriented research since its inception (Buckley 1967; Klir 1969; Holling 1986). However, research linking biophysical and social scales is much more recent, and has developed in the context of a research perspective that views human and natural systems as fundamentally linked 'social-ecological systems' (Folke 2006). Building on this perspective, a large and growing number of studies have so far contributed to the connection of different disciplinary perspectives on scale (e.g. Gibson et al (2000), Sayre (2005), Cash et al. (2006), Manson (2008), Buizer et al. (2011), Kok and Veldkamp (2011) and Veldkamp et al. (2011)).

However, while research focusing purely on spatial and temporal scales has been applied in practical contexts, most of the interdisciplinary work on multiple scales has been highly conceptual, focusing on integration of perspectives between the sciences in order to develop theoretical understanding. Some of the work in the scale-oriented science arena has discussed the practical value of consciousness of scale and cross-scale dynamics in environmental management and governance (Cash et al. 2006; Kok and Veldkamp 2011). But views on scale from actors beyond the scientific world remain largely unexplored (van Lieshout et al. 2011). In particular, there has been a lack of bottom-up research exploring what perspectives on scale and cross-scale dynamics are maintained by innovators working within practical social-ecological systems management and governance (Rossi et al. 2000; Westley et al. 2006). Little research exists on how these perspectives on scale by these societal actors relate to their ability to create accepted change in multi-scale and multi-disciplinary contexts. Furthermore, given that scale consciousness across sectors involved in environmental governance can help recognize deeply rooted problems and identify solutions (Cash et al. 2006) discussions about the role of scale and cross-scale dynamics should be taken beyond the scientific arena and into the worlds of policy and management (Kok and Veldkamp 2011).

This chapter provides a practice-based, bottom-up perspective on scale in social-ecological systems, based on an elicitation of the views of entrepreneurs and other sustainable development innovators connected to a network for agro-ecological innovation (Veldkamp et al. 2008). These key actors were found to be uniquely able to provide practice-based perspectives on scale and cross-scale interactions.

Before we explore what these bottom-up perspectives have to offer to interdisciplinary

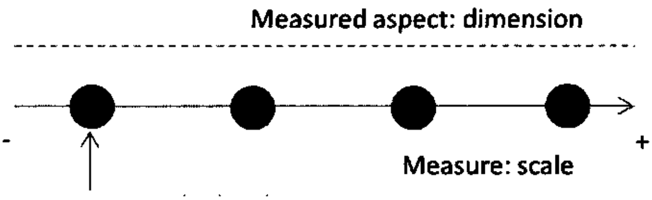


Figure 4.1: Dimensions, scales and levels as used in this study.

understandings of scale, we will provide a working definition of the concept of scale and associated concepts. Then, we will discuss the state of the art in interdisciplinary insights on scale to determine what a bottom-up exploration of scale could contribute.

Defining dimensions, scales and levels

A large number of papers exploring scales use the definition by Gibson et al. (2000) to describe what a scale is, either directly or by referring to Cash et al (2006; Kok and Veldkamp 2011). This definition states that scale refers to 'the temporal, spatial, quantitative and analytical dimensions used by scientists to measure and study objects'.

First of all, we would like add that scales are not only used by scientists, and are not just tools for the study of phenomena but deeply involved in the structuring of actions from personal decisions to global policies. Furthermore, we will use Gibson's distinction between scales and levels but also distinguish the concept of 'dimensions' more explicitly (see figure 4.1 for a visual scheme of our definition):

- We use 'dimension' to refer to the bare aspects of reality or phenomena to which scales are applied, such as time, space, temperature, etcetera.
- Following Gibson et al (2000), we use 'scale' to refer to the measures used to structure dimensions, such as the Julian calendar, the metric system, and different systems to divide areas of governance.
- Again like Gibson, we define the positions on a scale as 'levels'. Examples of levels are countries, watersheds, ecosystems and households.

The reason for distinguishing between dimensions, scales and levels instead of starting at scales is one of clarity. If we start with scales, this obscures the reality that multiple scales (metric system, customary system) can be applied to structure the same dimension (space). This understanding seems to be taken more or less as common sense in the scale-related literature, but is not made explicit, and all too often scale is used to stand in for dimension without the particular traits of that scale, and its alternatives, being questioned.

In many cases, 'scale' is used to stand for 'level' as well. Studies exploring the role of scale in environmental and social systems have pointed to interactions between processes occurring at different levels in a system, for instance between short-term and long-term processes in an ecological study (Levin 1999; Holling et al. 2002) or between local and national policies in political analysis (Hooghe and Marks 2003). It should be noted that many studies that refer to their work as analysing multiple 'scales' actually explore different levels according to Gibson's and our definition.

Since Cash et al. (2006) use the same definition of scales and levels as we do, we adopt their clear definitions of scale interactions: the demarcation multi-level stands for subjects or systems defined by multiple levels, while cross-level interactions identify interactions happening across levels. These are distinct from multi-scale as a demarcation for subjects or systems captured by multiple scales, and cross-scale interactions that occur across different scales.

Scale-oriented research across disciplines

While scales as such have long been a focus, implicitly or explicitly, for a wide spectrum of scientific disciplines, insights about scale dynamics originated mainly with the study of biophysical systems (Holling 1986; Levin 1992; Holland 1998; Kok et al. 2001). Since time and space are the dimensions in which biophysical systems operate, this has meant that the main focus in research on scale has long been on the spatial and temporal dimensions and their associated scales (Gibson et al. 2000; Holling et al. 2002). Ecologists have a long track record of research on interactions between processes across different spatial levels and time frames (Levin 1999). In physical geography, spatial and temporal scale issues are also critically important, and while physical geographers have traditionally taken a bottom-up perspective, consciousness of more complex cross-level dynamics has grown in this field (Meyer et al. 1992). In the social sciences, social systems are viewed as different from ecosystems in a number of ways. Social structures and systems of meaning can be said to operate in a range of social dimensions as well as in the spatial and temporal dimensions (Giddens 1990; Westley et al. 2002). Human geographers focus particularly on these links between the social, the spatial and the temporal dimensions. They assert that relationships between scales are continuously being changed and reconstructed based on power relations between actors across different levels (Sayre 2005). In political science, scale issues are often associated with the relationships between individual choice and political dynamics and with the effects of the size of political entities (Dahl 1989. ; Ostrom 1991 ; Ostrom 1997). Finally, there are sub-fields in economics that link to the more scale-oriented environmental, political and social sciences, such as institutional economics (Williamson 2000) and ecological economics (Daly 1992). In summary, perspectives on scale, while sometimes overlapping, are often indicative of fundamental differences between disciplines, and this poses a challenge for interdisciplinary systems analysis. Furthermore, perspectives on scale from outside of science are largely undocumented.

Interdisciplinary theory: integrating disciplinary perspectives

With the growing recognition that change in natural and human systems is intimately connected and requires integrated, interdisciplinary and multi-scale perspectives to be understood, an interest has developed in bridging of disciplinary perspectives on scale. Gibson et al. (2000) wrote a seminal review that defined scale and linked and compared perspectives on scale across a range of disciplines. They proposed that the challenge of global environmental change requires the linking of the physical and social sciences and the construction of a common understanding of scale issues. Sayre (2005) focused on the specific potential of linking perspectives on scale between ecology and human geography. A second benchmark paper by Cash et al.(2006) elaborated on the definition of scale and scale interactions proposed by Gibson et al.(2000) and provided a range of scales as examples. This paper also identified a number of scale-related challenges such as ignorance of cross-scale interactions, scale mismatches and a plurality of perceptions on the 'right' scales. To take on these challenges, Cash et al.(2006) explored different responses such as suitable institutional interplay across scales, multi-scale co-management and knowledge exchange, and boundary or bridging organizations. They asserted that types of environmental governance that deal consciously with issues of scale are better at assessing problems and finding solutions. Cumming et al. (2006)described scale mismatches between social and natural systems as a cause of many forms of environmental degradation and social issues. Silver (2008) saw a similarly central role for common perspectives on scale as a way to bridge disciplinary divides.

Building on this work and bringing in new perspectives, a special feature in Ecology and Society has provided a range of studies and overviews that represent the state of the art in the integration of disciplinary perspectives on scale in the context of social-ecological systems research (Kok and Veldkamp 2011). These contributions range from the bridging of specific disciplinary gaps (Termeer et al. 2010; Turnhout and Boonman-Berson 2011; Veldkamp et al. 2011) to the application of multi-scale analyses to practical case studies to show interactions between biophysical and social scales (De Blaeij et al. 2011; Van Apeldoorn et al. 2011; Van der Veen and Tagel 2011). Providing a more conceptual perspective, Buizer et al. (2011) discuss a debate that has opened on the ontological reality of scales according to different disciplinary perspectives, ranging from scales and levels as real and identifiable in the biophysical sciences to the social sciences that view all scales as constructed and contested. Manson (2008) frames this debate on the ontological value of scales as a 'scale continuum'.

From the overview of this special feature and other recent work, several recommendations for research on scale in social-ecological systems can be derived:

- Knowledge claims about the structure and reality of scales should be made explicit in any attempt to bridge disciplines through different scale concepts (Manson 2008; Buizer et al. 2011).
- The biophysical scales still dominate scale-related research more attention should be given to scales associated with research in other fields such as sociology, political

science, economics and human geography (Cash et al. 2006; Kok and Veldkamp 2011).

- The attempts to integrate disciplinary perspectives on scale across the sciences are not mirrored in policy, management and governance practice. The perspectives of non-scientist actors have to be included in interdisciplinary scale debates to involve practice-based perspectives in theory development on the one hand, and to foster consciousness of the role of scale in environmental governance on the other (Kok and Veldkamp 2011).

This study focuses on the value of practice-based perspectives for scale research. Through exploring this recommendation, we will also discuss how the outcomes of this study help take on the other two challenges.

Bottom-up perspectives: change agents in social-ecological systems

The bridging of interdisciplinary concepts of scale on a theoretical level has the potential to solve some of the challenges of applying the strengths of different disciplines together to scale-related problems in environmental governance. However, this integration of theoretical perspectives is far removed from the daily realities of those who are actively involved in the governance of social-ecological systems. Therefore, this study both advocates and explores the value of working in the direction from practice to theory. We believe it is particularly valuable to focus on the perspectives of those societal actors who move societies towards greater sustainability and adaptive capacity. These actors can be characterized as *change agents* (Westley et al. 2006) - actors who exert their individual agency to innovate and create sustainable, accepted change in the systems in which they operate (Moore 2011). These change agents often have to work to overcome gaps and mismatches between societal perspectives that operate across disciplines and dimensions (Westley and Mintzberg 1989; Rossi et al. 2000; Westley et al. 2006). This means that they have had to familiarize themselves with a range of ways in which the world is structured by different societal actors (Westley 2002; Moore 2011).

1. Change agents build their perspectives on social-ecological systems using a range of dimensions, and these dimensions can be structured using different scales.

2. The dimensions and scales used by change agents allow them to capture specific cross-scale relationships.

If these propositions are valid, this means that change agents have particularly rich insights to offer both scale-oriented researchers and society at large concerning interactions between the dimensions, scales and levels in social-ecological systems. Their practice-based perspectives on scale can offer insights on the crossing of disciplinary divides in the practice of environmental governance. Furthermore, the inclusion of practitioners in the generating of knowledge about scale and cross-scale interactions can create more accepted knowledge claims about scale, as well as broader societal consciousness about the diversity of scale-related views (Gibbons 1999; Van Asselt and Rijkens-Klomp 2002; Kok et al. 2006).

Earlier research has focused on the framing of scales by different societal actors, but have largely done so through secondary analysis of perspectives and source material (van Lieshout et al. 2011).This study aimed to take the next step by letting change agents actively explore their perspectives on dimensions, scales, levels and cross-scale dynamics. To do this, we chose to use an adaptation of an in-depth interview method designed specifically to elicit the ways individuals structure their world-views. The change agents in this research have been exceptional in their proven willingness to cross disciplinary and system boundaries and take action towards supported change. The research in this chapter elicits a spectrum of these practice-based perspectives and analyses them on the conceptual level of the interdisciplinary scale discussion in papers such as Cash et al. (2006), Cumming et al. (2006) and Buizer et al. (2011).

4.2 Objectives

Our main objective for this study is:

- Explore how practical perspectives on scale maintained by change agents in social-ecological systems can contribute to the development of interdisciplinary theory on scale and cross-scale dynamics.

We specify this objective through three sub-objectives:

- Capture the range of dimensions and scales used by change agents in social-ecological systems.

- Elicit a series of conceptualizations that visualize how the dimensions and scales used by these change agents allow them to capture cross-scale dynamics.

- Connect these conceptual summaries of practice-based perspectives to interdisciplinary theory development on scale.

In section 4.3 we will first discuss our case study and the change agents who participated in the research, the setup of the interview method, and the analysis of the interview output. Then, we will discuss the relationships between dimensions and scales found in the interviews (4.4) and based on these results, present a number of scales (4.4). We will then show examples in combinations of scales that were linked by the participants clarify cross-scale dynamics (4.4). Finally, we will discuss which insights the elicitation of scales and cross-scale dynamics provides for theory development on scale, as well as our recommendations for further research (4.5 and 4.6).

4.3 Methods

Case study: change agents in TransForum

TransForum was a Dutch innovation institute, set up on a six year project basis that ended in early 2011. Its goal was triggering transitions towards sustainable agricultural development (Veldkamp et al. 2008). For this, a wide range of practical and theoretical projects were executed, incorporating very different images of what sustainable agro-ecological development entails (Beers et al. 2010). This wide range was chosen deliberately and in the spirit of social-ecological systems thinking and transitions theory, on the premise that the way forward is never clear, and multiple solutions might be possible (Schwartz 1991; Yorque et al. 2002; Rotmans 2005).

What made TransForum a unique occasion for interdisciplinary, practice-based knowledge development was that each of the projects was driven by dedicated entrepreneurs willing to take risks in order to effect change working together with public servants and practice oriented researchers. The practical projects represented a number of practical system innovations that serve as successful pilots for larger-scale application (TransForum 2010), and their interaction with the research projects led to many insights about the co-production of knowledge to deal with the challenges of innovation in social-ecological systems (Van Latesteijn and Andeweg 2010).

In this study, we focused individuals that functioned as key innovators and change agents in TransForum's practical projects, and particularly on those involved in projects with a 'regional development' component to ensure that an interaction between environmental and social systems was part of all projects. These change agents have had to cross gaps between system levels, sectors and disciplines to develop agricultural system innovations (Veldkamp et al. 2009).

The projects that the participants in this study were involved in included several developing Green Ports in the Netherlands and one in Shanghai, the development of regional autonomy in sustainable agriculture, sustainable rural health care projects, the fostering of relationships between cities and the countryside and a saline agriculture project. From these projects, 16 change agents were identified in collaboration with TransForum coordinators, based on their roles in the histories of the projects. These participants took part in face-to-face, semi-structured interviews of two hours on average. This proved to be sufficient to capture the full spectrum of dimensions mentioned in these TransForum practical innovation projects (see section 4.3). Of these, 7 were commercial project and process developers, 4 were practice-oriented researchers, 3 were public servants, and 2 were members of the TransForum organization.

Interview method: Scale Repertoire

To facilitate participants' identification of dimensions and scales associated with their perspectives, we developed an interview method focused on a project storyline/future visioning approach inspired by Repertory Grid Technique (Kelly 1955; Ryle 1975; van de Kerkhof et al. 2009). Repertory Grid Technique is an interview method originating in construct psychology which has recently become more popular in other contexts such as market research, intelligence, human learning and policy analysis. This technique asks participants to frame 'elements' (such as people, products, policies) on the personal 'constructs' that make up their value system, such as wealth, reliability, intelligence, etc. These constructs are elicited discussing the similarities and differences between elements, and based on that, developing the constructs as bipolar scales (van de Kerkhof et al. 2009). Our approach, which we named the Scale Repertoire, combined an adaptation of the Repertory Grid with a scenario storyline building in the mode of 'middle-casting': starting with a normative vision of the future, and then working toward that future from the past, with the present as a center point in the time-line. We used this temporal structure because it allowed us to capture the dimensions of past change with participants, as well as giving them the freedom to envision future developments and dynamics that exist only in their perspectives. In our approach, the 'elements' were different drivers affecting events in the past and future storyline. The 'constructs' represented the bare dimensions and the way these dimensions were structured provided a basic characterization of associated scales. We used no predefined categories, instead allowing participants to develop the dimensions and scales that constructed their perspective in the storyline.

Our interviews were structured as follows: Part 1. Identifying drivers:

1. The participant develops a normative, desirable future vision for the subject matter (e.g. a project, development, region), on a personally defined time scale.

2. The participant explores which major changes or events have happened with regard to the subject in the past that brought it to its present state and develops a narrative path to the future vision.

3. The participant determines which drivers cause these changes/events to come about in the narrative.

Part 2: Eliciting dimensions and scales:

1. The interviewer facilitates the participant in determining the dimensions associated with each driver.

2. The participant decides whether similar definitions could be captured by a single dimension.

3. The result of this is a collection of dimensions that the participant sees as structuring his/her storyline. The participant then structures each dimension into a scale (opposite poles, quantity, quality, etcetera.)

4. The participant draws the dynamics of the past-to-future storyline in terms of each of the dimensions, in a field of scales where the horizontal axis represents the time-line, and the vertical axis represents a scale for any dimension that is currently in focus.

The result of this process is a storyline of the past moving towards a normative future, framed along a number of dimensions, each of which has been structured by a scale. The collection of scales captures the cross-scale dynamics in the storyline. In this chapter, we will not focus primarily on the sorylines developed with participants, but will instead focus on the more conceptual level of the results that capture dimensions, scales and cross-scale interactions.

Data processing

Our data processing consisted of two steps:

1. *Analysing whether a sufficient spectrum of dimensions was captured for the case study*

   The interviews resulted in 156 individual dimensions, or an average of 9.6 dimensions per participant (SD =1.8). Three researchers clustered these dimensions on similarity, and subsequently discussed categories to come up with a set of 27 clusters. Studies using Repertory Grid Technique claim that on average, and depending on the scope of the subject, 16 to 20 participants are sufficient to capture the full spectrum of constructs, or in our case, dimensions (Dunn 2001). In our case, no new dimensions were added after 13 participants were interviewed, which gave credibility to the conclusion that the dimensions elicited from participants were a good representation of the dimensions that framed perspectives in the case study.

2. *Exploring scales and cross-scale dynamics*

   An inventory was made of the scales used to structure the 27 dimensions. Some dimensions had scales that were only associated with that dimension, while other dimensions were only characterized by scales that were not explicitly linked. Most dimensions were structured both by associated scales and by scales that were not associated. By cross-referencing dimensions and scales, we evaluated how scales were applied to different dimensions. To depict the scales, we followed the visual format used by Cash et al. (2006). Interactions between scales in the participants' storylines brought cross-scale dynamics to light.

4.4 Results and analysis

Dimensions

Table 4.1 shows a selected cross-referencing of dimensions and scales used by participants in the interviews. This table shows only those dimensions that have their own associated scales. The network dimension has the most occurrences of specifically associated scales.

Table 4.1: Cross-reference between dimensions (vertical) and scales (horizontal).

	Network dimension	Knowledge dimension	Policy dimension	Management dimension	Spatial dimension	Temporal dimension	Vision Dimension	Innovation dimension	Sector dimension	Status dimension	Role dimension	Total scales per dimension
Network scales	**17**			1	1							19
Knowledge scales	3	**14**		2					3			22
Policy scales	1		**15**		2	1			1			20
Management scales	1			**12**					1			14
Spatial scales					**2**							2
Temporal scales				2								2
Vision scales	5				2	1	**3**		1		1	12
Innovation scales			2		2			**4**	1			9
Sector scales					1		1		**11**			13
Status scales	1	1	1		1				1	**2**		7
Role scales	1										**7**	8
total scale across dimensions	36	16	25	19	11	2	4	5	24	4	10	156

Network, policy, management and sectoral interaction scales are the most used to structure other dimensions.

Scales

Figure 4.2 shows the scales used by participants. Each section of the figure shows the scales associated with a dimension. Three general categories can be distinguished: scales defined by separate levels, scales with polar opposites and quantitative/relative scales. This section discusses each set of scales and their origin.

As can be seen in table 4.1, a number of scales were used not just to structure the dimension that they were principally associated with, but also used to structure other dimensions.

Network scales

scales were mentioned most frequently, and accordingly, the results show a large diversity of these scales. The network hierarchy, with a different composition to the example in Cash et al. (2006) was used most often, but other scales such as explicitness of interests and network accessibility reflected intricate network dynamics.

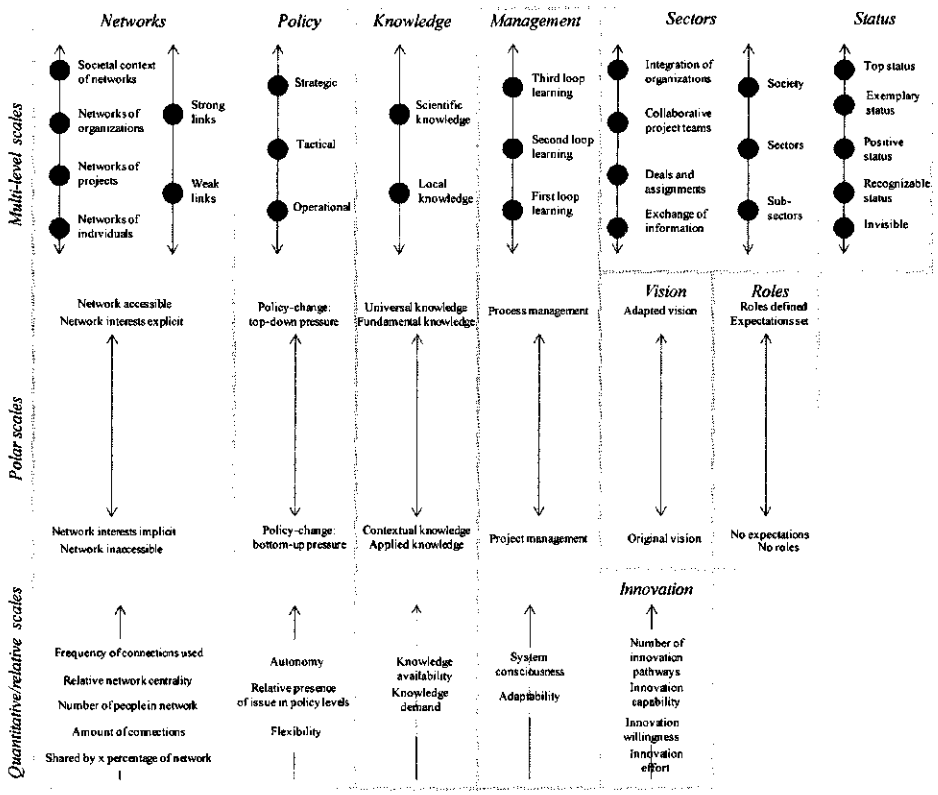


Figure 4.2: scales produced by participants using the Scale Repertoire. The blue dots in the top-most category represent levels on those scales. The polarized scales are presented with different alternate polarizations. The different terms in the quantitative/relative category represent a number of different scales per dimension.

Policy scales

Six scales were associated with the policy dimension. Dialogues, conflicts and collaborative change have featured heavily in their pasts and in the participants' visions for their futures. To frame policies, participants used different several scales specifically focused on cross-level policy dynamics.

Knowledge scales

Five scales were used by participants to structure the knowledge dimension. The fact that knowledge features prominently among participants dimensions and scales can be linked to the innovative nature of these projects, where new knowledge was implemented and developed through learning processes.

Management scales

Participants used five organizational management scales. Change agents dealing with organizational management in the TransForum case have had to work within highly dynamic policy, knowledge and network environments, and therefore, learning, process management and cross-level management feature often in the accounts of participants.

Sector scales

Participants framed many developments in their regions and projects in terms of sectors: which the sectors and sub-sectors that were involved, whether impacts across sectors were different, and how relationships between sectors were organized. This dimension and its associated scales was seen as essential for those seeking to create change towards sustainability across the societal spectrum.

Vision scales

Vision was seen both a future-oriented structuring of meaning for those in the present to act on, and in this interpretation, it was framed by its own scales, but it was also seen as a trait of individuals and organizations, in which case other scales were used to define it.

Innovation scales

Four scales were used by participants to structure innovation, with the innovative properties of projects and interventions both changing and being changed by societal dynamics. Specific innovation pathways were part of this dimension, but also several scales that together express innovation potential.

Status scales

Table 4.1 showed that the status dimension was framed by multiple scales including networks, policies, jurisdictional and sectors, and in each of these framing, status received a different interpretation. The scale developed specifically for status has associations with image, visibility and marketing.

Role scales

Two polar scales were defined by participants to structure the relationships of roles people, projects and organizations are assigned. Problems of role definition are especially likely in environments where complexity and uncertainty are high, compounded by the large number of different perspectives and types of experiences involved (Beers et al. 2010) and both of these were abundantly the case in our participants' projects.

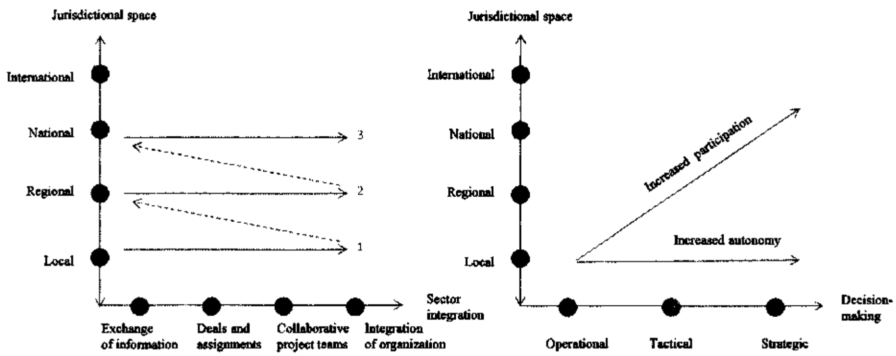


Figure 4.3: Sector integration set against jurisdictional space. The numbers mark the order of events: 1 represents the past integration at a local level, 2 represents current efforts to achieve the same degree of integration at the regional level and 3 represents future ambitions of taking this integration of sectors through to the national level. Figure 4.3b: Local autonomy and participation framed by policy decision levels set against jurisdictional levels.

Cross-scale dynamics

The scales that the participants in the TransForum case used to frame their perspectives on past and future allowed them to draw out system dynamics in specific ways. The following depictions of cross-scale dynamics were based on the participants' visual depictions. Figures 3a to 4b show cross-scale dynamics between spatial and social scales, while figures 5a to 7b show cross-scale dynamics between social scales. While each of these images captures a rich storyline or vision, we will elaborate on one cross-scale dynamic in each category as a primary example.

Cross-scale dynamics between spatial and social scales

While table 4.1 shows that geographical scales did not play a major role in participants' structuring of their perspectives, we chose to include a number of examples of conceptual implications of links between scales here because they are relevant to the interdisciplinary attempts to bridge geographical and social scales. Figure 4.3a will be our primary example.

Figure 4.3a shows a participant's activities to increase integration between sectors, building this integration up across jurisdictional scales. This individual has acted as a change agent by brokering between sectors related to the regional clustering of agricultural and horticultural activities and their interactions with environmental and social functions as well as logistics, knowledge development and innovation. This image represents both the past experience this participant has had with the developing of local integration between the public and private sectors and their sub-sectors (stage 1), his current efforts to build on past successes to create a similar degree of integration between sectors at the regional level (stage 2), and his future ambitions to move from regional integration of sectors to the national level (stage 3). This elicitation of cross-scale dynamics in the perspective of this change agent is indicative of his orientation towards both geographical and social scales and their interplay. He recognized qualitative differences between the requirements for the integration of sectors at different jurisdictional levels, as well as the differences between degrees of integration. This included his involving of different types of actors that possessed the skills specific to the requirements of those geographical and social scales.

Other examples of interactions between social and geographical scales are presented in figures 4.3b to 4.4b. Figure 4.3b shows a participant's setting of policy decision levels against jurisdictional levels to represent different types of governance in her storyline. Figure 4.4a shows a link between available physical space and the number of innovation paths or opportunities that could be taken, in this case for saline agriculture. A pilot plot allows for experimentation with different crops. As available space (test sites, commercial implementation) grows, qualitatively different innovations can be developed, such as infrastructure and treatment innovations and marketing strategies, and the relationship between space and innovation becomes more and more complex. Figure 4.4b shows system consciousness expressed by sector width in the societal spectrum set against jurisdictional levels. A local perspective is depicted that includes consciousness of most societal dynamics at the local scale. At a regional scale, its consciousness is limited to its sector. Nationally, it is mostly conscious of its sub-sector. An opposite example shows the perspective of an international organization.

Cross-scale dynamics between social scales

Despite the geographically rooted character of the TransForum regional development projects, the majority of cross-scale dynamics identified by the participants in their perspectives were dynamics between social scales. A number of these combinations consisted of network scales paired with scales connected to vision, knowledge, organizational and role scales. Figure 4.5 will be our primary example.

Figure 4.5 uses the knowledge availability and 'percentage in network' scales set against a network hierarchy to show how the spread of knowledge and vision through this hierarchy. In the scale-structured account of this participant, several like-minded and similarly positioned individuals acquired knowledge and developed a vision through their networks (1). They disseminated this knowledge and the vision that was built on into their organization, which acquired further knowledge and developed the vision at an organizational level using the resources in its network (2). Both were then passed on in a top-down fashion to the networks of various projects that this organization was taking part in (3). The relationship between knowledge acquisition and vision development is made with different levels in the network hierarchy - it shows how an individual acquires knowledge and develops a vision, and how these work through networks on different levels, in this case, a mix of bottom-up and top-down development and dissemination. Here again, the participant demonstrated a

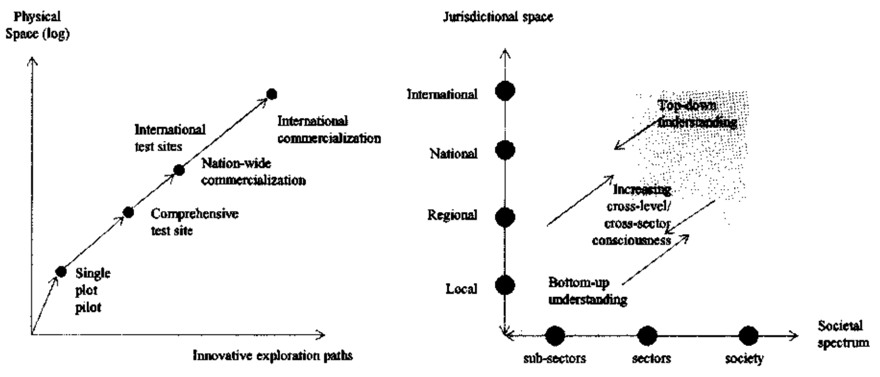


Figure 4.4: The number of innovation paths that could be taken, set against logarithmic physical space. Figure 4.4b: System consciousness expressed consciousness of processes at multiple jurisdictional levels and across multiple sub-sectors, sectors and the societal context. The bottom left area stands for a local perspective, the top right area for an international overview. Arrows depict the potential for growth of this consciousness

keen sense of the different dimensions associated with knowledge and vision development in the context of individual networks, practical projects and their organization, as well as an understanding of the qualitative differences between the levels in the network. This example is particularly relevant considering the prevalence of the 'network hierarchy' scale among the participants' perspectives in our case.

Figure 4.6a combines a relative knowledge scale with a scale for sector width to show the mismatch between currently available knowledge in a project (primarily specialist, concerning sub-sectors of the project's context) and required knowledge (primarily knowledge of the societal context of multiple sectors). Figure 4.6b sets knowledge availability against the polar process vs. project management scale to show the overlap and gaps between a project's members and their facilitator. It also shows what the facilitator expected to be the knowledge requirement of the project members, and their actual knowledge requirement.

Figure 4.7a uses a polar scale for role definition, set against the network hierarchy to show two examples from interviews of how role definitions of individuals, projects and organizations can differ. In one example, roles of organizations and projects in networks were clearly defined, and it is only on the individual level that we found people in the network that had less-defined roles and thus more flexibility to induce change. In the other example, key individuals had clearly defined roles, but projects and organizations did not. Figure 4.7b shows various mismatches between the roles assumed or assigned by societal actors related to the degree to which these roles have been defined in the expectations of others.

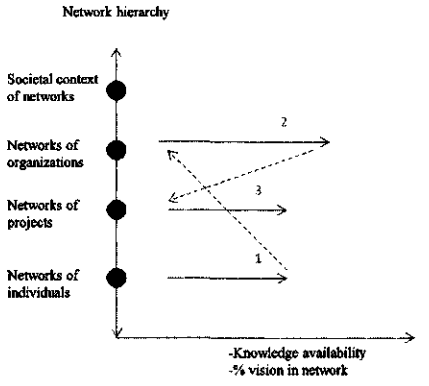


Figure 4.5: Knowledge availability and the spreading of a vision set against different network levels. The gathering of knowledge to construct a vision started at the level of individuals and their networks in this example (1), was subsequently picked up by the organization and developed further (2), and then dispersed among its projects (3).

4.5 General discussion

The previous sections discussed examples of individual results from our elicitation of scales in the perspectives of change agents. Here, we will discuss the implications of these findings for both conceptual and practice-oriented efforts to explore the role of scale in the governance of social-ecological systems.

Extending the scale vocabulary with dimensions

In this study, we used the term 'dimension' to describe the bare phenomena or aspects of reality to which various scales are applied. We proposed that this distinction would be useful, since different scales can be applied to structure the same dimension. Our use of this distinction has indeed proven useful in both the practical work with participants as well as the analysis of the results of our study. While using the Scale Repertoire with participants, the identification of dimensions preceded the structuring of scales. This allowed participants to acknowledge certain dimensions as important, even if they were not able to come up with a useful way to structure them. The usefulness of the distinction between dimensions and scales was also clear in the analysis of our results - showing that while in many instances, dimensions were structured according to specifically associated scales (e.g. network nodes for the network dimension, or decision levels for policy), there were also many instances where dimensions were structured by scales that were not primarily associated with them.

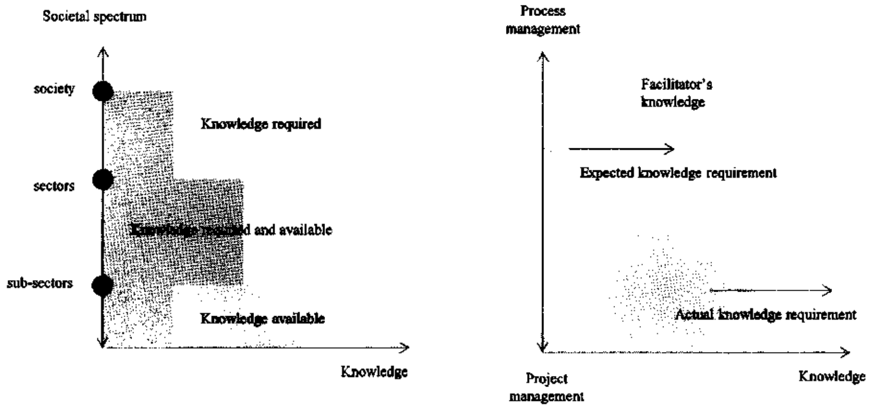


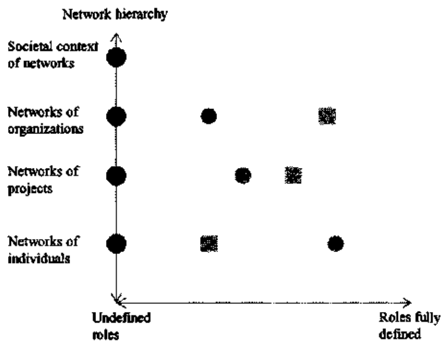
Figure 4.6: A relative knowledge scale set against a scale for sector width showing the contrast between available knowledge and required knowledge in an example. 4.6b: Facilitating a project framed by available knowledge set against a polar scale for process vs. project management.

Method: the Scale Repertoire

Though inspired by Repertory Grid Technique in its basic approach (Kelly 1955), the narrative-based structure of the Scale Repertoire, and the section where participants use their scales to draw graphs of the dynamics in their narrative have made it sufficiently different that an evaluation of this new method is in order. The use of the Scale Repertoire turned out to be advantageous in many respects for our purposes. Its only requirements are a narrative, driving forces on that narrative, and the elicitation of the dimensions and scales that are essential for framing the narrative and its drivers. The participant is not prematurely constricted by consecutive framing steps while building the narrative. Instead, dimensions and scales are allowed to arise from the narrative. What can be seen as a weak point of this method is that because of its open format, there are no requirements for participants to structure their scales in a very detailed fashion. An argument against this criticism is that in this way, the participants are not forced to create constructs that are artificial and not actually characteristic of their perspectives. Still, this potential tension between flexibility and structure is a point for further research on methods for the eliciting of scales that make up societal perspectives. Finally, it should be stressed that the Scale Repertoire focuses explicitly on subjective views of cross-scale interactions, and does not provide a way to test these perspectives.

Scales used by change agents to frame their narratives

While we discussed particular scales in section 4.4, our findings bring up general points for discussion, based on our first hypothesis and objective:



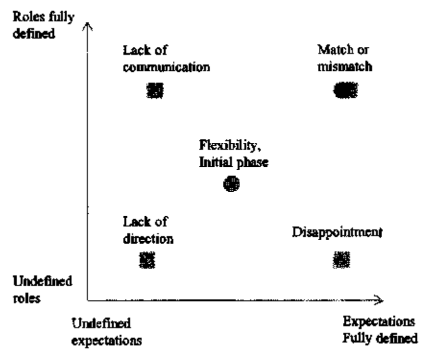


Figure 4.7: A polar scale for role definition set against a network hierarchy with two examples (circles/squares).Figure 4.7b: Role definitions versus role expectations including different examples from interviews. Circles indicate a positive situation as perceived by the participant, and squares indicate negative situations.

- Change agents can describe their perspectives using a spectrum of biophysical and social dimensions and a range of scales to describe the same dimensions. This underlines the need to consciously consider the multiplicity of scale framing between societal actors. Studies such as van Lieshout et al. (2011) have explored the placing of emphasis on different levels and scales by different actors through secondary analysis. We however propose that our findings advocate the value of having these actors make their scale framing explicit themselves. Additionally, the scales captured in our case study provide different ways to structure and study processes in these dimensions.
- The prominence of social scales in our results runs counter to the dominance of biophysical and geographical scales in the literature(Kok and Veldkamp 2011). Part of this focus on social scales could be explained by the heavily regulated and institutionalized Dutch context of the case study. But it can also be an indication that the social scales (including political, economic, knowledge and other scales) and not the biophysical scales are seen as limiting, challenging or providing most leverage from the perspective of change agents. It would be valuable to repeat this exercise in cases that are even more explicitly focused on physical environments and biophysical processes to see if social dimensions still dominate the accounts of the change agents.

Cross-scale dynamics

The combinations of spatial and social scales, as well as the pairings between social scales presented by several examples in sections 4.4 and 4.4 reveal much about the sustainable development efforts our change agents were involved with, and additionally reveal information about the actors themselves:

- Sections 4.4 and 4.4 have shown that the range of scales used by the change agents interviewed in our case study has allowed them to capture specific cross-scale dynamics. These cross-scale dynamics represent the success stories and lessons the interviewees saw as crucial, as well as the visions and directions to where they see themselves taking their work in the future. The essence of these cross-scale narratives would have been lost when framed only by spatial and temporal scales. These examples are therefore demonstrative of the value of the inclusion of such key societal perspectives. They also show the value of linking fundamentally different scales for systems analysis.
- The examples in figures 4.3 to 4.7 and the examples we discussed more elaborately indicate a strong sense of consciousness among these change agents about the dynamics between different dimensions as framed by scales. The specific narratives described in these examples therefore give credibility to our hypothesis that the understanding of and playing on dynamics between different dimensions and scales helps actors to create system-wide changes in social-ecological systems.
- The examples that linked spatial and social scales provided multi-dimensional representations of the concept of bottom-up change. Our elaborate example (figure 4.3a) in particular shows the conscious attempt of the change agent to move further along the scale of integration at the lowest spatial level before up-scaling this aim, while being cognizant of the qualitatively different challenges that are to be found both at each level of integration and at each spatial level.
- The examples that linked different social scales captured dynamics that were not directly related to biophysical change but crucial to the change agents in the interviews. Dynamics in networks, knowledge and roles were central in these examples. The example we elaborated on (figure 4.5a) shows how a good understanding of the role of new knowledge and a gathering vision at different levels of network organization can work to proliferate both across the entire system.

Implications for theory development

Gibson et al. (2000) and especially Cash et al. (2006) have often been referenced as the standard overviews of scales stemming from different disciplines. Comparing the dimensions, scales and cross-scale dynamics that resulted from our case study to the seminal work in these papers, we propose that:

- These studies do not give an overview of possible scales, but have, in our view, rather presented a range of different dimensions, using examples of one or multiple scales for each dimension and demonstrating the diversity of dimensions, particularly social dimensions, as guides for further research.

Table 4.2: Key references of knowledge domains linked to dimensions and scales from case studies.

Network	Affiliation hierarchy: (Breiger 1974, Wasserman and Faust 1994) Implicit vs. explicit: (Crown and Rosse 1995)
Knowledge	Local/scientific knowledge: (Berkes and Folke 2002, Gagnon and Berteaux 2009) Knowledge mismatches:(van Eeten 1999, Hermans et al.)
Policy	Policy and Flexibility: (Choe and Fraser 2001, Aldy et al. 2003) Policy decision levels: (Jantsch 1970)
Management	Organizational learning: (Argyris and Schon 1978, Flood and Romm 1996) System consciousness: (Westley 2002, Westley et al. 2006.) Process vs. project management: (Meier and O'Toole Jr 2001, Edelenbos and Klijn 2009)
Sectors	Inter-sector cooperation: (Faulkner and Senker 1994, Casimir and Dutilh 2003, Peterson 2009, van Mierlo et al. 2009)
Vision	Vision development and adaptation: (Westley and Mintzberg 1989, Berson et al. 2001, van der Helm 2009, O'Connell et al. 2011)
Innovation	Innovation pathways: (Feder and Umali , Kash and Rycroft 2002, Rycroft and Kash 2002) Capacity, effort, willingness: (McGrath 2001, McDermott and O'Connor 2002)
Status	Organizational status: (Podolny and Stuart 1995, Podolny and Phillips 1996, Gray and Balmer 1998)
Roles	Role definitions and expectations: (Sverrisson 2001)

- These studies and the more recent work in the Ecology and Society special feature (Kok and Veldkamp 2011)advocate the need for further explorations of the spectrum of scales, and especially social scales. On these basis of our results, we would like to expand this point of view by proposing that researchers should explore a broader spectrum of a. dimensions and b. the scales associated with them, as well as c. differences between scales used to frame dimensions familiar to scale research.

- This exploration entails connecting to a broader spectrum of disciplines by current scale-oriented researchers, but also an involvement in the scale debate of experts in those fields. Table 4.2 provides some key references from research domains that connect to the dimensions and scales found in our case studies.

- Given our results that suggest that cross-scale dynamics have helped change agents explicate crucial dynamics within the systems in which they operate, the study of cross-scale dynamics should receive a more central focus than is currently the case. Cash et al. (2006) and Cumming et al. (2006) provide a strong theoretical basis for these explorations, and the cross-scale dynamics described in our practical case studies show the potential value of a stronger focus not just on dynamics between environmental and social scales but also between different social scales.

Linking scale research to practice

We have aimed to demonstrate the value of eliciting practice-based perspectives on scale for the development of research based on our case study results. We hope this study provides incentive for further investigations into the dimensions and scales that make up the perspectives of those involved in environmental governance and innovation for sustainability, through scale-oriented interview methods like the Scale Repertoire, and the analysis of strategies, policies and media. However, this link between practice and theory should be developed more fundamentally and in different ways:

- Develop strategies to bring together societal actors and researchers to exchange perspectives on dimensions and scales. Use translations between different theoretical and practical perspectives on scale to bridge gaps in understanding between knowledge domains.
- Build on the recognition of the value of scale consciousness in governance to create cross-level and cross-scale communication pathways, exchange platforms and initiatives for practical action.

4.6 Conclusions

Attempts at linking disciplinary perspectives on the role of scale and cross-scale dynamics in social-ecological systems have so far mainly linked theoretical and academic insights. This study provides practical perspectives on scale, elicited from societal actors that have created accepted change in social-ecological systems. Extending the scale terminology to a framework of dimensions, scales and levels, we proposed that 1. these 'change agents' would be able to explicate a range of dimensions and scales and 2. that these would allow them to understand cross-scale dynamics in ways that would be valuable to interdisciplinary research on scale. Our results from the TransForum case study showed a wide range of scales produced by change agents in the interviews, and a number of combinations of these scales that were able to capture the cross-scale dynamics they saw as crucial. The elicitation of dimensions, scales and cross-scale dynamics can open up new paths for research and reframe past work. It also shows the potential value and need for bridging the divide between theory and practice in terms of scale consciousness.

Chapter 5

Combining analytic and experiential communication in participatory scenarios

Don't let your mind do all your walking,
boy you'll stumble every time.

-16 Horsepower, Haw, 1995

Chapter is based on:
J.M. Vervoort, K. Kok, P-J Beers, R. van Lammeren, R. Janssen. *Combining analytic and experiential communication in participatory scenarios*. Submitted to Landscape and Urban Planning.

Abstract This chapter combines two modes of participatory exploration of the possible futures of social-ecological systems: analytic understanding and experiential engagement. Humans use two distinct mental modes to deal with salient information: analytic processing and experiential processing. Analytic processing deals with abstract information. Experiential processing focuses on immediate experience. Communication using both modes of processing has benefits that are complementary and essential for science communicators. In this chapter, we combine two tools, each geared to one mode of communication, to create complementary results. The System Perspectives Scope is a tool aimed at eliciting and sharing analytic perspectives on social-ecological systems change. ScenarioCommunities facilitates the communication of perspectives on the future in an experiential mode. In a case study in Oxfordshire, UK, we applied these two tools in two scenario development workshops. Each workshop featured the tools in a different order to compare the effects of each tool on the other. The System Perspectives Scope was able to elicit participants' analytic perspectives and let them reflect on the systems they described. ScenarioCommunities communicated scenario storyline segments in an experiential mode. This in turn stimulated the creation of individual, experiential perspectives on the scenarios. The workshop that used the tool focused on experiential engagement followed by the tool focused on analytic understanding yielded the best results for both tools and reinforcing effects of the first tool on the second. This study has shown that analytic and experiential communication can indeed be used to generate both understanding of and engagement with social-ecological systems change.

Introduction

The last decades have seen a growing recognition among researchers and policy makers alike that the challenges of global environmental change require the involvement of a broad range of societal actors (Schwartz 1991; Gibbons et al. 1994). Natural and human systems have become connected to such a degree that they are better described as social-ecological systems (Folke 2006). Because of the pervasive complexity and uncertainty because of this connectedness, environmental governance can no longer be the exclusive domain of specialists or bureaucrats. Instead, collaborative knowledge development strategies are needed that incorporate a wide spectrum of perspectives from different system levels and sectors (Gibbons 1999; Van Asselt and Rijkens-Klomp 2002). Furthermore, since top-down environmental policies have often met with societal indifference or resistance, the challenge is not only to increase understanding of social-ecological change, but also to foster a willingness to cooperate and take action among societal actors (Yorque et al. 2002).

Communication strategies and technologies can play a crucial role in making knowledge and perspectives accessible between societal actors. But the demands for information to handle abstract analysis as well as be vivid and engaging are often at odds. Scientific communication has difficulty conveying complex analyses of future uncertainties in ways that engage non-specialists (Marx et al. 2007). In contrast, in films, news stories, documentaries and other media, future uncertainties are presented in vivid and engaging ways that can affect societal attitudes, but these representations provide very little insight into the system dynamics underlying social and environmental change (Beers et al. 2010). The challenge lies in the fact that these two goals are linked to fundamentally different ways in which humans process information (Epstein 1994). Taking on this challenge in communicating about social-ecological systems change is the focus of this chapter.

Analysis and experience: a psychological perspective

Social psychology shows us that humans have two complementary modes of mentally processing information *experiential* processing and analytic processing (Marx et al. 2007). Experiential processing deals with an individual's direct experiences, as well as with vivid images and stories. Through this type of processing, experiences, images and stories can have a strong emotional impact that is vividly remembered, and that more easily leads to action and behaviour change. By contrast, analytic processing works with abstract information, large sets of data and analytic schemas, and is more involved with cognition and less with memory and the emotions (Epstein 1994). Experiential processing can more easily take precedence over analytic processing than vice versa, because of its association with strong emotions (Fagerlin et al. 2005). The first response to situations where both types of processing are possible is also more likely to be one based on experiential processing, with analytical processing following to add analytical depth (Tversky and Kahneman 1974; De Neys and Glumicic 2008).

The importance of dual processing for the communication of future uncertainties associated with environmental change has recently been advocated by Marx et al. (2007). In this context, communication focusing on experiential processing, or *experiential communication* in shorthand, is more suited to generate engagement and willingness to take action. Benefits of experiential communication for participatory scenarios are:

- *Concreteness and imaginability:* Communication grounded in the direct experience of the world can represent abstract concepts, such as those associated with social-ecological systems change, in ways that make them concrete (Shaw et al. 2009).
- *Vividness and engagement:* Interactions in an experiential mode that involves imagery and storylines have the potential to be engaging and vivid, fostering active involvement with the subject matter (Fagerlin et al. 2005).

Conversely, communication focusing on analytic processing, or *analytic communication*, is more conducive to the development of knowledge on the system dynamics underlying change dynamics in social-ecological systems. Used for participatory scenarios, the benefits of analytic communication are:

- *Elicitation of mental models:* the analytic communication mode can enable those taking part in the development of scenarios to make their models of social-ecological change explicit and directly available to others (Holling and Gunderson 2002).
- Analytic reflection: Through expressing knowledge in an analytic mode using schemes, conceptual models and data, those interacting with the content can reflect on the consequences, consistencies and inconsistencies of their models (van Vliet et al. 2010).

Analytic and experiential communication in scenario development and related fields

This chapter explores the potential of participatory scenario development to overcome the dichotomy of facilitating analytic understanding and experiential engagement. We define scenarios as 'descriptions of possible futures that reflect different perspectives on past, present, and future developments' (Gallopin 2002; van Notten et al. 2003). Scientists, governments and businesses have adopted the practice of participatory scenario development to explore future uncertainties in a way that incorporates a broad range of perspectives (Kok et al. 2006). Rather than being predictive, scenarios aim at capturing some of the uncertainty inherent to complex systems by envisioning possible system developments in concrete futures (Xiang and Clarke 2003). Scenarios have the potential to facilitate understanding of social-ecological systems by describing development dynamics and pathways. By creating concrete views of the future, scenarios can also generate engagement with future uncertainties.

Scenario development dealing with social-ecological change employs both analytic communication through graphs, schemes, (conceptual) models and brainstorms, as well as more experientially oriented communication in the shape of iconic images, vivid scenario storylines and spatial planning tools (Xiang and Clarke 2003). There is, however, still a gap between the audiences and contexts in which analytic and experiential content are used, the relative importance allotted to them, and the degree to which they are integrated (chapter 2 of this thesis). Furthermore, the use of experientially powerful techniques is still underdeveloped in this context.

However, there are several related fields of research that together provide pieces of the puzzle on ways to present information that connects with both modes of mental processing. We look to these fields for clues on how to bridge the gap between experiential and analytic communication in scenario development (chapter 2 of this thesis). *Landscape visualization* (Sheppard 2001; Scharmer 2007) focuses on experiential communication, bringing future landscapes and urban environments to life in a vivid and realistic manner. *Knowledge visualization* and *visual analytic* are related research domains, where the focus is on abstract schemas, concepts and metaphors as accessible, clear and intuitive carriers of information (Thomas and Cook 2007). In commercial gaming, experiential interaction is the main strategy. In contrast, *serious gaming*, the use of gaming techniques and processes for education and knowledge exchange, is focused on both engagement and understanding, and so more analytic communications are sometimes part of the strategies used in this field (Squire 2005). We build on insights from these fields to develop our participatory tools.

Introducing two participatory tools

In this study, we applied and evaluated two participatory scenario development tools in live workshop settings. Each of these tools is geared towards harnessing the specific benefits of one communication mode.

1. *The System Perspectives Scope* is an analytical communication method employing simple, interactive visual formalisms to explicitly focus on the conceptual dimensions and dynamics of social-ecological systems.

2. *Scenario Communities* is an experiential communication method focusing on participants' creation of scenario content in response to animated storylines of the future.

We implemented both of these two methods in two case studies in the county of Oxfordshire (United Kingdom), where participants from two regional sustainable development communities participated in two future visioning workshops. We used the tools in different sequences to study the interactions between analytic and experiential communication.

5.1 Objectives

The main objective of this study is to evaluate whether the analytical tool 'System Perspectives Scope' and the experiential tool 'ScenarioCommunities' produce complementary benefits for the participatory exchange of individuals' perspectives on environmental change when applied together.

We posed five research questions in order to address this main objective:

- Does the System Perspectives Scope explicate personal perspectives on social-ecological systems?
- Does the System Perspectives Scope stimulate participants to reflect on their own mental models?
- Does the Scenario Communities tool facilitate the creation of new experiential content containing complexity?
- Is the interaction with the Scenario Communities tool characterized as an engaging and vivid experience by the participants?
- How are these benefits affected by different sequences of both tools?

We will first describe this study in terms of case and tool design (5.3, 5.4) and workshop setup (5.5) and measurements (5.6). Then, we will present our case study results (5.7) and discuss their implications for participatory scenarios on social-ecological change (5.8, 5.9).

5.2 Case study: Oxfordshire

Both the System Perspectives Scope and Scenario Communities were developed to work with sustainable development communities in the county of Oxfordshire, UK. With approximately 600,000 inhabitants, Oxfordshire is a relatively rural county by the standards of the densely populated South-East of England. The city of Oxford dominates the county, and it in turn is characterized by the presence of Oxford University (Oxfordshire County Council 2011). There are a number of regional and local sustainable development communities in Oxfordshire. For this study, we conducted two workshops, one in each community.

The first workshop was run with Sustainable Woodstock, a local sustainable development community in the municipality of Woodstock. The second workshop was run with the Oxfordshire Rural Community Council (ORCC), an organization that facilitates the tackling of various issues for rural municipalities, including sustainable development and housing challenges. Both workshop groups were comparable in terms of their regional focus. Education levels of participants were also similar. The participants in the Sustainable Woodstock workshop consisted of people working in the (sustainable) business sector, government, education and NGOs. In the ORCC, most participants classified themselves as working in an NGO or government body. The participants in the Sustainable Woodstock workshop were 11 years older on average than those in the ORCC.

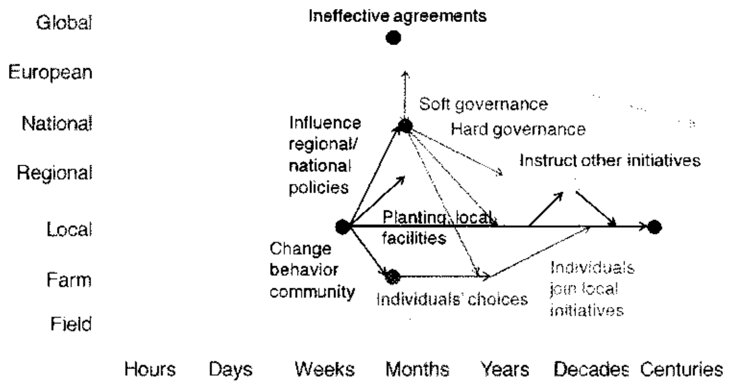


Figure 5.1: The Scale Perspectives Chart with an input example from the workshop. Users move their pre-selected issues on this fixed scale space of time and geographic space, and place them on the levels that reflect their perspectives.

5.3 Analytical and experiential communication tools

Analytic communication: The System Perspectives Scope

The System Perspectives Scope (SPS), first described in chapter 3 of this thesis, is an interactive, visual tool that can be used to elicit stakeholder perspectives on the dimensions and dynamics of social-ecological systems. This tool consists of two parts, the Scale Perspectives Chart and Myths of Nature.

The Scale Perspectives Chart allows stakeholders to explicate their perspectives on relevant temporal and spatial system scales for issues related to social-ecological change. In the tool participants provide the issues they find most relevant in the context of the exercise. They then place these issues in a field framed by fixed scales of time and space (figure 5.1). Each marker on the scale indicates a new level on the spatial and temporal scales. This way, participants can pinpoint the spatial and temporal levels for these issues. Participants can also indicate how a single issue expresses itself on multiple levels, and use connection arrows and area demarcations to indicate cross-level effects. Earlier research has focused on the capturing of stakeholder perspectives on the role of different spatial (Lima and Castro 2005) or temporal (Hoogstra and Schanz 2009) levels in the context of environmental change, but the Scale Perspectives Chart provides more flexibility for stakeholders to dimensionalize their issues. It is also the first participatory tool to connect both temporal and spatial levels in this integrated manner.

Whereas the Scale Perspectives Chart allows stakeholders to map out the dimensions of social-ecological change, Myths of Nature focuses on the dynamics. Myths of Nature

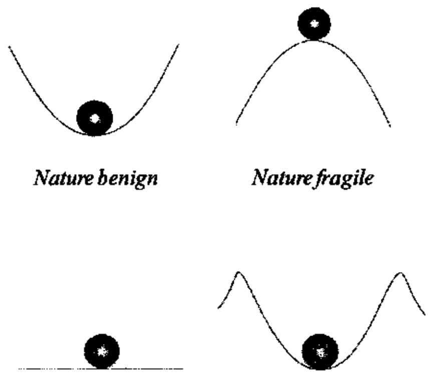


Figure 5.2: The Myths of Nature. Each image depicts the dynamics of natural systems in response to disturbance.

is a simple, visual depiction of different implicit perspectives that exist among institutions and individuals on the nature of ecosystems' dynamics and the way they respond to disturbance, based on the work of Holling (1979; Holling 1986) and Timmerman (1986). These perspectives provide a way to explore perspectives on system dynamics in an accessible, clear way linked these perspectives to worldviews on the nature of social relationships explored by Douglas and Wildavsky (1982). In this exercise, participants pick the myth of nature that most closely resembles their perspective on the responses of natural systems to (human-induced) disturbance. In keeping with our focus on direct, visual communication, we followed Hoogstra and Schanz (2009) in the choice for a visual depiction, see figure 5.2. We changed the names of the perspectives slightly in our uses of the perspectives, to make the test more accessible to our audience. They are, as described in chapter 3 of this thesis, *Nature forgiving*, *Nature malleable*, *Nature resilient* and *Nature fragile*.

Experiential communication: Scenario Communities

Scenario Communities is a participatory, experiential scenario storytelling method developed for both on-line platforms and live workshops. We draw on elements from serious gaming and landscape visualization to focus on multi-media storytelling since audio, visuals and narratives are all ways in which information can be rendered experientially powerful (Marx et al. 2007).

There are two basic elements to this method, reflecting the benefits of experiential communication discussed in section 5.1:

1. Creating multi-media animations capturing scenario storylines through visuals, sounds

and vocal narrative.

2. Participants creating location-based storyline fragments that reflect their perspectives in the storyline in a concrete, imaginable experiential mode.

Capturing the dynamics of social-ecological systems in a visual scenario storyline is a challenging task for most existing experiential communication strategies (chapter 2 of this thesis): many dimensions of both natural and human systems are not clearly recognizable in the biophysical space. To meet this challenge, we chose drawn multi-media animations. In this medium, we can capture the full richness of visual language to represent biophysical change together with anything from social interactions to metaphors, while integrating multiple scales, all in an intuitive, experiential mode. See figure 5.3 for an example of this ability to mix content.

Responding to each animation representing a time step in the storyline, participants create individual storyline fragments from their local perspectives selecting the geographical locations from which their perspective is told. In this process, the audiovisual content together with the facilitation of personal contributions aim at creating a vivid, engaging interaction.

Essential to this approach is that the local perspectives are individual rather than based on group consensus. This allows for an individual relation to the storyline and creates a diversity of perspectives to be expressed undiluted and in very specific, varying contexts. In that way, the Scenario Communities process retains the richness of a range of individual perspectives, making sure every voice is available for a subsequent group scenario development as well as remaining accessible to other audiences.

5.4 Workshop preparation and setup

As a scenario context for the regional storylines, we introduced the Millennium Ecosystem Assessment scenarios (Millennium Ecosystems Assessment 2005), because this scenario set aims to fully integrate complex systems thinking on social-ecological systems into the storylines. Scenarios were developed in discussions with a panel of 12 of Oxfordshire sustainable development experts. We set up three different time periods: 2009-2019, 2019-2029 and 2029-2039. Scenario animations were visualized by an artist and developed using Adobe Flash (Adobe Systems Inc. 2008). Voice-overs were provided by a professional. Music was added to set the atmosphere of each animated time period.

We explored the combined use of the System Perspectives Scope and Scenario Communities methods in two contrasting configurations. In the first workshop, organized with Sustainable Woodstock, we started with the System Perspectives Scope, and followed up with the Scenario Communities exercise. For the sake of brevity, we will refer to this workshop as *analytic first*. Conversely, in the second workshop, organized with the Oxfordshire Rural Community Council, we started with the Scenario Communities storyline and then introduced the System Perspectives Scope. This workshop will be referred to as *experiential* *first.* The workshop with Sustainable Woodstock consisted of 10 participants; the workshop with the ORCC consisted of 11 participants.

5.5 Measurements and analysis

We used two types of data to evaluate the tools and their interactions: content created using the tools; and results from questionnaires -participants' open comments and Likert scale questions (Likert 1932). For the Likert scale questions, we used the Wilcoxon signed rank test (Lowry 1999) to determine the significance of differences.

System Perspectives Scope

Explication of personal perspectives: for the Scale Perspectives Chart, we examined the range of spatial and temporal levels relevant to an individual issue, and the spectrum of issues and their dimensions found in the workshop group. For the Myths of Nature Test, we reviewed participants' choices and any elaborations on their part about the chosen myth in

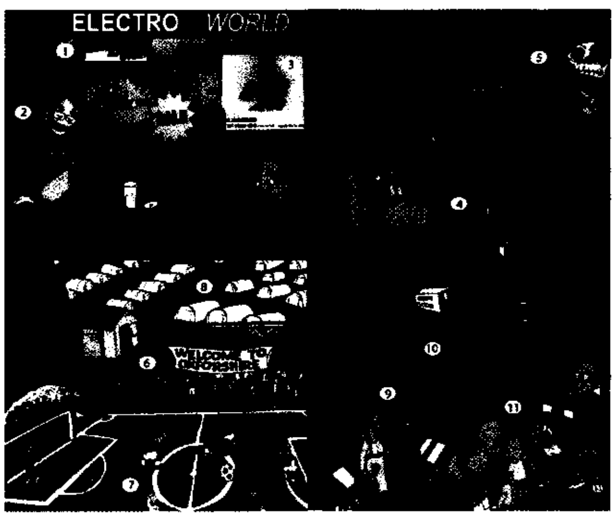


Figure 5.3: Some examples of the integration of social-ecological dynamics in the storyline animations. Additional information in the animations is provided by a voice-over. 1. Strife between local and national interests. 2. Failure of large corporations. 3. Effects of climate change on a national level. 4. Dynamic change in communities. 5. Changing functions of urban areas. 6. Social integration and xenophobia. 7. Social institutions go local. 8. Mass migrations. 9. Local feedbacks: local produce. 10. Agricultural innovations. 11. Education about agro-ecological systems.

the designated open comments box.

Reflection on mental models: to evaluate whether participants were able to reflect on their mental models using the System Perspectives Scope, we analysed first-person reports of the experience of the exercise, written down by participants at the end of the workshops. These were responses to an open question: participants were asked to describe their experience of the exercise. In our analysis, we coded these reports for positive and negative comments with regard to whether the exercise stimulated reflection on system dynamics and dimensions.

ScenarioCommunities

Creation of new experiential representations of social-ecological change: following van Vliet et al. (submitted), we evaluated whether the scenario exercise had prompted participants to create new scenario content. We coded the personal scenario content on the following characteristics:

- The length of the contributions
- The total number of concepts in each contribution
- The amount of concepts reflecting those present in the provided storyline
- The total number of new concepts

To evaluate whether concepts from social-ecological systems theory were represented experientially in participants' individual storylines, we scored each personal scenario text according to the presence of a basic social-ecological system characteristic in the text (chapter 2 of this thesis):

- One (1 point) or more (2 points) non-local spatial levels
- Cross-level dynamics (1 point)
- System developments over time (1 point)
- Non-linear system dynamics (e.g. resilience dynamics, system transformation, sudden events breaking continuity) (1 point)

Vividness and engagement: we used a number of questions on a 7 point Likert scale (-3 = very low, 0 = neutral, +3 = very high, as pertaining to the question):

1. whether or not participants found the scenario storyline engaging
2. the influence of the multi-media format on their engagement
3. influence of the contribution of a personal storyline on their engagement

We asked these three questions again for participants' experience of the vividness of the storyline. These two wordings provide a different emphasis: engagement puts more focus on the interaction, while vividness is more a perceived quality of the principal material itself.

We also collected open comments by participants by asking them to describe their experience of the Scenario Communities exercise. In our analysis, we coded comments in these reports for positive or negative with regard to whether the exercise was vivid and/or engaging.

Evaluating interactions between exercises

We evaluated whether the benefits of each tool also affected the use of the other tool. Using a 7 point Likert scale, we asked the participants in the analytic first workshop whether the System Perspectives Scope altered the clarity of the subsequent Scenario Communities exercise. Conversely, in the experiential first workshop, we asked whether the Scenario Communities exercise altered the engagement with the content in the System Perspectives Scope.

To evaluate the connectedness between the content of both tools, we calculated which percentage of the personal scenarios was linked to the content of the Scale Perspectives Chart, depending on the sequence of tools used per workshop.

We asked a 9-point Likert scale question about the spent mental effort directly after each exercise, a standard measure for cognitive load (Sweller et al. 1998). These questions allowed us to judge the cognitive load experienced during individual exercises, and thereby examine whether differences in exercise order influenced cognitive load.

5.6 Results

Because of our interest in the interactions between the analytic and experiential communication tools, we present the results from the two workshops separately and side by side for comparison.

The System Perspectives Scope

Explication of perspectives on social-ecological systems

The results of the Scale Perspectives tool are presented in figures 5.4 and 5.5. The arrows show the spectrum of spatial and temporal levels covered on average per individual for each workshop. The arrows demonstrate that stakeholders in both workshops dimensionalized their selected issues across multiple spatial levels and time frames. However, the arrows also show that in the *analytic first* workshop, participants focused more on European to global and long-term dimensions of their issues, while in the *experiential first* workshop, there was more of a focus on the local to national spatial levels and a slightly shorter term.

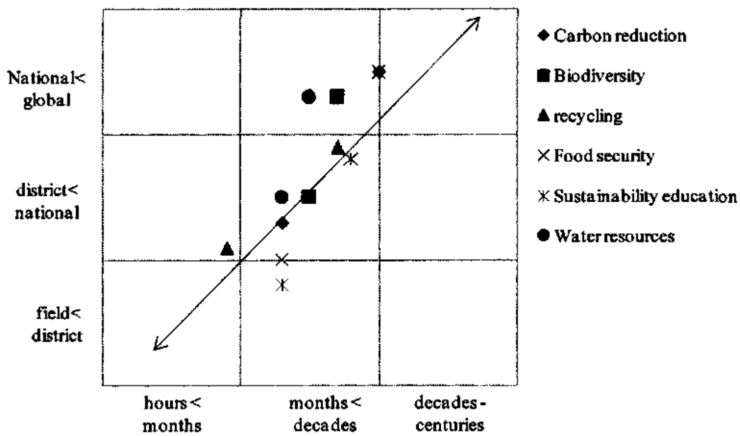


Figure 5.4: Overview of Scale Perspectives Chart entries in the analytic first workshop. The arrow shows the average spectrum of levels covered per individual, the markers show the top 6 issues. The marker with the lowest spatial and temporal levels for each issue represents an average of the lowest levels at which a participant dimensionalized each single entry, while the markers at the highest spatial and temporal levels represent the highest levels per entry.

The markers represent the average dimensions of the top issues in the Scale Perspectives Chart from each workshop. For each issue, there is a point that represents its occurrence on the shortest time frame and smallest spatial level, and a point representing the entry of that issue on the longest time frame and largest spatial level. The top 5 issues in the analytic first workshop (with a tied fifth place for sustainability education and water resources) represent 70% of the contributions in the System Perspectives Scope for that workshop; the top 5 issues from the experiential first workshop represent 58% of the contributions made there.

Partly, similar issues such as food provision/security and carbon reduction/renewable energy came up, but the other issues were different. In the analytic first workshop, sustainability education, food security and recycling were seen as issues that should be tackled on the district to national levels, while carbon reduction, food security, biodiversity and the management of water resources were characterized as requiring policies that interaction between the local and international levels.

In the experiential first workshop, community development was seen as a local, long-term goal, while food provision and housing were more short-term local concerns. In contrast, transport and renewable energy policies should interact across levels from the local to the national on a short to middle term. Overall, both plots show a high degree of linkages across spatial levels and time frames in the participants' issues, even when looking at the averages.

Table 5.1 shows the outcomes of the Myths of Nature test. These results show that in both groups the 'nature resilient' myth was dominant. Other myths were rarely chosen 'nature benign' and 'nature capricious' are therefore not present in this table as principal myths. However, other myths were used to elaborate on the 'nature resilient' myth and provide a more complex picture. In both workshops, a transition was perceived by participants from a state of relative resilience in global environmental systems to a state of 'nature fragile' and nearness to a global tipping point. In the experiential first workshop, the myths of nature were used by participants to present the perspective that while on the long term, the global environmental system is essentially changing, malleable and dynamic, knowing no equilibrium, on the short term, systems resilience and tipping points are indeed relevant. In terms of differences between workshops, though the 'nature resilient' myth was dominant in both groups, more participants in the experiential first workshop provided nuance and elaboration.

Facilitating participants' reflections on their analytical models

Table 5.2 shows a summary of participants' comments when asked to describe their experiences with the exercise. Positive comments indicating a reflective process include words

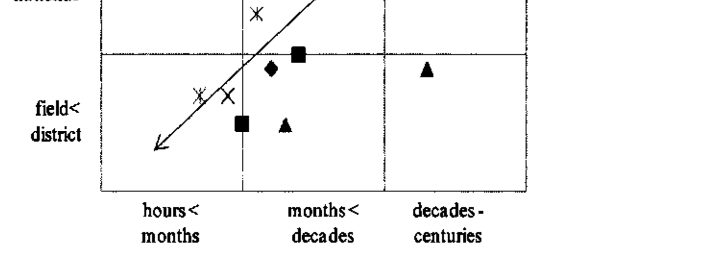


Figure 5.5: Overview of Scale Perspectives Chart entries in the analytic first workshop. The arrow shows the average spectrum of levels covered per individual, the markers show the top 6 issues. The marker with the lowest spatial and temporal levels for each issue represents an average of the lowest levels at which a participant dimensionalized each single entry, while the markers at the highest spatial and temporal levels represent the highest levels per entry.

like 'realization', 'enlightening', 'encouraged holistic/system-wide considerations' and 'encourages to think about own responses' The limited amount of time for the exercise was a criticism in both workshops, though this point was emphasized more in the analytic first workshop. There was no difference between the number of positive comments.

Scenario Communities

Creation of new experiential representations of social-ecological change

The following text is an example of the individual scenario contributions by a participant from the experiential first workshop. Its length is average for the contributions in that workshop. This contribution is based around 13 concepts (marked by c) and is characterized by references to other spatial levels (s), cross-level dynamics (x), temporal change (t) and non-linear system dynamics (n).

'*2019: Local is something I can visualize and recognize, it feels comfortable. This seems to mean growing our own food, making, repairing, choosing better products*^{c} *rather than quickly replacing/disposing them. ORCC will be supporting networks*^{c}, *promotion*^{c}, *co-operatives*^{c}, *local services*^{c}, *distribution of information*^{c}. *From a global perspective*^{sx}, *this way of life seems very isolated and narrow, it's winding the clock backs. We would still have to exchange ideas and trade. This scenario would mean scaling down the choice of goods*^{c}.'

'*2029: This sounds like historical times desolation and then the birth of new ideas, like the post-war period changing into the 60's*^{nt}. *Personally I don't know, we would need to be good neighbours*^{c}, *work together for shelter, sharing, survival and protection*^{c}. *We cannot stay cut oft*^{ct}. *The ORCC could liaise and work with other Rural Community Councils to keep wider perspectives*^{cxs}, *and spread news and good practice*^{c}. *Globally, there would be a need for travel networks*^{cs}.'

'*2039: This sounds wonderful, a 'real' way of life, the appreciation of resources and stability*^{t}. *We should aim to keep a rein on the scale of development*^{c}. *I don't know about the role of the ORCC in terms of a global perspectives*^{x}.'

Table 5.1: Myths of Nature.

	Analytic first	Experiential first
Nature resilient	81%	40%
Nature fragile	9%	10%
Nature resilient changing to nature fragile	9%	30%
Nature resilient on the short term, malleable on the long term	0%	20%

Table 5.2: Myths of Nature.

Analytic first	*Experiential first*
Positive: 7	**Positive: 7**
Enlightening (1),	Thought provoking (1),
Well done (1),	Stimulating (1),
Useful (1),	Stimulating (1),
Thought provoking (1),	encouraged holistic/ system-wide considerations (1),
encourages to think about own responses (1)	very interesting (1),
Interesting (2),	clarifies individual thoughts (1),
	Realisation (1)
criticism: 3	**criticism: 1**
Difficult to choose only five (1),	Not enough time (1)
needs more time (2)	

Table 5.3 shows the size of the personal scenario contributions and the average number of concepts per contribution in the workshop. This table also shows how much of these concepts reflect the content of the animated storyline, and how many of these concepts are new contributions or original elaborations.

The lengths of the contributions in the experiential first workshop average more than twice as long as those in the workshop where it was used last. In the analytic first workshop, most contributions reflect the animated storyline, while in the experiential first workshop, most contributions are new concepts.

Table 5.4 shows how much of these concepts were representations of social-ecological system dynamics in the experiential communication mode.

Overall, spatial levels, cross-level dynamics, temporal dynamics and non-linear dynamics are present in the personal scenarios of both workshops. The largest difference between workshops can be found in the fact that a far larger percentage of the participants in the experiential first workshop, 80 percent as opposed to 30 percent in the other workshop, discussed more than one non-local spatial scale.

Vividness and engagement

Table 5.5 shows the means and standard deviations for each question related to vividness and engagement of the Scenario Communities tool, on a 7-point Likert scale, divided by the two workshops. Participants in the analytic first workshop were divided about the engagement and vividness of the storylines and about the effect of the multi-media aspects and the construction of their individual storylines. In contrast, participants in the experiential first workshop almost uniformly viewed the storyline as vivid and engaging, and a significant effect is found of the multi-media presentation and the writing of individual storylines on both vividness and engagement.

Table 5.6 shows the open comments made about the Scenario Communities tool. Participants' reports of their general experience of the experiential first workshop are much more numerous and positive about the Scenario Communities tool. These comments are coherent with judgements of the engagement and vividness in the questionnaire in this workshop. In the analytic first workshop, negative comments about the lack of time for this section predominate.

Effects of exercise orders

Table 5.7 shows the outputs of questions regarding the interactions between the benefits of both tools. In the analytic first workshop, the System Perspectives Scope was seen as having some influence in terms of clarity on the Scenario Communities storyline, but this effect was ultimately not significant. Conversely, in the experiential first workshop, both the Scenario Communities storyline and the writing of individual contributions had an effect of significantly increasing engagement with the System Perspectives Scope.

Table 5.8 shows the links between the content in the Scale Perspectives Chart and the

Table 5.3: Average word counts and numbers of concepts in individual scenario storylines and in the overall groups.

	word count	total concepts	concepts from animated scenario	new concepts
ScenarioCommunities last				
mean	72	9	6.3	2.7
st.dev.	24.1	4.5	2.7	1.9
Group totals (n=11)	812	99	69.3	29.7
ScenarioCommunities first				
mean	199.8	20.2	4.8	15.4
st.dev.	98.6	8.2	4.1	8.2
Group totals (n=10)	1991	202	48	154

Table 5.4: Percentages of personal contributions per workshop that contain story elements reflecting social-ecological systems concepts.

	Analytic first	*Experiential first*
One non-local spatial level	80%	90%
Multiple spatial levels	30%	80%
Cross-level dynamics	60%	70%
Temporal dynamics	100%	100%
Non-linear dynamics	80%	70%

content of the personal scenarios. In the analytic first workshop, the overlap between the concepts in the Scale Perspectives Chart and the personal scenarios is almost twice as large as in the experiential first workshop.

Table 5.9 shows the cognitive load measurements of each test. These results indicate that for both tools in both workshops, there was an active interaction with the tools, but that the exercises were not too challenging to perform. There is no significant difference between the scores of the same tool in each workshop.

5.7 Discussion

We will begin by discussing each individual tool based on our research questions and then discuss the interactions between the exercises. Based on this analysis, we will discuss the complementary value of experiential and analytic communication and offer recommendations for environmental change communication.

Analytic communication: System Perspectives Scope

Does the System Perspectives Scope explicate personal perspectives on social-ecological systems?

In the Scale Perspectives Chart, the participants were allowed more freedom to describe spatial and temporal levels for their focus issues than was previously available in an online version (see chapter 3). Instead of being asked to pinpoint a key level per issue, they could provide multiple interacting levels to describe each issue. And in fact, all participants used this freedom to describe each of their issues, resulting in a rich image of interacting system levels from the perspective of each participant. The experiential first workshop showed more of a focus on the local/regional/national spatial levels than the analytic first workshop. Since the scenario story sections in the Scenario Communities exercise were focused locally, this

Table 5.5: Questionnaire results on the Scenario Communities method for both workshops, and the differences between workshops, on a 7 point (+3 to -3) Likert scale. The cells in bold represent significant effects and differences.

	Analytic first (n=10) mean	st.dev	Experiential first (n=11) mean	st.dev	Difference between workshops (Z)
Did you think the scenario storyline was vivid or not vivid?	0	1.4	1.4	0.7	1.6 (p>0.05)
Did the multi-media presentation make the scenario storyline less or more vivid?	-0.1 (p>0.05)	1.6	**2.4 (p<0.01)**	1.5	**2.0(p<0.05)**
Did writing your own contribution make the scenario storyline less or more vivid?	0.7 (p>0.05)	0.4	**1.5 (p<0.01)**	0.8	1.8 (p>0.05)
Did you think the scenario storyline was engaging or not engaging?	0.4	1.5	1.8	0.2	**1.4 (p<0.01)**
Did the multi-media presentation of the story make the scenario story-line less or more engaging?	0.3 (p>0.05)	1.2	**1.8 (p<0.01)**	1.2	**2.1 (p<0.05)**
Did writing your own contribution make the scenario storyline less or more engaging?	1 (p>0.05)	0	**2.1 (p<0.01)**	0.7	**1.9 (p<0.05)**

order of exercises could have prompted participants to explore the parts of their perspectives that were more local and experientially embedded.

In our previous work with the System Perspectives Scope, we found significant link between the chosen myths of nature and the spatial as well as the temporal dimensions of individual perspectives (chapter 3 of this thesis). In this study, however, the choice of 'nature resilient' was so dominant that significant relationships between myths of nature and chosen system levels could not be established. However, the comments on and elaborations on the myths of nature do indicate a need to apply the myths differently to different systems and system levels that could be explored further.

A drawback of the System Perspectives Scopes becomes clear when we compare the tool to analytic communication tools such as conceptual and semi-quantitative participatory models (Sendzimir 2007; Kok 2009). In the System Perspectives Scope, each element provides an explicit perspective on a characteristic of social-ecological systems: dimensions and cross-level links, and general system behaviour. This information is clear, quickly produced and accessible, but it does not allow for a more extensive exploration of how system elements interact. Participatory models go further in specifying these relationships and constructing a coherent whole. On the other hand, participatory models generally do not focus explicitly on interactions across system levels, nor do they directly explicate general perspectives of system dynamics. To overcome the limits of either method, the Scale Perspectives Chart could be combined with semi-quantitative values to explore not just which relationships exist between system levels, but to model the dynamics of those relationships. Similarly, the Myths of Nature could be used to test semi-quantitative models under different assumptions of system behaviour.

Does the System Perspectives Scope stimulate participants to reflect on their own mental models?

In the open comments, participants in both workshops attested to having been motivated to reflect on system levels and dynamics. Participants used wording specifically indicative of reflection on system dynamics and dimensions. In both workshops, a discussion on the Scale Perspectives Chart evolved from specific subjects to the question of scaling governance and

Table 5.6: Positive keywords and criticisms in the comments on the experience of the ScenarioCommunities exercise in both workshops.

Analytic first	*Experiential first*
Positive: 3 Engaging (1), Thought provoking (1), Okay(1)	**Positive: 15** Interesting (4), challenging (2), thought provoking (7), alarming (1), animation helped frame thinking - much more visual! (1)
negative: 5	**negative: 2**
Not enough time (4), storyline unconvincing (1)	Too much focus on the local (1), more group work needed (1)

Table 5.7: Questionnaire results on the translation of benefits, on a on a 7 point (+3 to -3) Likert scale.

	Mean	st.dev.
SPS: clarity effect on multi-media storyline	0.5 (p=0.10)	0.9
SPS: clarity effect on personal scenario	0.7 (p=0.08)	0.7
Multi-media storyline: engagement effect on the SPS	**0.8 (p=0.04)**	1
Personal scenario: engagement effect on the SPS	**1.5 (p=0.01)**	0.8

community action. The benefits and drawbacks of bottom-up and top-down forces of change were discussed, as were the challenges of exporting local success stories to the regional level and above.

Participants characterized the reflection on myths of nature in the comments and during the workshop as an 'eye-opener'. In the discussions, the Myths of Nature exercise pointed to the challenges of communicating between perspectives, which was both recognizable and enlightening to both groups. It made their sense of this communication gap explicit. In terms of workshop order, no major differences were found. An overall criticism on the power of the System Perspectives Scope to allow for reflection on systems is that the two elements of the tool have to be connected better. This is especially relevant since our previous use of this tool shows promising relationships between their results (chapter 3 of this thesis). To deal with this issue, we discussed the relationships between scale and myths of nature after the tools were used in the workshops.

The complementary benefits and drawbacks of the System Perspectives Scope and participatory model building concern the participatory process as well the first is more accessible and allows for quick system overviews that focus explicitly on scales and system dynamics, while the latter allow for an exploration of specific system behaviour. Again, a mix of the two methods could be synergetic.

Table 5.8: Percentage of personal scenario concepts reflecting or reflected by the content in the Scale Perspectives Chart.

Experiential first workshop:	
% of personal scenario concepts subsequently found in Scale Perspectives Chart	13.6%
Analytic first workshop:	
% of personal scenario concepts previously found in Scale Perspectives Chart	24.9%

Table 5.9: Cognitive load results for both tools in both workshops, on a 7 point (+3 to -3) Likert scale.

	Mean	st.dev		Mean	st.dev	Difference(Z)
Cognitive load: System Perspectives Scope (first)	0.7	0.9	Cognitive load: System Perspectives Scope (last)	1.1	0.5	0.8 (p=0.41)
Cognitive load: ScenarioCommunities (last)	1	1.4	Cognitive load: ScenarioCommunities (first)	1.2	0.1	0.3 (p=0.79)

Experiential communication: Scenario Communities

Does the Scenario Communities tool facilitate the creation of new experiential content containing complexity?

There is a marked difference between the outputs from the Scenario Communities tool in both workshops. Participants' personal scenarios in the experiential first workshop were longer than those from the analytic first workshop. They also contained more new concepts that were not derived from the multi-media storyline. Clues for the reason of this difference can be found in the 'engagement and vividness' indicators, as well as in the measures for interactions between the tools, which will be discussed in the next sections.

Van Vliet et al. (submitted) compare group creativity in a number of workshop methods such as collages and conceptual modelling. Storyline lengths and numbers of new concepts are used as a measure for creativity. In that study, the longest group storyline, based on a two-day workshop with four different scenario development tools, is about 400 words. In the experiential first workshop, the overall collection of storylines is 1991 words for that workshop. Even in the analytic first workshop that seemingly suffered from an interaction effect between the tools, the collection of storylines is 812 words. The same is true for the number of new concepts. In the study by van Vliet et al., the highest number was 12.1 new concepts in a group storyline. Our idea of concepts aligns closely with that of issues in van Vliet et al. (submitted). In the experiential first workshop, 156 new concepts were introduced in total, while even in the analytic first workshop, the new concepts totalled 30.

However, participatory scenario development methods such as those evaluated by van Vliet (submitted) are not primarily concerned with capturing diversity. Instead, these methods are focused on collaboration and consensus. Conversely, a clear drawback of the Scenario Communities tool is that it does not focus on the building of a group storyline, and therefore lacks the benefits of integrating and mixing perspectives. To capture both diversity and the integration of perspectives, both individual storylines and group storylines could be constructed.

The coding of individual story elements representing social-ecological systems change shows that in both workshops, participants included multiple levels, cross-level dynamics, temporal change and non-linear system behaviour. The majority of concepts in the analytic first workshop were reflections of those from the multi-media story sections. It can be assumed that the social-ecological system dynamics in these storylines are also reflections of the original multi-media stories. Conversely, in the experiential first workshop, a number of concepts from the multi-media story sections were reflected in participants' storylines, but a higher number of concepts were new. Combined with the high percentages of system dynamics present in these storylines, we conclude that participants contributed their own perspectives on social-ecological systems change.

We did not test the engagement and vividness of the participants' individual scenarios. In landscape visualization, new tools allow for live collaborative landscape design (Stock et al. 2008). They have the advantage in providing participants with visual tools to express their perspectives, and so surpass the simple textual responses of Scenario Communities in terms of attractiveness and concreteness. However, Scenario Communities allows participants to contribute much more original content. Likewise, serious games allow for user comments and choices (Susi et al. 2007). But these interactions are much more structured, and do not allow for a full spectrum of social-ecological dynamics to be expressed. The challenge is to reconcile the freedom of expression in textual storylines with the communicative power available through visual formats. Games such as From Dust (Ubisoft unpublished) and Spore (Electronic Arts 2008) are beginning to provide the technologies to overcome this gap and have users create fully dynamic worlds of their own design.

Is the interaction with the Scenario Communities tool characterized as an engaging and vivid experience by the participants?

The measures for the vividness and engagement of Scenario Communities show a significant difference between both workshops. Participants in the experiential first workshop were uniformly positive with regard to the overall vividness and engagement of the scenario storyline. Participants also indicated significant positive effects of the multi-media component on both vividness and engagement. These results confirm that the multi-media visualization of the scenario fragments was not only able to convey experiential representations of system dynamics, but also able to bank on the benefits for engagement and vividness that are part of the potential of experiential communication. Finally, the creation of individual storylines was itself judged to have contributed significantly to the engagement and vividness of the scenario material. These valuations were also reflected in the general comments.

In the analytic first workshop, on the other hand, opinions were divided. Some participants held the same opinions as those in the opposite workshop, including positive evaluations of the effect of the multi-media element and the opportunity to create personal scenario storylines. In fact, this element of personal contribution is the only variable that scored a mildly positive score for both vividness and engagement, despite the dividedness of participants. The relative lack of general comments may be seen as reflecting a lack of engagement as well. As these comments show, a lack of time was seen as a problem in this workshop, but since the time difference between workshops amounted to 15 minutes on two hours, could there be other reasons for this difference in evaluation? For this, we go to the discussion on interactions between our experiential and analytic tools.

Experiential and analytic communication: interactions

As discussed in section 5.1, experiential and analytical communication compete for prominence in human processing, and experiential processing is often the first and dominant processing mode in situations that allow for both modes (Tversky and Kahneman 1974). This concept provides a basis for the following research question:

How are these benefits affected by different sequences of both tools?

Participants in the analytic first workshop produced shorter personal storylines, and these storylines included less new concepts and fewer descriptions of other spatial levels. A number of variables can conceivably have played a role in this difference - open comments indicate that the slightly shorter time allotted for the workshop has been a contributing issue. Also, there was an age difference of 11 years on average between the groups that might have influenced attitudes toward multi-media technology. Still, the significant differences between vividness and engagement ratings in the questionnaires between the workshops suggest another reason. We hypothesize that the tendency for experiential communication to be more engaging and vivid created an impetus for participants in the experiential first workshop to create elaborate storylines that contained many new concepts in vivid experiential settings. This engagement created momentum and inspiration for the participants to engage with the subsequent System Perspectives Scope. This hypothesis is supported by participants' answers in the questionnaire that confirm the increased engagement with the System Perspectives Scope created by Scenario Communities. Conversely, the System Perspectives Scope, while considered thought-provoking and resulting in in-depth analytic discussions, did not feature the same quality of experiential engagement and vividness, and was therefore unable to bring these qualities to the subsequent exercise for some participants. From a psychological perspective, it could be surmised that this difference between workshops is a practical consequence of the fact that experiential processing often takes precedence in mental processing, and that therefore, a transition from experiential to analytic processing is more intuitive, while a transition from analytic processing to experiential processing is counter-intuitive (Kolb and Fry 1975; De Neys and Glumicic 2008).

Complementary benefits

The results from the experiential first workshop are strongly indicative of the potential of combining experiential and analytic communication in participatory scenario development. Participants were engaged with the multi-media scenarios and motivated to create their own storylines that were fleshed out and rich in ideas. Building on that engagement, the System Perspectives Scope allowed participants to capture their perspectives on system dimensions and dynamics. Through this analytic communication tool, participants were able to translate their ideas and engagement to a system description that made challenges and opportunities for action clear. In the following group discussion, strategies and plans were made to create a more system-conscious perspective, for instance by actively forging cross-level policy links.

The analytic first workshop presents a contrasting result, indicating that the sequence from analytic to experiential communication tool is counter productive. Nevertheless, even with this handicap the participants in this workshop also moved to strategic thinking on the basis of the analytic communication exercise, and subsequent contributions in the Scenario Communities exercise do reflect the multi-media storylines including experiential representations of social-ecological change concepts.

On a whole, both tools proved promising in their ability to harness the benefits of combining analytic and experiential communication modes. We discussed criticisms of the individual methods in previous sections. Criticisms on the combination mainly concern the lack of conscious translation between the content of both tools. This choice was made to allow us to study interactions between tools without coercion, but we hypothesize that encouraging the translation of content is beneficial for the entire process. The relatively limited time available for the overall workshops can have distorted the effectiveness of the combination as well. Still, we believe that both the results documenting participants' experience as well as the tools' products advocate the value of combining analytic and experiential communication for participatory explorations of the future. The combination provides both the analytical 'bones' perspectives on system characteristics- and the experiential flesh -concrete, vivid scenarios- for the exchange of insights on social-ecological dynamics.

5.8 Conclusions and recommendations

This study explored the position that the experiential and analytical processing modes are vital, complementary ways for participatory scenario development to create both systems understanding and engagement with future uncertainties. We used two complementary tools, each focusing on one mental processing mode, in two workshops in a practical case study. The following are our conclusions (a) and related recommendations (b):

- 1a: The System Perspectives Scope, an analytic communication tool, was able to produce participants' perspectives on social-ecological systems in a way that focused explicitly on system dimensions and dynamics. Participants reported that the tool allowed them to reflect on the systems they described.

- 1b: To allow for more in-depth and analysis of system behaviours, the System Perspectives Scope elements should be combined with semi-quantitative participatory modelling.

- 2a: Scenario Communities, an experiential communication tool, helped create individual scenarios that amounted to a larger quantity of information based more ideas compared to group storyline building. These personal scenarios also contained experiential representations of social-ecological system dynamics

- 2b: We recommend that the next steps should focus on combining benefits of diversity and integration of perspectives, as well as providing participants with the means to present their own perspectives using multi-media.
- 3a: This study has given an indication that confirms the psychological perspective that experiential communication coming before analytic communication is more intuitive.
- 3b: We therefore recommend that participatory process designers start with an interactive, experiential exchange to generate engagement and the creation of vivid perspectives, and then transition to an analytical mode to explore system dynamics and dimensions. We would also propose research that explores iterative alterations and integrations of the two communication modes.
- 4a: Despite the prototypic nature of the tools used, this study has shown that analytic and experiential communication in participatory scenario development can indeed be used to generate both understanding of and engagement with social-ecological system dynamics in the context of future challenges and uncertainties.
- 4b: Our overall recommendation is for environmental science communicators to become more conscious of the role of analytic and experiential processing modes, not just in their own communications, but in the ways they help other societal perspectives to express their views.

Chapter 6

A sense of change: media designers and artists communicating about complexity in social-ecological systems

Beyond the walls of intelligence, life is defined.

-Nas, NY State of Mind, 1994

Chapter is based on:

J.M. Vervoort, D. H. Keuskamp, K.Kok, R. van Lammeren, T. Stolk, A. Veldkamp, J. Rekveld, R. Schelfhout, B.Teklenburg, A. Borges, S. Jnokva, W.Wits, N. Assmann, E. Abdi, K. Cunningham, B.Nordeman. *A sense of change: media designers and artists communicating about complexity in social-ecological systems.* To be submitted to Ecology and Society.

Abstract In order to take on the current and future challenges of global environmental change, fostering a widespread societal understanding of and engagement with the complex dynamics that characterize interacting human and natural systems is essential. Current science communication methods struggle with the challenges associated with communicating about complex systems. This study reports on a series of workshops that aimed to harness the insights of interactive media designers and artists to overcome these challenges. The workshops resulted in new interactive media concepts by 86 participants, 12 of which were selected by the workshop participants and the interdisciplinary workshop team using a set of criteria specific to the communication challenges discussed in this chapter. These 12 concepts were then evaluated using the same criteria by a panel of communication and design experts and a panel of complex systems scientists using the same criteria, and the best 8 concepts are discussed in this chapter. These concepts fell into the categories of serious games, group interaction concepts and social media storytelling. The serious games focused directly on complex systems characteristics and were evaluated to be intuitive and engaging designs that combined transparency and complexity well. The group interaction concepts focused mostly on feedbacks and non-linearity but were fully developed and tested in the workshops, and evaluated as engaging, accessible and easy to implement in workshops and educational settings. The social media storytelling concepts involved less direct interactions with system dynamics - but were seen as highly accessible to large scale audiences. The workshops in this study show the potential of interdisciplinary collaboration between complex systems scientists, designers and artists. The results and process discussed in this chapter point to the need for more structural engagement of interactive media designers and artist communities in the development of communication tools about human and natural systems change.

6.1 Introduction

Accelerating, interconnected changes in all spheres of life on earth - environmental, cultural, technological, economic, and political- have led to a world facing deep and unprecedented complexity and uncertainty (Gallopin 2002).The consequences of ignorance of this reality and the lack of willingness and ability to deal with the challenges of global change are far-reaching environmental degradation and growing threats to human well-being (Millennium Ecosystems Assessment 2005).

New scientific paradigms identified under the umbrella of 'complex systems science' have been developed to gain a more comprehensive understanding of the structures and dynamics of human and natural systems (Levin 1999). Complex systems science recognizes that traditional mono-disciplinary knowledge development fails to generate the types of understanding needed to govern the interactions of these systems (Holling and Gunderson 2002). Instead, social and environmental systems should be understood as interconnected 'social-ecological systems' (Folke 2006).

Complex systems science has proven to be an effective way to organize and clarify information on systems across scales and disciplines (Jacobson and Wilensky 2006; van Bilsen et al. 2010). However, research in education science has shown that many of the basic principles at work in complex systems are counter-intuitive. For non-experts, a radical shift in perspective is required for the development of complex systems thinking (Jacobson and Wilensky 2006). Furthermore, developing a shared understanding is not enough to create the impetus for change in the face of future challenges. Actors across the societal spectrum must be engaged with global environmental change and willing to take concerted action(Sheppard 2005).

The challenge of communicating about complexity in social-ecological systems is exacerbated by the influence of dominant societal images, mental models and discourses about environmental governance and sustainable development. Images, mental models and discourses are all perspectives on the ways in which reality is framed and simplified by individuals, groups and societies (Barrouillet et al. 2000; Beers et al. 2010; Hermans et al. 2010). The complexity of social-ecological systems change can be obscured by simple and biased framing. The limited possibilities in the traditional media to create communication with any depth further constrains the space for creating societal understanding of and engagement with change dynamics in complex social-ecological systems.

Interactive media offer ways to overcome the limitations of societal communications on social-ecological change, showing potential for the facilitation of analytic understanding of complex systems (Andrienko and Andrienko 2007; Thomas and Cook 2007) as well as for the generation of affective engagement (Al-Kodmany 2002; Sheppard 2005; Freeman 2010). These new media also offer ways to make communication about social-ecological complexity more accessible (Gooding 2008). However, current science communication tools and methods meet with a number of challenges when aiming to communicate about social-ecological complexity.

Our purpose for the research in this chapter is to step outside the science communication niche and harness the potential of a wider field of interactive media for communication on complexity in social-ecological systems. To this end, we have organized collaborative workshops where we brought together complex systems researchers and interactive media designers and artists to develop concepts for communication. This linking of complementary disciplines has the potential to be strongly synergistic, building on a wide range of communication methods and perspectives from interactive media design and art while also building directly on insights into social-ecological systems complexity. These new forms of communication can help generate new images, mental models and forms of discourse that are more conducive to understanding and engagement with regard to environmental governance.

The challenges of communicating about social-ecological systems change

Communication about the nature of social-ecological systems change brings up a number of challenges from the perspective of complex systems science. We will refer to these as the 'complexity challenges':

- People with no special background in complex systems thinking generally do not appear to consider *feedbacks*, *non-linear dynamics* and *interacting processes* at multiple scales (Dorner 1996; Wilensky and Resnick 1999; Sweeney and Sterman 2007).
- Feedbacks, non-linear dynamics and cross-scale interactions result in a deep *uncertainty* in complex systems that is difficult to grasp (van der Sluijs 2005).
- Insight into complex systems requires the opportunity to both express and experience different *perspectives* in those systems, a possibility that is underdeveloped in current communication tools (Gibbons et al. 1994).
- Communications about social-ecological systems change should aim to facilitate the development of *strategic knowledge* of how to operate in a complex, dynamic environment (Hmelo-Silver and Azevedo 2006). This type of experience is rarely aimed for in science communication (Bishop 2011).

A particular difficulty for science communication is that the above prerequisites for the understanding of systems change are at odds with basic design criteria from interaction design that are crucial for any effective communication (Resnick and Wilensky 1998; Mennin 2007; Ramirez and Ravetz 2011). We will refer to these as the 'design challenges':

- Most science communication tools fail to be *engaging* enough to draw in users and make them care about the content (Sheppard 2005; Scharmer 2007; Wilkinson and Eidinow 2008; Ramrez and Ravetz 2011).
- *Accessibility* is crucial for any communication tool or method. If it is not accessible, few people will be able to use it (chapter 2 of this thesis(Mennin 2007).

- Capturing the complexity of social-ecological systems can be at odds with cognitive *clarity* and transparency (Hmelo-Silver and Azevedo 2006).

- Communicating through *intuitive designs* crucial, even more so since complex systems are characterized as exhibiting counter-intuitive behaviors (Thomas and Cook 2007)

The collaborative workshops in this chapter provided many responses to the challenges listed above. Because the collaboration between complex systems scientists, interactive media designers and artists is largely uncharted territory with unmapped potential, we have deliberately not focused on the development of a single tool. Instead, we aimed to capture a wide range of perspectives on complexity communication, brought to life through a series of workshops that resulted in design concepts in different stages of development. Through an expert-based evaluation of these concepts, this chapter offers a panoramic set of design possibilities that will help take on the challenges of communicating about social-ecological systems change in very different ways.

6.2 Objectives

This chapter focuses on the following question:

- How can interactive media designers and artists help science communicators to create communication concepts that take on the challenges of communicating about social-ecological systems change?

In order to address this question, we use the following objectives:

- Evaluate the range of communication concepts resulting from the collaborative workshops on their ability to deal with communication challenges associated with social-ecological systems.

- Review the workshop process itself and draw conclusions on how collaborations between complex systems scientists and multi-media designers and artists can be set up effectively.

In section 6.3, we introduce the setup of our collaborative workshops, the participants, and the selection process that led to the concepts discussed in this chapter. Section 6.4 presents a general overview of the workshop results. Sections 6.4 and 6.4 introduce the final selection of concepts and their evaluation. In section 6.5, we discuss the workshops and their results, leading to conclusions and recommendations as presented in section 6.6.

6.3 Collaborative design workshops

In order to elicit insights on how to take on the challenges of communicating about social-ecological systems change from beyond the domains of science communication, we organized a series of collaborative workshops with multi-media design and art education institutes in the Netherlands.

Participants

We organized two workshops in different formats. The first was a combined course, taking six weeks, for MSc students of the Art Science program at the Royal Academy for Visual Arts, and students in the MSc program Media Technology at Leiden University. 29 students enrolled. This group was made up of students at the MSc level and consisted of a number of nationalities. Both the Art Science and Media Technology masters focus on a combination of arts, design and science. With Art Science, the scientific element serves as inspiration and the emphasis is on the artistic. Conversely, in the Media Technology master, the emphasis is on scientific research.

Another, single-session workshop taking one afternoon was organized at the Utrecht Arts Academy. 80 students attended that workshop a mixture of BSc and MSc students from a wide range of art, design and multi-media backgrounds.

Workshop organization

During both workshops, we gave an opening presentation that introduced complexity in social-ecological systems in a step-wise fashion, discussing complexity in biophysical systems and in human systems. Subsequently we introduced ways in which human and biophysical systems are fundamentally connected (Westley et al. 2002). Following this, we discussed the meaning of this complexity in terms of environmental management and governance and the individual positions of societal actors, considering the present world and the future. We presented the challenges in communicating about social-ecological systems change discussed in 1.1, but avoided examples of science communication.

We then set the following -deliberately open-ended- challenge for the students:

Create a design that allows for the communication of complexity in interconnected natural and human systems. Design your concept so it does not just convey analytic understanding but provides an experiential sense of this complexity and what it means.

Students were given 30 minutes to come up with a first concept. Then, all students were asked to discuss and evaluate their own concepts and those of others in one-on-one speed-dating sessions, using a 10-point rating system (0 = extremely bad to 10 = extremely good) reflecting how well their or others' concepts dealt with a number of criteria based on the design challenges from section 6.1. Because of the widely different characters of the design concepts, detailed comparisons would be nonsensical, so the following basic design criteria were used, inspired by interaction design research (Facebook 2004; Scharmer 2007; Wilkinson and Eidinow 2008; Wilkinson 2009; Wilkinson and Ramirez 2010):

1. The concept is accessible.
2. The concept has the power to engage users.
3. The concept conveys the right amount of information.
4. The concept is transparent while capturing complexity.
5. The concept is clear.
6. The concept is designed to be intuitive.

Criteria 3 to 5 were designed to provide different perspectives on the transfer of information.

The Art Science/Media Technology course was extended over the remaining weeks through 3 days of design work per week, an interim workshop to discuss students' progress, and a final symposium where students' ideas were presented.

Evaluation of concepts

The workshops resulted in a total of 86 concepts, in different stages of development the Art Science/Media Technology concepts were more developed because of the longer time allotted to them.

Most concepts were not in a sufficient state of development that they could be tested on users. Instead, we chose to ask two independent panels of experts, one panel of four multi-media and communication experts and one panel of four complex systems scientists, to judge a selection of concepts.

To limit the amount of time needed for these evaluations, the workshop team made a first selection of these concepts, bringing them down to the top 12 concepts best able to deal with the complexity as well as the design challenges. To avoid bias, we based this selection on the participants' self-evaluation and those of their fellow workshop participants, evaluating which concepts were judged to deal well with as much challenges as possible. The workshop team (consisting of researchers with backgrounds in complexity science, art and design) evaluated the concepts on their ability to deal with the 'complexity' challenges. Where comparisons were difficult to make (for instance, if average scores were the same but resulted from different perceived strengths and drawbacks) we used our own judgement.

The 12 concepts resulting from this first selection were evaluated by both the communication experts and complexity experts according to their perceived ability to deal with the 'design' challenges in 1.1. Additionally, the complexity experts were also asked to judge the concepts on their ability to communicate the 'complexity' challenges. The experts also used the 10-point rating system. Experts were also able to comment on the concepts they reviewed. The following are the criteria used to evaluate the ability of the concepts to communicate about systems complexity:

1. The concept captures non-linear system behaviour
2. The concept captures feedbacks
3. The concept captures cross-scale dynamics
4. The concept captures path-dependence
5. The concept communicates the value of multiple perspectives on a system
6. The concept conveys how complex systems are characterized by deep uncertainty
7. The concept facilitates the development of strategic knowledge

Again, these criteria have not been designed to be very detailed, because of the wildly different nature of possible concepts. We also asked both groups of experts which audiences and contexts they thought each concept would be most suitable for.

6.4 Design concepts

Overview

The 86 concepts covered a broad range of media. In the ArtScience/Media Technology workshop, the majority of the ArtScience students focused on dynamic visualizations, social media storytelling concepts, live performances and interactive group installations. The Media Technology students focused on interactive, computer-based visualizations and games. The Utrecht Arts Academy workshop produced concepts covering a wider range of media.

10 of the 12 selected concepts originated in the 6 weeks-long Art Science/Media Technology workshop, while 2 of the concepts from the afternoon-long Utrecht Arts Academy workshop were included in the final selection. A number of concepts from this shorter workshop consisted of basic ideas that were strong with regard to one or several communication challenges. In the Art Science/Media Technology workshop, the concepts had more time to be realized and elaborated on. These concepts were seen as responding to a wider range of challenges. From both workshops, 51 concepts were seen as having strong responses to one or more of the communication challenges. Appendix 2 summarizes these ideas (right column) and shows the range of media they propose to employ (left column).

The 12 concepts that were selected by the workshop participants and the team as dealing best with the communication challenges from 1.1 fell into the categories of games, group interactions, visual metaphors, dynamic visualizations and social media storytelling. The next sections will provide in-depth results organized by three categories games (6.4), group interactions (6.4) and social media storytelling (6.4)- that contain 8 of these 12 concepts. Four concepts were either judged weak on most points by the communication experts as well as the complexity experts, seen as promising but underdeveloped, or seen as serving a fundamentally different communication function. We will quickly summarize these concepts at the end of this section.

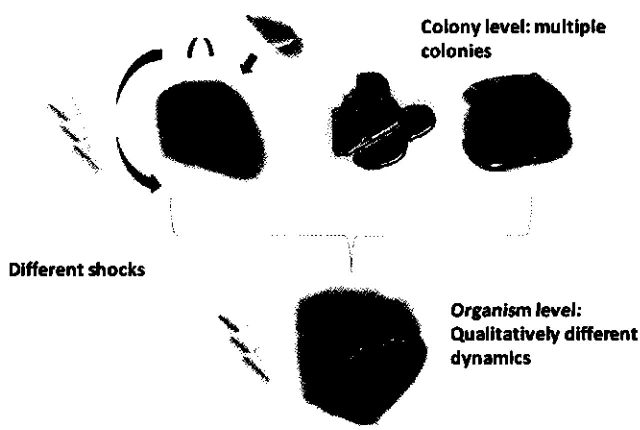


Figure 6.1: Organismus, showing the conceptual versions of the colony and organism levels in the game space.

Game concepts

Four games concepts were included in the final selection and evaluated by our expert panels. Each of these games aims to offer a way for players to directly and dynamically interact with complex systems dynamics. Two games, 'Organismus' and 'Chaosgolf' take a highly conceptual and approach, using abstract environments and system elements, while the two other games, 'Spaceship Earth' and 'Levels of Life' embed their games in real environments. Table 6.1 shows the evaluation of these games as done by the communication experts and the complexity experts. For the sake of brevity, we will present 'Organismus' and 'Levels of Life' here, and 'Chaosgolf' and 'Spacehip Earth' can be found in appendix 3.

Organismus

A 3D organism building puzzle (6.1) consisting of living cells suspended in space that change shape and properties over time. New cells appear. The pieces rarely fit as they are, but experimentation helps discover that they can adapt to each other depending on their general shape and properties (e.g. colors) to temporarily form an organic colony. This whole develops its own set of change rules, though, and when crucial parts change too much to remain compatible, the organ can fall apart. The player can prevent this by changing and adapting the units.

The player can create multiple units, or colonies, like this that remain available and suspended in space. If the player manages each unit well, he/she can combine these colonies into an organism given the same dynamics of compatibility that hold true on the simpler level. On the organism level however, different change dynamics occur which leads to different requirements on the management of the player. Also, the player will be less likely to have replacement elements on hand at this level. On the upside, the meta-level constructs yield much more points per second.

The aim of the game is for the player to get challenges that have to be adapted to. Strategies have to be revised constantly, different strategies apply on different levels, each system has its own rules, multiple systems have to be monitored and managed at once, upscaling success can be a different kind of challenge. Moreover, there is no final solution, even though it might seem so for a while. External shocks in many shapes and sizes can cause sudden disturbance or success. Radical changes on the organism level can cause similar shocks or beneficial events.

Evaluation by expert panels:

- Communication panel experts found this game lacking in accessibility because of its challenging premise, but solidly engaging, intuitive and informative and possessing a good balance between transparency and complexity.
- Complexity panel members found this game to be informative, clear and intuitive and found this game to be particularly suited to communicate principles of scale interactions and uncertainty between individual units, the 'organs' and the 'organisms'. The game scored high in terms of creating a strategic knowledge development experience but low on making multiple perspectives available.
- Suitable contexts: college-level education and on-line communication.

Levels of Life

The player plays a series of micro-games that take place on different biophysical levels, from the cellular level through individuals, societies and ecosystems to the global level (figure 6.2). This means managing gene replication, the survival of a cell, the organization of an organ, an individual's role in a community, the community itself, and so on. The micro-game goals and dynamics are particular to the level, but dynamics that are universal to complex adaptive systems should also stand out. This is pointed out at the beginning of each micro-game the player is told how much he/she can rely on experience from previous levels, and how much will be new. On each level, the player has to deal with influences playing out at other levels. The final goal of the game is to collect as much level linkages as possible which is shown in a meta-map between the levels (see figure 6.2 for an example imposed on an image of biophysical scales). The regular path through the game is to move up progressively and down through the levels via different paths but there are many places where, as a bonus, scale jumps can be made. These scale jump 'bonus levels' show how cross-scale influences are not just between consecutive levels. Think of playing at a single cell stage, and as a bonus getting to play a level where a bacterium becomes a pandemic, seen as a kind of strategic game at the appropriate level.

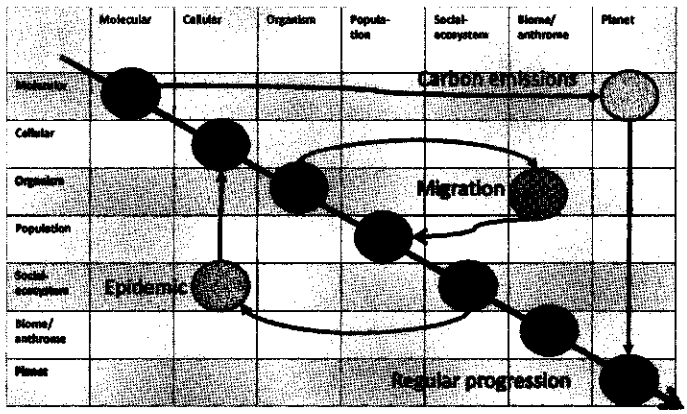


Figure 6.2: Figure 6.2.Levels of Life a map showing various micro-game levels. The regular progression is shown, as well as some examples of cross-level games.

Evaluation by expert panels:

- The communication panel judged this game to be accessible and engaging with a good approach to combining of complexity and transparency.
- The complex systems science panel saw Levels of Life as accessible and engaging and very informative, communicating about scale interactions primarily but also on path dependence, perspectives and uncertainties.
- Both panels saw the micro-game structure as both positive in terms of learning curve and negative in terms of freedom of game play.
- Suitable contexts: secondary school, college, physical installations, on-line communication.

Group interaction concepts

Two concepts were included in the final selection that each use physical interactions in a group to communicate about complexity in systems. We will discuss the concept 'Ouija Drawing' here as second example, 'Breathing Feedbacks', can be found in appendix 3.Table 6.2 shows the evaluation of both concepts by the communication panel and the complexity panel.

Table 6.1: Evaluation of game concepts by the communication and complexity panels. Each number represents a rating between -5 and +5, with -5 standing for 'extremely bad' and +5 for 'extremely good'. The bold text highlights values that are either in the highest quadrant (>2.5) or negative (<0).

Communication Expert	Accessibility	Engagement	Information	Complexity /transparency	Clarity	Intuitive design
ChaosGolf	**3.0**	1.3	0.8	**3.5**	**2.3**	**3.3**
Spaceship Earth	1.8	**3.0**	2.3	2.0	**2.7**	**3.0**
Organismus	1.2	1.1	0.8	1.4	1.2	1.6
Levels of Life	1.5	**2.8**	1.8	**3.8**	**2.5**	**3.8**

Complexity Expert	Accessibility	Engagement	Information	Complexity /transparency	Clarity	Intuitive design
ChaosGolf	**3.9**	1.9	1.4	2.2	2.2	**2.9**
Spaceship Earth	1.3	**3.3**	**4.5**	1.3	**3.3**	**2.8**
Organismus	0.8	**2.5**	2.3	1.3	2.0	**2.5**
Levels of Life	**2.5**	2.0	**3.8**	1.8	2.0	**2.8**

Complexity Expert	Nonlinearity	Feedbacks	Scale dynamics	Path-dependence	Multiple perspectives	Uncertainty
ChaosGolf	1.2	1.1	**-2.0**	1.8	**-0.4**	2.1
Spaceship Earth	**2.5**	**2.5**	0.3	0.8	**-0.8**	0.8
Organismus	0.5	1.0	1.5	1.5	**-0.3**	1.8
Levels of Life	2.0	2.0	**4.8**	1.8	2.3	2.3

Complexity Expert	Strategic knowledge
ChaosGolf	0.6
Spaceship Earth	0.3
Organismus	2.3
Levels of Life	1.0

Ouija drawing

A group of people sit around a table or on the floor, in a circle (figure 6.3). They are all connected at the wrist by a structure of connectors, so the movements of each person affect the movements of the others and vice versa. Each of them is given a pen and paper to draw objects. The individual drawing patterns represent local variability and agency, while the structure and properties of the connectors represent network structure as well as constraints (biophysical, institutional) on the nature of interactions. The group can be given different drawing assignments to reflect different system dynamics, for example:

- One person draws an object or person, and the other participants let their pens follow whatever movements are passed on by the drawing actions of the 'principal drawer'. The result of this is a degrading similarity between the drawings as their creators are in positions further away from the principal drawer. This assignment can represent

Figure 6.3: Ouija Drawing as tested in the ArtScience/Media Technology workshop

the changing character of the impact of a single local process throughout a system.

- Each person draws the object or person individually, creating an interplay of effects and feedbacks between the participants, with different people alternatively leading and responding to the movements in the process. This assignment can represent a dynamic interplay between local processes or network agents, and the feedbacks that result from this.
- All participants hold their pens still on the paper, allowing the 'system noise' - involuntary movements in the body, a changing balance between participants and other effects to appear on paper, and feedback throughout the system.

Evaluation by panel experts:

- The communication experts also saw this concept as very accessible, engaging and clear but did not believe it was highly informative.
- The complex systems science panel awarded this concept with a highly positive evaluation in terms of accessibility, engagement, information, combining transparency and complexity and intuitiveness. They saw it as mainly communicating about feedbacks, non-linearity and uncertainty.
- Suitable contexts: secondary school, college, workshops, physical installations.

Table 6.2: Evaluation of group interaction concepts by the communication and complexity panels. Each number represents a rating between -5 and +5, with -5 standing for 'extremely bad' and +5 for 'extremely good'. The bold text highlights values that are either in the highest quadrant (>2.5) or negative (<0).

Communication Expert	Accessibility	Engagement	Information	Complexity /transparency	Clarity	Intuitive design
Ouija Drawing	4.0	3.5	0.0	3.0	2.3	2.0
Breath Feedbacks	2.8	3.8	-1.0	1.3	2.8	3.0

Complexity Expert	Accessibility	Engagement	Information	Complexity /transparency	Clarity	Intuitive design
Ouija Drawing	**4.5**	**3.5**	2.0	**3.8**	**3.0**	**4.0**
Breath Feedbacks	**4.3**	2.0	1.5	**4.3**	**3.8**	**4.5**

Complexity Expert	Nonlinearity	Feedbacks	Scale dynamics	Path-dependence	Multiple perspectives	Uncertainty
Ouija Drawing	1.0	**2.8**	**-3.0**	1.8	**0.0**	**2.5**
Breath Feedbacks	1.3	2.0	**-2.5**	**-2.8**	**-2.5**	**-2.8**

Complexity Expert	Strategic knowledge
Ouija Drawing	0.6
Breath Feedbacks	**-3.0**

Social media storytelling

Two concepts in the final selection each used social media to tell stories. The examples presented here is 'Time Capsules'. The other example, 'Indicators' can be found in appendix 3. Table 6.3 shows the evaluation of these two concepts by the communication and complexity panels.

Time capsules

A fake set of documents (figure 6.4) is created and promoted as real these documents appear to be a vision of the future of a seemingly deranged individual, who has a very rigid, one-dimensional perspective of the world, history and the future. The document makes this person appear to be insane, and engages the reader, who thinks the document is real, to consider his/her own perspectives on the change of societal and natural systems through time. The document was presented in a group context as well as dispersed over the internet, where the illusion that it was real was maintained (see above figure for some responses through Facebook).There are two principles at the basis of this concept: Presenting fabricated information as real, and eliciting the desired response by presenting the opposite perspective. The illusion of reality can make for an interaction with the concept that has

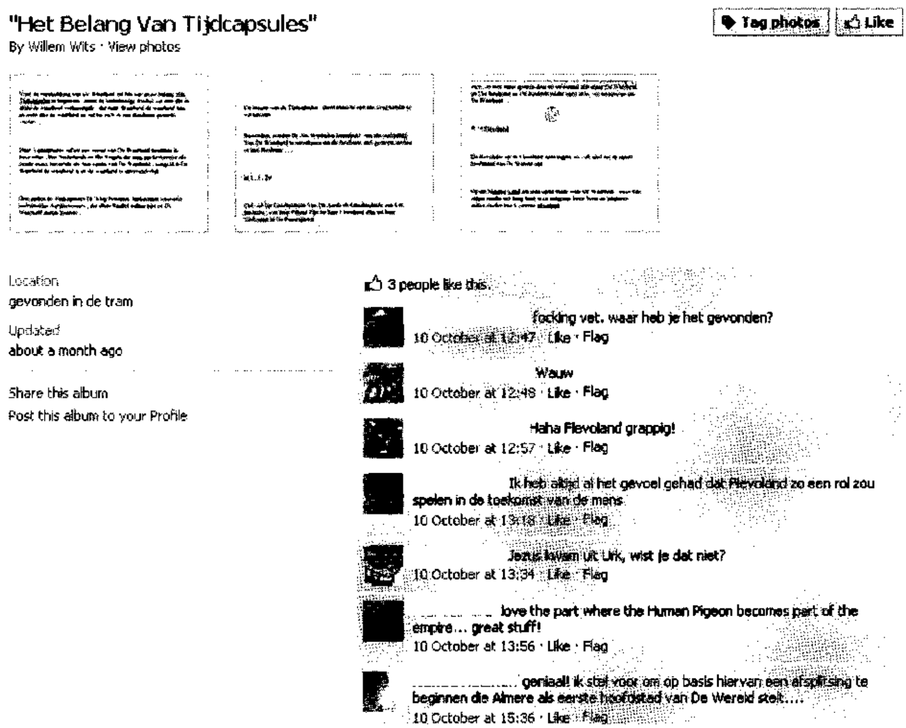


Figure 6.4: Time Capsules storyline placed online in Facebook (Facebook 2004) showing reactions that assume the meta-story (documents found on the tram by unknown author) is true.

very little framing, and can therefore be more direct and outside of a person's expectations. The presentation of a perspective that is so obviously extreme in its static, peculiar dogmatism can elicit an opposite response. This combination of techniques makes this concept into a 'scenario storytelling' exercise in a very different mode than is usual.

Other concepts

Four other concepts were included in the final selection, but are not presented in this section. Two of these concepts were dynamic visualizations that extended the adaptive cycle and panarchy concepts from the social-ecological systems literature (Gunderson and Holling 2002). Both of these concepts were given low marks with regard to most criteria by both panels, especially in terms of the design criteria, because they were seen as too esoteric for

Table 6.3: Evaluation of social media storytelling concepts by the communication and complexity panels. Each number represents a rating between -5 and +5, with -5 standing for 'extremely bad' and +5 for 'extremely good'. The bold text highlights values that are either in the highest quadrant (>2.5) or negative (<0).

Communication Expert	Accessibility	Engagement	Information	Complexity /transparency	Clarity	Intuitive design
Indicators	1.3	**4.3**	**3.0**	**3.0**	1.3	**3.3**
Time Capsules **3.0**	**4.5**	1.8	2.0	**-0.8**	1.0	
Complexity Expert	Accessibility	Engagement	Information	Complexity /transparency	Clarity	Intuitive design
Indicators	1.0	2.0	1.3	**4.0**	**3.0**	1.0
Time Capsules	**3.7**	**4.1**	1.8	1.8	**3.4**	**3.3**
Complexity Expert	Nonlinearity	Feedbacks	Scale dynamics	Path-dependence	Multiple perspectives	Uncertainty
Indicators	-0.8	0.0	-2.0	**0.0**	**-0.5**	1.3
Time Capsules	0.5	1.8	-0.5	1.3	**3.0**	1.3
Complexity Expert	Strategic knowledge					
Indicators	**-0.3**					
Time Capsules	**-1.3**					

non-experts. One concept was a collection of ways in which a group of participants can be tested as a complex system through numerous outside disturbances of group work. This concept was deemed too underdeveloped by the panels. Finally, a strong visual metaphor made the final selection, as a wild-card addition. This concept consisted of a picture of a man whose lower body was frozen, and whose upper body was on fire, accompanied by the title 'on average, he's fine'. This concept was seen as clearly and engagingly communicating the problem of relying on averages and trends in a very accessible way, but little else and it did not allow for flexibility or interactivity at all.

6.5 Discussion

We will begin by discussing the overview of created concepts and the media for which these concepts were designed. Then, we will discuss the evaluation of the concepts in the final selection: what are their strengths and drawbacks in comparison to the state-of-the-art in science communication? How can the potential value of these types of concepts be taken forward in practice?

After discussing the concepts, we will review our general approach to creating collaboration between social-ecological systems scientists and interactive media designers and artists, and the potential of linking these disciplines.

Overview

The collaborative workshops have resulted in a wellspring of concepts with different forms of potential, including a smaller selection of concepts that were evaluated as being able to take on a range of communication challenges. Most of the 51 remaining concepts summarized in the overview were not selected because they were underdeveloped. Most of them consist of a general notion that would benefit from a longer period of conceptualization and development. Although these concepts do not lend themselves to direct translation into practical tools and products, the quantity and diversity of ideas captured demonstrates the potential of the collaboration between complexity scientists and interactive media designers and artists.

Furthermore, the range of media and genres proposed for these concepts widens the perspectives and options that could be taken into consideration for the communication of complexity in social-ecological systems. The level of interactivity allowed by different media played a crucial role in the evaluation of the potential of different concepts. Games, group interactions and social media storytelling all allow for interactivity and for the integration of many functions - our selection has depended strongly on our use of criteria, and the need for concepts to deal with most of these challenges simultaneously. We will discuss alternatives to this approach in section 6.5.

Practical feasibility was a criterion that has not been included in the challenges but has been an unavoidable consideration. Feasibility has come up chapter 2 of this thesis, but we have avoided it here to keep the space for innovative thinking open at first. Still, based on conversations and comments, feasibility was an implicit consideration in the evaluations among both the participants and the expert panels.

Game concepts

Organismus

Strengths and weaknesses: Organismus was seen as overall solid in terms of the design criteria. The complexity panel was most enthusiastic about its ability to engage and be intuitive. It was expected to be a little problematic on the accessibility side, because the game has the potential to become very complex. This problem could easily be solved by paying strong attention to the learning curve of the game (Squire 2005). Organismus gets some high markings for crucial criteria of complexity communication a solid value for its tackling of scales, and the strongest value of the four concepts for its ability to generate strategic knowledge. This last criterion is crucial, as it integrates analytic understanding and experiential engagement into a single learning experience.

Practical usefulness: Because of the way complexity in this game is combined with intuitive, engaging and even frantic game design, we think this game would be very useful as a basic and versatile tool to teach about complex systems in a wide range of educational settings.

Feasibility of implementation: The game does not depend on powerful graphic design; however, the game mechanics are very complex, especially because of the nearly unlimited outcomes, and would require expertise, not so much in terms of manpower but in terms of knowledge and experience, to develop.

Levels of Life

Strengths and weaknesses: The 'network of micro-games' approach is a real strength of this game in the eyes of both panels. It allows for the game to communicate much information and capture complexity while remaining clear, intuitive and engaging. It also allows for the game to deal excellently with a crucial element of complex systems dynamics that the other games have more difficulty with: scale interactions.

Practical usefulness: As an educational tool, levels of life shows much potential. Its piece-by-piece approach, learning curve design, focus on specific cases and explicit emphasis on cross-scale interactions make it very suitable for secondary school and college environments. Because of the extensive character of the game, it is not as useful as a quick intervention as games like ChaosGolf (appendix 3) would be.

Feasibility of implementation: This game is far less of a challenge in terms of the model(s) driving the game play than the other games, because of its micro-game structure. However, there would be a large amount of content and designing to produce. A solution posed by one of the communication experts is to approach this game as an open-source project where different contributors develop and discuss the various levels.

Overall discussion

The four games from the workshops show the potential of serious games to capture systems complexity in intuitive, engaging ways that are able to mix the challenges of communicating about complex social-ecological system while remaining clear and transparent. In these qualities, the games have very few precedents. The abstract games ChaosGolf and Organismus are particularly unique in their direct focus on complex systems dynamics when compared to the state of the art of serious games. The biggest drawback of all of these games is their lack of focus on capturing the perspectives and contributions of their players. The games follow a traditional game model - the player deals with the game content. A related gap in these games is the social, multi-player element. Even though, these elements would give the games different functions than the ones they were designed for, multi-player gaming is a very promising avenue for the sharing of perspectives on complex systems that has not been explored in this chapter. In terms of practical feasibility and implementation, the game designs are challenging but would not require the resources of mainstream commercial games. In this, they follow the trend of web-based casual games that are often developed by a few experts(Part et al. 2010). The suggestion by our communication panel to take an open-source approach for these games would be fitting.

The following recommendations suggest avenues for future research and development of games for the communication of complexity in social-ecological systems, as well as some examples of these directions from other fields of research and the commercial gaming world.

- *Focus on the potential of serious games that focus directly on the communication of complex systems characteristics in order to generate strategic knowledge* (Hmelo-Silver and Azevedo 2006).
- *Use the learning curve used in commercial games to manage the tension between oversimplifying and overloading content* (Squire 2005; Parker 2010).
- *Build on the potential of complex systems simulations to provide an engaging mix of structure and dynamism, of the controllable and the uncontrollable* (Cowley et al. 2008).
- *Focus on multi-player interactions* (van Bilsen et al. 2010).
- *Build on the increasing popularity and available technology for open-endness in games* (Jenkins 2007; Sefton 2008).
- U*se developments in user content creation from characters to storylines to worlds to game modes- to allow participants to create and share their own perspectives within the game* (Rieber 1996; Edge Staff 2007; Electronic Arts 2008; Blizzard Entertainment 2010; Barry 2011; Ubisoft unpublished).

Interactive group concepts

Ouija Drawing

Strengths and weaknesses: Overall, the interactive group concept Ouija Drawing was evaluated as good to extremely good regarding nearly all design criteria. But while the communication panel thought the amount of information that thought could be communicated was low and a drawback of the method, the complexity panel thought the concept actually captured a good amount of information. We explain this difference by considering that the complexity panel recognized the system dynamics captured by this concept better. However, this might be an indication of bias after all, the understanding of system dynamics has to be communicated to groups of non-expert participants. A solution for this would be paying close attention to what information guides the exercise. In terms of the complex systems criteria, the complex systems science panel saw a problem with the communication of scales and multiple perspectives. We would like to argue that cross-level dynamics can be recognized in the exercise, represented by the constraints of the group structure. Again, the communication of this insight would depend on the guiding information.

Practical usefulness: We agree with the members of both panels that this exercise is a great way to introduce the concept of feedbacks causing non-linear effects in a connected system. It could easily be used in a range of settings, as long as these settings are physical. Extensions to mix physical exercises with on-line connections could also be possible.

Feasibility of implementation: This concept was already complete and tested at the end of the ArtScience/ Media Technology workshops. Its implementation requires some basic materials and some group coordination, nothing more. It can be easily captured in simple instructions.

Overall discussion

The use of interactive group concepts for the communication of complexity has some precedence (Resnick and Wilensky 1998; Mennin 2007).However, the ways groups were used in the concepts in this workshop bring up new ways to embody complex systems dynamics. In doing this, they show that group interactions have much untapped potential for education and workshop settings and warrant future exploration. Their great advantages lie in their practicality and their ability to create a very intuitive understanding of systems dynamics by using the human body and mental processes. Their disadvantage lies in the fact that they do not scale up as easily as for instance web-based games do.

We recommend to:

- *Focus on ways to upscale the benefit of group-oriented concepts (Bishop 2010).*
- *Use group interactions to represent a full range of complex systems characteristics, including cross-level interactions* (Resnick and Wilensky 1998; Colella 2000; Yoon 2008).
- *Develop an index and instruction manual of available group concepts that could be applied to communicate different systems characteristics and subjects in various contexts.*
- *Discuss and emphasize the commonalities and differences between different perspectives in the group exercises* (Resnick and Wilensky 1998; Colella 2000; Mennin 2007).

Social media storytelling

Time Capsules

Strengths and weaknesses: The high values given to Time Capsules by both panels in terms of both accessibility and engagement have a lot to do with its flexible format (on-line, physical) and its intriguing premise. The strength of the concept is based in two ideas: presenting fictional information as if it is real, and using a reverse message to convey the communication. These ideas create a type of engagement and cognitive involvement that has not been used in complexity communication before. The drawback of this approach is that it can be cryptic and problematic in its clarity. The communication panel commented that much of the impact of this concept relies on later framing of the lessons learned.

Practical usefulness: The Time Capsules concept and similar social media storytelling projects have potential in providing a re-frame or a wakeup call in a range of educational and organizational settings. Its viral quality allows it to potentially upscale its impact far beyond these contexts (Bodin 2006).

Feasibility of implementation: Since this project has already been tested on-line, and has elicited the responses that were aimed for, feasibility is not an issue. The project could be repeated ad infinitum as long as new social environments are available on-line.

Overall discussion

Both the Time Capsules and Indicators concepts are examples of a main strength of social media storytelling: accessibility and flexibility of content. The social media formats both concepts use also make them highly feasible in fact, both concepts have been tested with on-line audiences. Each concept is also very engaging in its own way which is partly a result from the freedom in terms of content that is possible in social media. The problem with this highly original and engaging content is that in both cases, it is also quite cryptic and could be confusing. A more fundamental issue with the way social media are used in both instances is that they are not so interactive as say games or group interaction concepts they do not allow for a direct, sense-based interaction with systems complexity. Furthermore, participants' contributions can be taken beyond on-line comments in social media (Writerguy 2007).The lack of space for creative contributions is a handicap shared by all concepts in this study.

The evaluations of these group concepts and the literature they connect to give rise to the following recommendations:

- *Use the power of social media to connect people to their content through mass interpersonal persuasion processes* (Busselle and Bilandzic 2008; Fogg 2008; Kim et al. 2008).
- *Get people involved over longer periods of time to create a sense of living with complex systems in their own lives* (Ornebring 2007; Zhang et al. 2010).
- *Stimulate participants to write, film and create different artifacts on the theme of the interaction* (Writerguy 2007).

Reviewing the workshop approach for the development of collaborative design concepts

The results of the study presented in this chapter demonstrate the potential of bringing in designers and artists to develop new ways to communicate about complexity in social-ecological systems. Our approach to exploring their perspectives and ideas is one of many paths that could have been taken. Even within our project, a differentiation can be seen, producing different results. The Utrecht Arts Academy workshop was a single day session with a large number of participants. This workshop generated ideas that showed much potential, but participants lacked the time to fully shape these ideas. In the Art Science/ Media Technology workshop, there were less participants, but there was much more time to develop the concepts. A crucial difference between these workshops was the interaction between researchers from the social-ecological systems perspective, the art and design educators involved in the workshop and the participants. This interaction helped to develop the concepts in the direction that was most valuable in terms of our communication challenges. At the same time, it does show that while more limited, a single day workshop can bring up much potential. This is useful to know when the time frame for collaboration is in fact limited for instance, when a large group of researchers and high-level designers and artists can be brought together for a single occasion. We would like to suggest that this kind of momentary exchange would require a mix of both art and design and complex systems expertise among the participants in that way, design concepts can immediately integrate a deeper systems understanding.

The Art Science/Media Technology workshop showed a different prospect for future art/science collaborations. Those involved were able to generate the most useful concepts and recommendations, because they were already undergoing a training that included the reflections of art, design and science on one another. This made the participants uniquely capable of applying approaches and concepts from beyond the science communication spectrum to the problem of communicating about complexity in our world. We see the education of hybrid artists/scientists as a crucial requirement for the emergence of communication strategies that create public engagement with and understanding of social-ecological change on a large scale.

A design choice that was fundamental to our workshops and for our evaluation in particular, was the view that a single concept should be able to deal with most or all of the challenges of communicating about complex systems we posed. An alternative approach could be to focus on specific, single challenges and aim for a toolbox instead of a single tool/game. A problem with that approach would be that the characteristics of complex systems are in fact interconnected, and communicating some of these characteristics in isolation could produce a bias. Also, our use of a set list of criteria can have limited our evaluation of the concepts by using a single frame on a wide variety of ideas. An alternative using grounded theory is proposed by Isenberg (1998).

The implementation of the kinds of concepts that have come up in the workshops was only marginally addressed. For a number of concepts we have proposed that their development and implementation is feasible. Several concepts were already developed to the level of working prototypes. But for these kinds of ideas to be fully realized and used the structural support of both the science communication domain and media design and innovation cultures is needed.

Untapped potential: collaboration between social-ecological systems scientists and designers and artists

This study has only begun to tap into the potential of collaborations that link complex systems scientists and interactive media designers and artists. Our results demonstrate that there are many affinities between modes of communication in interactive media and art and scientific perspectives on social-ecological systems change. Art is appreciative of complexity and uncertainty and has the ability to convey understanding on an analytic level as well as through experience. Aesthetic appreciation has its own type of rationality that warrants more exploration in the context of complex systems communication (Richards 2001; Ramrez and Ravetz 2011).

More efforts are needed that focus on harnessing the potential of connecting art, design and complex systems science. We have seen the benefits of organizing spaces for encounters between individuals from both disciplines. We have also reported on the value of hybrid education focusing both disciplines in this study. Another approach would be to focus on inspiring and informing communities of interactive media designers and artists to take on the challenge of communicating about social-ecological complexity as long-term, collaborative projects. For instance, many open-source projects have been developed out of shared curiosity, chances for collaboration and shared engagement with different subjects. These engines of innovation should be harnessed.

The following recommendations address the organization of collaborations between designers and artists and social-ecological systems scientists to create better communication:

- *Short brainstorms about communicating about social-ecological systems complexity could be useful with expert-level participants aim for a mix of art and science expertise and allow for much interaction between small groups of individuals.*
- *Foster hybrid science/art/design education and training to create the interdisciplinary expertise needed for truly effective communication on complexity in social-ecological systems.*
- *Explore different ways in which media innovators and artists can be engaged, informed and inspired to employ their skills and experience for the full development and implementation of interactive media communication on social-ecological complexity.*

6.6 Conclusions

In this study, we started with the premise that interactive media designers and artists can contribute new perspectives and ideas in collaborative design efforts to generate societal engagement with and understanding of complexity in social-ecological systems. This collaboration is crucial because current science communication strategies are only partially able to deal with the challenges that come up in trying to turn this potential into a reality.

We defined the challenges first. Then, we introduced a study that aimed to take on these challenges by harnessing the expertise of interactive media designers and artists. Facilitated by an interdisciplinary team in several workshops, multi-media designers and artists developed communication concepts that aimed to facilitate understanding and engagement in an integrated fashion.

This case study produced 51 out of 86 concepts using a range of media with the potential to take on one or a few challenges, and 12 out of 51 concepts that were evaluated by the participants and workshop team as providing possible ways to deal with the entire set of challenges. A second evaluation of these concepts by a panel of communication experts and a panel of complexity scientists resulted in the 8 concepts presented in this chapter. These concepts fell into the categories of games, group interaction concepts and social media storytelling. Though exhibiting very different characteristics, all concepts proved engaging, accessible, intuitive and well able to combine complexity and transparency. Overall, the concepts have the most difficulty with capturing scale interactions, and they provide little opportunities for the contribution of participants' perspectives. The concepts could be used in education to help facilitate shifts in understanding from linear, central models of understanding to complexity-based understanding. In workshops, they could be used as quick interventions for (re)framing. The feasibility of developing and implementing these concepts in is strong the games require expertise in the development of challenging game models, but do not have to be large projects like most mainstream games, and the group interaction and social media storytelling concepts were already working concepts that could be tested in the workshops and on-line. All of these concepts show different feasible, complementary ways in which audiences could be engaged with social-ecological systems complexity that are not currently part of science communication.

In terms of the collaboration between scientists and artists, the workshops in this study show the benefits and drawbacks of different formats, including single sessions with large groups and longer workshops. They also demonstrate the value and potential of interdisciplinary education that combines science, art and design. Finally, they show the need for the inspiring, engaging and informing of artists and designers to get collaborative design arenas to take the potential of these concepts to the level of full development and implementation. The result could be vibrant communities of interdisciplinary innovators that build on developing new ways to create and interact with images, mental models, discourses and realities and overcome the limits of current societal communication on social-ecological systems change.

Chapter 7
Synthesis

The past is a liar, the future a whore.

-La Dispute, Bury Your Flame, 2008

Chapter is based on:

J.M. Vervoort, Kasper Kok, P-J Beers, R. van Lammeren, A. Veldkamp *Exploring interactive visualization strategies for communication about social-ecological systems change.* in preparation.

7.1 Introduction

Throughout this thesis, we have argued that the environmental and social challenges facing humans in the twenty-first century require deep societal understanding of and engagement with the complexities of social-ecological systems change. This understanding and engagement have to be built on the perspectives of a wide range of societal actors, both to ensure a broad base of knowledge and experience, and to enable system-wide action. But societal communications about social-ecological systems change are often framed by dominant, simple and heavily biased images and mental models. The different chapters of this thesis have each reported on different ways in which the challenges of communicating about social-ecological complexity can be approached through the use of interactive visualization and multi-media. Chapter 1 identified two main challenges:

- Capturing and communicating different societal perspectives on the complexity of social-ecological systems.
- Combining the facilitation of analytic understanding with the need to generate experiential engagement with systems change

Both of these challenges are framed by the following preconditions: for any such communication tools to be viable, they should be accessible, flexible and feasible.

Chapter 2 used these challenges to review the different strategies and tools available in environmental science communication and developed a possible framework that would combine their strengths and complement their weaknesses. Chapters 3 and 4 went beyond the state of the art and presented and evaluated two new tools that took on the challenge of capturing analytic perspectives on social-ecological complexity. Chapters 5 and 6 focused on the challenge of combining understanding and engagement.

This synthesis chapter will first discuss the collection of tools and methods developed and evaluated in this thesis in terms of the challenges I introduced in chapter 1 to discuss the strengths and weaknesses in our overall approach (7.2). This evaluation will also serve to discuss which of these challenges have proven to be easier or more difficult to tackle. The next section discusses the complementarities between our collection of tools and approaches, the ways they translate between different types of content and interaction, and where the gaps lie (7.3). In 7.4 I will focus specifically on the link between the tools in this thesis and future-oriented participatory processes such as scenarios development and visioning. I will then discuss the merits and problems of alternative avenues we might have explored (7.5). Section 7.6 discusses how these methods could be embedded in societal communication to up-scale their impact and overcome current limitations. In section 7.7, the challenges of communicating in a context of diverse societal actors are reviewed. Section 7.8 looks briefly at the communication challenges in the TransForum programme that was the context for this research, and how these link to our findings in this thesis. This thesis will end with the conclusions of different case studies and general conclusions in the form of recommendations (7.9).

7.2 Taking on the challenges of communicating about complexity in social-ecological systems: lessons learned

The development and evaluation of the tools and concepts discussed in this thesis has been a process of continuous reflection and learning, guided by the ambition to take on the challenges of communicating about social-ecological systems change. Building on the conceptual framework, this section reviews the measure of our success in taking on these challenges, and discusses the lessons that resulted from this process.

Capturing complex systems characteristics to facilitate analytic understanding

Our self-imposed requirement for any tools to be accessible, flexible and feasible was helpful, because it gave us the focus to start with a very basic approach to the communication of complex systems characteristics. We chose non-linearity and scale dynamics as the most accessible and basic traits of complex social-ecological systems. This choice gave rise to the System Perspectives Scope, a method that was accessible, flexible, generalizable and that built on the perspectives of participants. One of its main strengths was the way that it focused directly and explicitly on complex systems characteristics. Its main issues were a lack of quantification and a strong pre-framing of participants' perspectives through the focus on spatial and temporal levels and myths of nature. To go beyond these limitations, we developed the Scale Repertoire. This tool sacrificed elements of generalizability, large-scale application and accessibility for a much more in-depth systems analysis. The Scale Repertoire was largely unprecedented in its explicit focus on not just cross-level but also cross-scale dynamics. A characteristic of complex systems that we did not focus on in the Scale Repertoire chapter but for which this method also shows potential is the conveying of the idea of path dependence (Rycroft and Kash 2002). Its storyline structure, focusing on interacting drivers, dimensions and scale provide a suitable platform for understanding path dependence. Other storyline-based tools such as Scenario-Communities share this potential, as do the game concepts where progressive consequences of choices and actions drive the direction of the game play.

As we explored the combination of analytic understanding and experiential engagement, our case studies indicated that the engagement-oriented methods were best able to convey the idea of uncertainty in complex systems. There is a logic to this deep uncertainty is partly something that can be understood analytically, but it should also be experienced for it to have any meaningful impact. The engaging, distressing nature of the story sections and participants' contributions in the Scenario-Communities case study and the challenging open-endedness of the games, group concepts and social media storytelling concepts showed much potential for the intuitive conveying of uncertainty.

Lessons learned:

- It is possible to create forms of interactive communication that focus directly on the traits of complex systems, and to do so in ways that build on a wide range of societal perspectives.

- There is a challenge in resolving the tension between the need for accessibility and generalizability on the one hand and capturing the full richness and structure of different perspectives on the other.
- A grasp of the uncertainty associated with complex systems appears to be captured better by experience-oriented tools.

Combining analytic understanding with experiential engagement

The complexity of social and environmental change can invite disengagement (Macey and Brown 1998; Levin 1999). In the absence of simple cause and effect relationships, clear goals and defined distinctions, it is easier to disconnect from problems. Facilitating societal engagement with the challenges that complex social-ecological systems present is no easy task, but it should be a crucial focus for communication strategies and tools. If individuals, communities and organizations are not engaged, there is no potential to move towards action (Sheppard 2005). Furthermore, without engagement, there is no drive to understand issues more deeply. On the other hand, understanding can also block or foster engagement (Pritchard and Sanderson 2002). Communicating about social-ecological systems change therefore means combining the analytical and the experiential in ways that are mutually supportive.

In our combination of the System Perspectives Scope and Scenario- Communities, we concluded that it is indeed possible to effectively combine analytic and experiential methods as separate approaches. In our work with multi-media designers and artists, we explored the potential for fully integrating experiential engagement and analytic understanding on a conceptual level. Serious games, group interaction concepts and social media storytelling concepts appear to be realistic yet powerful approaches to integrating understanding and experiential engagement. Steps toward the implementation of such methods are essential.

We see potential in connecting tools such as those in this thesis to a different type of engagement-oriented work that comes from the worlds of community participation and management. In methods such as Theory U (Scharmer 2007) and various examples of reflective practice (Macey and Brown 1998), there are strategies in use of 'presencing' issues of social and environmental change that anchor the meaning and relevance of these issues affectively among their participants. There could be a role for multi-media scenarios, games and group interaction concepts in such processes, and valuable lessons could in turn be drawn from these engagement-oriented processes for the design of multi-media tools.

Lessons learned:

- Combinations of methods that are clearly distinct in their functions (analytic understanding/engagement) can be complementary and synergistic, with the two modes of communication supporting each other. Additionally, they allow for the separate study of analytic and affective aspects of perspectives.

- A full mix of engagement and analysis in games, group interaction concepts and social media has the potential to create simulation-type interactions that are conducive to the development of strategic knowledge born from experience (Hmelo-Silver and Azevedo 2006).

Design lessons: accessibility, flexibility and feasibility

In terms of accessibility, the result is that the tools in this study are either web-based or applicable in a range of live settings, and that some (Scenario-Communities, System Perspectives Scope) work in both modes. Designs have either been kept simple enough for short instructions to guide participants, or a conscious choice has been made to rely on facilitation (Scale Repertoire). In terms of flexibility, the tools geared toward analytic understanding like the System Perspectives Scope and the Scale Repertoire can support very different types of content and can therefore be used in a wide range of social and environmental change contexts. Moreover, these tool designs themselves are easily adjustable to fit different needs. For instance, the System Perspectives Scope could easily feature different scales from the spatial and temporal scales that were used. The flexibility of the System Perspectives Scope has made it possible to use this tool in European-level as well as local-level cases. The games and group concepts are less flexible in terms of content. However, because of their focus on the conceptual, they can be used as metaphors and interventions to connect to very different concrete issues. The scenario and storyline-based tools revolve around multi-media stories that have to be prepared for each case, which makes them the least flexible. The System Perspectives Scope, Scale Repertoire and Scenario-Communities, as well as collaborative design concepts such as Oujia Drawing and Time Capsules have proved their feasibility because they were developed and used by small groups of researchers and designers with limited resources. A working prototype of the on-line design framework discussed in chapter 2 has also been developed, though it has yet to be used in a case study. We discussed the game concepts in chapter 6 in terms of feasibility, identifying possible challenges, but on a whole the development of these concepts falls into the same order feasibility in terms of expertise and resources needed.

Lessons learned:

- There is a positive relationship between accessibility, flexibility and feasibility of design for communication tools. This limits what is possible, but it creates the kinds of tools that can actually be used and adapted in different settings and for different purposes.
- Start testing non-digital versions of the design whenever possible before constructing digital prototypes to retain flexibility.
- Discuss designs with target audiences from the first day. This will help tailor communication designs to their audiences, get potential users to support the design, and help them understand the concept from a designer's perspective.

- Take time to introduce designers to the content of complexity in social-ecological systems, and train the researchers in digital design. Create a truly interdisciplinary team. Designers and artists with mixed backgrounds in science as well as art and design, such as the participants in the chapter 6 study could be crucial.

7.3 Tools in an analytic framework: complementaries and gaps

The strategy outlined in chapter 1 provided us with an axis (analytic understanding / experiential engagement) that helped evaluate and distinguish the strengths and weaknesses of our own tools and the state of the art in terms of core challenges. However, as we developed and tested our tools, another relevant axis of analysis emerged (see figure 7.1). Tools could focus more on content that was rooted in practice and embedded in concrete environments, or focus more on abstract, conceptual approaches to systems. Translations along this axis are crucial for both analytic understanding and experiential engagement. The resulting model has similarities to Kolb's learning cycle (Kolb and Fry 1975), though it should not be restricted to the cyclic sequence.

Translating knowledge developed in practical contexts to more conceptual, abstract understanding is at the heart of knowledge development and capacity building. But so is the translation of abstract, conceptual understanding to practical contexts. In the context of complex systems, the latter appears to be an easier transition (Hmelo-Silver and Azevedo 2006). This is where our analytic tools fit in, and where they show their opposite natures: the System Perspectives Scope starts at the conceptual level, while the Scale Repertoire starts at the practice level to build conceptual understanding.

Communication modes focusing on experiential engagement most naturally align with practical settings and content embedded in specific environments (Marx et al. 2007). Experiential engagement with systems on a conceptual, abstract level is the most elusive combination, but this link could potentially be very powerful, generating an intuitive involvement with complex system dynamics. The Scenario-Communities tool fits in the quadrant of experiential engagement embedded in practical contexts. The collaborative design concepts from chapter 6 fit in the category of experiential engagement with systems on a conceptual level. The conceptual framework shows that our aim to combine analytic understanding and experiential engagement through the use of the System Perspectives Scope and Scenario-Communities is a diagonal translation the System Perspectives Scope focuses on a conceptual level, while Scenario-Communities aims for a practice-oriented, embedded context.

So where are the gaps that could be explored? The framework shows that we have not focused explicitly on the interaction between experiential engagement with and analytic understanding of practical cases and embedded content, instead moving directly to analytic understanding on a conceptual level. However, a combination of Scenario-Communities with the Scale Repertoire would certainly be possible moving from an engaging, experience-oriented account to the more analytic storyline development in the Scale Repertoire that

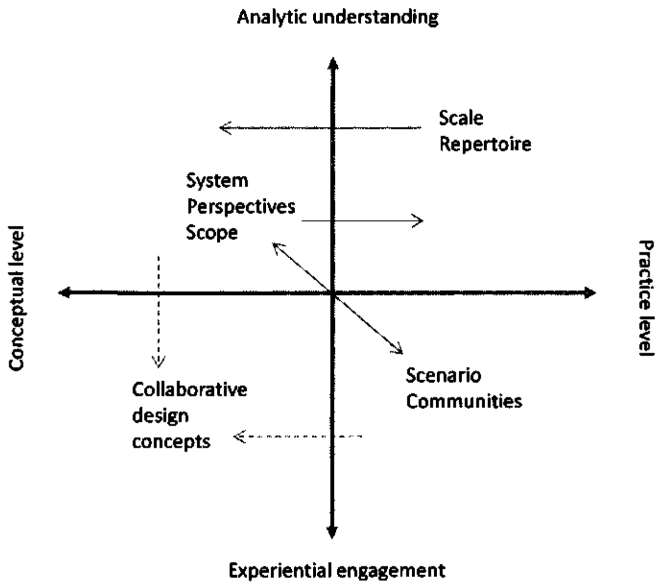


Figure 7.1: Mapping the ways the tools in this thesis bridge practical and conceptual content, and analytic and experiential communication modes.

leads up to an analysis of dimensions, scales and cross-scale dynamics. This combination could even function in an online context with a simplified version of the Scale Repertoire.

Another gap is the link between analytic understanding in a concrete context and experiential engagement on a conceptual level. This combination appears to be counter-intuitive, but not impossible. Just as the experiential engagement from the Scenario-Communities method could be brought over to the analytic understanding in the System Perspectives Scope, so could experiential engagement on a conceptual level be brought to a concrete, analytic context. In workshops and educational settings, experiential engagement with systems change on a conceptual level could bring this material to life and make it intuitively accessible. That experience could then be applied to a range of specific cases and environments.

7.4 The focus on individual perspectives in the context of futures exploration

Several tools examined in this thesis either use individual, exploratory scenarios and normative visions as a format for content to explore different communication technologies and strategies (chapter 2), aiming to capture analytic perspectives that allow for the framing of scenarios exercises (chapter 3), eliciting value systems from normative visions (chapter 4) or exploring the creation of individual scenarios as ways to capture personal, experiential world views (chapter 5). As discussed in chapter 1, our use of scenarios and visions has been different from other uses in multi-stakeholder future-oriented work in that our focus has almost completely been on individual perspectives. Scenarios and visions merely provided at suitable format for the elicitation of rich experiential content (chapter 5) and individual value systems/scales (chapter 4).

It is clear that focusing exclusively on individual scenarios and visions misses many of the benefits of group work in single organizations and especially in multi-stakeholder settings. That said, there are a number of ways in which this elicitation of individual perspectives can provide a valuable step specifically to the different purposes to which group-focused scenarios and vision development are put.

Exploratory scenarios can be developed to explore uncertainties in a multi-stakeholder setting and provide communal learning through their development and use (Wilkinson and Eidinow 2008). For this purpose, starting with the capturing of individual perspectives can capture a wider range of elements and subject matter for the scenarios, each of these captured undiluted in the idiosyncrasies of the framing by participating individuals. When these individual perspectives are shared, participants could develop a greater understanding of each others' viewpoints before a group effort is made.

Exploratory scenarios can also be used as a basis for action, to create relationships, commitments and ideas (Kahane 2010). For this purpose, a step in the process focusing on individual perspectives along the lines of the tools used in this thesis has the potential to make clearer what futures mean for individuals in their spheres of action and influence. This could facilitate the development of relationships. This step can then be used in a scenarios development process to create scenarios that are relevant to stakeholders' contexts and to identify connections and ideas on which to move forward together.

When the focus is on creating explicitly normative visions desired futures to move toward (Robinson et al. 2011) making individual aspirations explicit can be vital for an assessment whether the group vision reflects these aspirations. As argued in chapter 4, individual, normative visions are excellent for the elicitation of individual value systems. Then, in back-casting style exercises, individual perspectives on how to get to these desired futures could be valuable in capturing a range of truly different pathways.

Finally, in models for scenarios development that aim for a more continuous, involved process such as RIMA (Wilkinson and Eidinow 2008) and story-and-simulation (Alcamo 2008), there could be much value in having an iteration between the development and use of scenarios on a group level and by individuals who provide fresh perspectives. On-line tools such as proposed in chapter 2 would lend themselves very well to this kind of iterative process that seeks strong societal involvement.

In general, i would like to argue that a major part of the value of scenarios and visions in a multi-stakeholder arena is the explication of individual needs and values to others. This explication is partly a natural feature of group-oriented work, but a step or steps that focus explicitly on individual perspectives would strongly reinforce this value in such processes.

Several future directions can be suggested for exploring the role of eliciting individual perspectives in multi-stakeholder scenarios development on a theoretical level. The first is exploring the differences between eliciting individual and group perspectives on a psychological/behavioural level, in terms of overcoming bias and cognitive barriers to considering the future (Schoemaker 1993). The second is examining how individual scenarios and visions fit into attempts to provide a theoretical framework for multi-stakeholder scenarios development (van Notten et al. 2005, Wilkinson 2009).

7.5 Alternative research strategies

Our exploration of the potential of interactive visualization and multi-media to help take on the challenges of communicating about social-ecological change started with a review of existing methods, and then followed the strategy of developing and evaluating a range of new tools. This led to insights into the potential of methods specifically designed for the facilitation of analytic understanding and experiential engagement in the context of complex systems. What limitations to this approach can be recognized, and what other approaches could be taken? What kinds of insights can we expect different approaches to lead to?

We did not use our new tools in combinations or comparisons with existing methods to evaluate how they match up in real case studies, and therefore, we were restricted to comparisons with literature such as van Vliet et al. (submitted). It would be valuable, for instance, to compare the System Perspectives Scope with Fuzzy Cognitive Mapping (Kok 2009) to directly evaluate the benefits, drawbacks and complementaries of each method. The same goes for different engagement-oriented approaches. For instance, we moved away from landscape visualization and towards interactive, drawn animations in our Scenario-Communities visualizations, but it would be valuable to measure the differences between these approaches in a case study, and not just in a literature review (chapter 2).

Another research avenue that we did not take up concerns serious games. Given our evaluation in chapter 2 and the discussion of game concepts in chapter 6, it is clear that games show high potential for the communication of complexity in social-ecological systems. Since the main challenge with games is the resources and expertise needed for their development, we could have used existing, commercial games to evaluate the potential of this genre (Squire 2005). This approach would not have allowed us to look into games specifically developed for communication about social-ecological systems, but it would have enabled us to explore how games incorporate characteristics of complex systems such as non-linearity and uncertainty, and how interactions with these games affect users. The same strategy could have been used for other formats such as social media storytelling and landscape visualization.

In defence of our approach, it allowed us to focus specifically and exclusively on the challenges posed in chapter 1. It also gave us the direct experience of the conceptual design, development and participation issues that come up when taking on these challenges.

7.6 Up-scaling the impact of complexity-conscious communication

In a world where societal communications are dominated by overly simple, one-sided and uncertainty-averse images, mental models and discourses (Ravetz 2006, Veldkamp et al. 2008, Beers et al. 2010), how do we up-scale the impact of complexity-conscious forms of communication, based on a multiplicity of perspectives? In our definition of the dynamics of communication, individuals and groups are simultaneously senders and receivers, and the exchange of information is heavily connected to the formats and modes through which communication happens (Barnlund 2008). In terms of impacts, though, communication creates and reflects individual and shared realities that help determine spaces for response, action and innovation in societies (Craig 1999). So how can interactive media help create new, complexity-conscious societal realities and spaces?

Web-based social media can play a crucial role in opening up the possibility for different contributing perspectives, offering more possibilities to search out key actors as well as more possibilities for them to find communication arenas and contribute their perspectives. Research on the impact of social media on civic action indicates that social media storytelling can integrate into the lives of participants to a degree where it changes their civic involvement (Zhang et al. 2010). Craglia et al (2010) offer a number of essential proposals for both innovation and up-scaling for interactive geo-web applications.

An avenue that has been unexplored in this study is linking communication methods to large-scale, traditional media and media institutions. It would be straightforward to summarize large-scale participatory processes into media reports. Another strategy is to use traditional media to broadcast initial content and provide many options for response.

However, we can imagine more structural up-scaling and embedding of communication tools. If tools such as the System Perspectives Scope and Scenario-Communities are flexible and effective enough, they could be used by a wide range of societal actors (government branches, NGOs, businesses) as their own platforms for internal and external exchange of perspectives. The perspectives elicited could well be biased and dominated by the mental models, discourses and images of these groups, but if they are framed within a complex systems structure such as the System Perspectives Scope, this could help draw attention to the role of such complex systems traits as cross-level and scale interactions, non-linearity and feedbacks in the issues that are discussed. The same goes for more in-depth tools such as the Scale Repertoire a tool that would be suitable for scale-conscious strategic analysis in a wide range of organizational and policy contexts.

Finally, a point we brought up in chapter 6 is the need to inform, motivate and inspire media designers and artists to create innovative ways to communicate about social-ecological systems complexity. The case study in chapter 6 has shown the potential of a wider involvement of these communities in the design of communication methods. If incentives of finance, networking and community-building, curiosity, skill-building and social engagement work together to create the wide range of high-quality, free, open-source media projects that exist today (Hippel and Krogh 2003; Garriga et al. 2011), it would be worthwhile to explore how these incentives could be used to help start similar movements for the development of tools that facilitate the exchange of perspectives on social-ecological systems change.

7.7 Communicators in context: contributors, participants and audiences

The immediate goal of the communication efforts discussed in this thesis has been to facilitate greater societal understanding of and engagement with complex social-ecological systems. However, this goal is in turn instrumental to help create more sustainable forms of social-ecological systems governance. Considering this goal, it is important to put the value of communication into perspective.

Facilitating change in social-ecological systems could be viewed as a catch-22 situation: while actors' choices can be motivated by developing shared understanding and engagement, there are many limiting factors that could constrain them from actually taking effective action, and that go beyond communication issues(Stern 2000). Therefore, if we would be discussing science communication in the classic sense, as a broad-casting to 'the public', the methods discussed in this thesis would have very little potential indeed. However, these limiting factors can in turn be altered or influenced by societal actors operating at different levels and in different sectors. It has therefore become clear that opportunities for systems change can only be recognized and accepted through a cooperation of actors across system levels and sectors (Stern 2000; Ostrom 2009). This is where the types of communication methods discussed in this paper can play a crucial role.

Obviously, communications of perspectives on social-ecological systems change do not happen in an even space. Instead, actors representing different societal forces advocate perspectives using discourses, images and mental models that each interact in different ways with a range of ambitions for social-ecological systems governance (Beers et al. 2010; Hermans et al. 2010). This clearly includes those seeking to use multi-media methods to facilitate change.Ideally, communication tools such as those in this thesis could be instrumental in the sharing of mental models and inhabiting the perspectives of others. We do not see this development of shared understanding and engagement as an unrealistically communitarian and power-free process that necessarily has to lead to action based on consensus; power relations and differences in goals and attitudes could be brought to light just as well (Kahane 2010).

For instance, in the Scale Repertoire case study, contrary and conflicting interests and perspectives of different individuals were made highly explicit by this tool. And in the use of both the System Perspectives Scope and the Scenario-Communities method, different power relations across spatial levels were brought to the table. The way these tools framed such issues led to cross-level strategic planning. Awareness of this play of perspectives and consciousness of the potential role of communication tools in these processes is crucial. And so is consciousness of the role of the science communicator. From a complex systems knowledge development point of view, communicators should aim to capture very different perspectives, images, discourses and mental models operating across system levels and sectors. This way, more and different types of knowledge become available that may hold new insights. However, from the perspective of those seeking to facilitate change, the choice of perspectives that should be enhanced through multi-media becomes even more value-laden. Those perspectives that they see as conducive to goals related to social-ecological systems governance, such as building adaptive capacity and creating accepted transitions, should be empowered in terms of engagement and analytic content. Those perspectives that are blocking change should be re-framed. Clearly, the danger here is that the communicators themselves become orchestrators of perspectives.

Depending on the roles envisioned for communication tools in this interplay of societal perspectives, strategies to engage contributors and participants should be very different. These differences reflect on tool designs. The goal could be to elicit, exchange and present a wide range of societal perspectives. In our case studies, the System Perspectives Scope and Scenario-Communities focused on the elicitation of a wide range of societal perspectives. Furthermore, we focused on the capturing of the richness of content and particularities of individual perspectives. These tools showed potential in their ability to even the playing field: the System Perspectives Scope allowed participants to express their mental models in a systems-oriented format, thereby providing potential alternatives to dominant structurings of problems. The Scenario-Communities tools allowed participants to express their visions of the future in an engaging way that could provide other images than those commonly propagated.

Alternatively, the goal could be to capture just the key perspectives in specific groups of societal actors. The Scale Repertoire focused such a specific group of actors: the agents of change in the TransForum network were selected for their specific insights on how to effect accepted change in agricultural systems. These insights were given a platform through our elicitation method.

The games and interaction concepts from our work with multi-media designers and artists did not in themselves focus on the elicitation of perspectives. Importantly, however, these concepts in themselves represent valuable new perspectives, images and mental models of complex systems.

7.8 Multi-level lessons in communication: TransForum

Several lessons for communicating about complex systems change at higher system levels can be identified in the history of the TransForum programme for agro-ecological innovation that constituted the context of our research. As an organization operating on multiple different jurisdictional, organizational and geographical levels, it proved easier for TransForum to create strong communication for its local projects, but harder to communicate the insights of higher level processes. At local levels, projects and initiatives had a concrete presence, long-term involvement of familiar faces and tangible results (TransForum 2010). Therefore, it was easy to cater to both analytic and experiential communication modes. TransForum used these local projects to create a strong media presence (TransForum 2011). At higher levels these benefits were not so clearly present.

TransForum was also conscious of the limiting nature of images, mental models and discourses, and refrained from overlaying these over the diverse nature of the projects in the programme to avoid homogenization and a forced direction (Veldkamp et al. 2008; Beers et al. 2010). Later in the programme, though, an overall vision was created Metropolitan Agriculture (Van Latesteijn and Andeweg 2010). This vision allowed for different discourses on sustainable agriculture to exist side by side while still providing an overarching image with both analytic and experiential connotations. In retrospect, such a vision would have been valuable from the beginning of the programme, given that it could have been used as a gathering image for the projects under its wings while still allowing for a multiplicity of specific directions and interpretations. These lessons provide higher level links to the challenge of balancing the pre-framing of analytic perspectives as discussed in chapters 3 and 4 and to the challenge of combining experiential and analytic modes of communication in chapter 5 and 6.

7.9 Conclusions and recommendations

This thesis has sought to explore new ways to facilitate societal understanding of and engagement with social-ecological systems change. All of the case studies in this thesis contribute to the conclusion that interactive media tools can take on essential communication challenges in the context of social-ecological systems. They have communicated about social-ecological complexity not by broadcasting information but by letting their users explore and reframe their own perspectives. The design philosophy and application of these tools has pointed toward potentially powerful new ways to use interactive media for more inclusive and participatory forms of science communication.

The following are the basic conclusions regarding our two challenges and design preconditions:

- Interactive visualization can be developed to focus directly on the elicitation and communication of analytic perspectives on social-ecological systems change.
- Combining analytic understanding and experiential engagement can be achieved through separate methods to create flexible outputs with complementary benefits or through full integration to aim for the development of a new type of experience-based, strategic knowledge.
- The preconditions of flexibility, accessibility and feasibility were turned from limitations into guidelines that focused the design of communication tools clearly on complexity while avoiding complicatedness.

The evaluation of the ground covered in this thesis and the gaps and alternatives we recognized in this chapter lead to the following conclusions:

- The conceptual framework mapping out analytic understanding and experiential engagement, and practice-level and conceptual-level content is useful to understand translations within and between communication strategies and tools.
- As a research strategy, we chose to focus on designing tools that focus directly on our communication strategies. This provided specific insights and an in-depth learning experience. Other valuable strategies are comparing new tools with existing tools, and evaluating tools existing outside the science communication domain.

In terms of the societal context of science communication and the facilitation of knowledge development and action, our research has led to these conclusions:

- Participatory strategies in multi-stakeholder contexts aiming for consensus and diversity/individual perspectives in processes such as scenarios development and visioning have problems and benefits. The research in this thesis has focused on eliciting individual perspectives in order to capture the richness of these perspectives first, both in an analytical and experiential sense. We believe this provides an essential basis for more consensus-oriented work.
- The eliciting and sharing of perspectives serves different purposes when seen from a position of knowledge development and capturing uncertainty or from a position of change advocacy- though in practice these goals are strongly interlinked.
- The various tools developed in the research in this thesis have demonstrated that a chosen mode of communication represents a framing of possible perspectives and that the creation of new modes of communication can themselves represent new spaces for perspectives.

Chapter 8
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Appendix A

Guidelines for interactive media design from Landscape Visualization, Serious Gaming and Visual Analytics

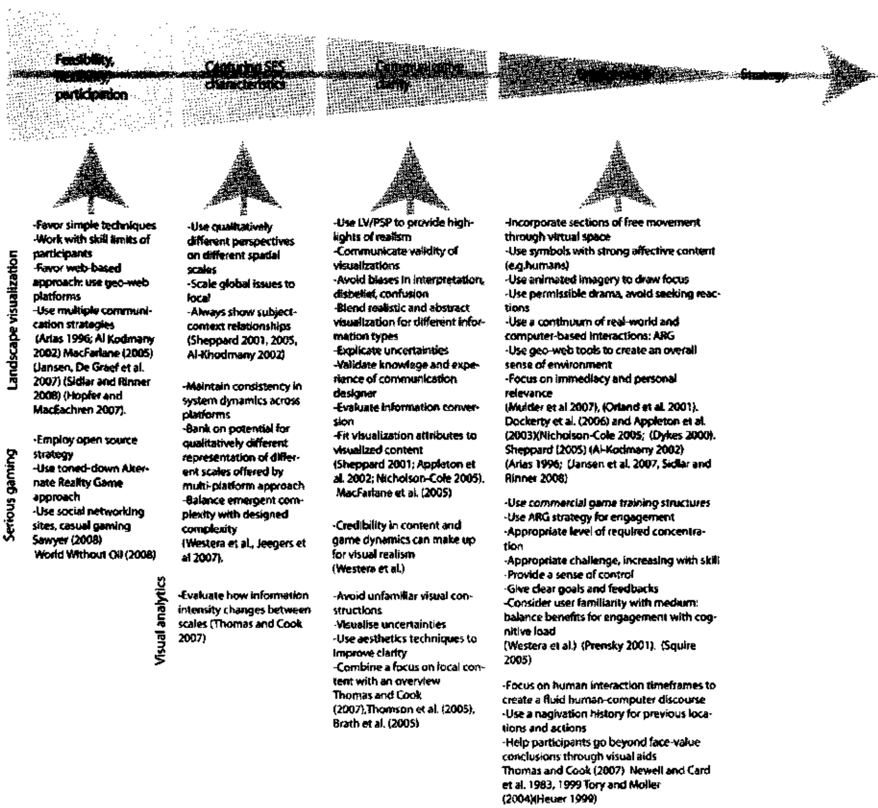

Figure A.1: General guidelines and references for interactive media scenarios. Guidelines in squares are derived from LV/PSP, rounded squares contain guidelines from serious gaming, and circles contain guidelines from visual analytics. Complementing the strategy proposed in this paper, these guidelines can serve as a checklist: considering them can increase the quality of any method of scenario communication wishing to meet the challenges set up in section 3.

Appendix B
Overview of workshop concepts

Table B.1: 51 Workshop concepts that were evaluated as being able to take on one or more of the communication challenges as framed by the criteria in sections 6.3 and 6.3, organized by media formats.

Medium	Concepts
Interactive visuals (5)	1.Show cross-scale change through self-similar fractals. 2. Show sensitivity to initial conditions through chains of effects. 3. Show path dependence of the timing of interventions.
Cross-modal perception (2)	1. Use different senses to capture consistencies and incongruities between system perspectives. 2. Remove specific senses to reframe the environment.
Serious games (digital) (4)	1. The adaptive constructing of organisms. 2. 'Steering' the planet across scenario axes. 3. Playing with the dynamics of a stability landscape. 4. A complex of micro-games moving across scales.
Physical game	1. Create a false sense of order in a system with labels that hide underlying complex dynamics.
Dynamic network visualization (4)	1. Develop storylines through a dynamically changing network. 2. Visualise worldwide communication patterns. 3. Visualise long-term effects of actions passing through networks.
System dynamic modelling visualization (3)	1. Visualize different interacting rhythms in a system dynamic model. 2. Create system transformation in a dynamic model and mark qualitatively different phases.
Agent-based model	1. Create multi-scale nested agent based models.
Physical group interaction (2)	1. Set up a system for connected group drawing to explore feedbacks 2. Use amplification of breathing in a group to explore feedbacks, equilibrium and instability.
Role playing (4)	1. Switch identities for a time to experience different perspectives. 2. Hide individual fields of expertise to reframe identities and the value of knowledge. 3. Re-describe reality by creating a new language with a group that captures complex system dynamics differently. 4. Do as much tasks as possible in a short time to re-experience the relationship between knowledge and action under uncertainty.
Physical installation (5)	1. Start with an object interacting in a set space, then break through that space to a more complex, open environment. 2. Create visual storylines that display the evolution of ideas through reinterpretation by participants. 3. Use moving light profiles programmed to exhibit edge-of-chaos-behaviour. 4. Create a walking machine producing cascading effects. 5 Create moving wall furniture that allows users to play with feedbacks.

Table B.2: 51 Workshop concepts that were evaluated as being able to take on one or more of the communication challenges as framed by the criteria in sections 6.3.2 and 6.3.3, organized by media formats.

Medium	Concepts
Posters, single images (3)	1. Use 3d posters to combine different system perspectives. 2. Use simple, shocking anthropomorphising metaphors. 3. Play with perspectives by linking strong emotions to neutral content and vice versa.
Sculptures (3)	1. Create a sculpture that shows a transition from early life to man through qualitatively different forms of complex systems, using different materials. 2. Create an embedded, multi-level version of the mythological Atlas carrying the world.
Video, animation, documentary (3)	1. Use language as metaphor for complexity and the limits of knowledge in a short film. 2. Visualize different would-have-beens to illustrate path dependency in a short film. 3. Capture the complexity of production and consumption chains through multiple branching storylines.
Use existing environments and infrastructure (3)	1. Hide ambiguous messages pointing to unknown locations and events in formal information infrastructure. 2. Cause periodic or unpredictable disturbances in a given environment to use those present as responding systems. 3. Cause periodic or unpredictable disturbances in a given environment to use those present as responding systems.
Comic	1. Create a path dependence comic with different storylines spiralling outward. 2. Create a coming on a multi-scale timeline that shows cross-scale interactions.
Autobiography	1. Create an autobiography that follows as many storylines of what could have happened as possible.
Store presentation of products	1. Combine the physical setup of in-store product presentation with multi-media to show a range of aspects of the development of the product/food.
Music	1. Use music to link the interplay of processes with a sense of uncertainty.
Elementary school education	1. Start teaching young children how to cultivate their skills of perception, attention and observation
Social media storytelling (2)	1.Present fictional material as real and create viral storytelling. 2. Use the opposite of your message to elicit implicit knowledge.

Appendix C
Other concepts from the final selection

The following concepts from the workshops discussed in the paper were among those selected for review by the complex systems science and design panels, but were omitted to keep the chapter succinct.

Games

ChaosGolf

ChaosGolf is an on-line game of virtual, 3D mini golf, where the player has to navigate a ball through a dynamic, moving landscape that is symbolic for choices and challenges faced by a manager of nature-society interactions. The ball represents the state of the system that is managed, the putts represent actions, and the landscape represents the dynamically evolving field of opportunities and difficulties faced by the manager - this landscape changes while the game is played. The game is framed by a context that explains in what ways the hole the player is playing represents a certain case or scenario. A level editor can allow participants to design their own levels to reflect certain cases or scenarios. The ball changes in shape and properties to reflect change of the subject or agent itself.
Evaluation by expert panels:

- Communication panel experts found this game to be accessible, intuitive and possessing a good balance between transparency and complexity. Their criticism was that the gameplay was not directly involved with the management of uncertainty, but rather with navigating it.

- Complexity panel members gave this game a good evaluation in terms of clarity and engagement criteria. They found its communication of complex systems characteristics to be mostly focused on non-linearity, path dependence and uncertainty.

- Suitable contexts: high-school education and on-line.

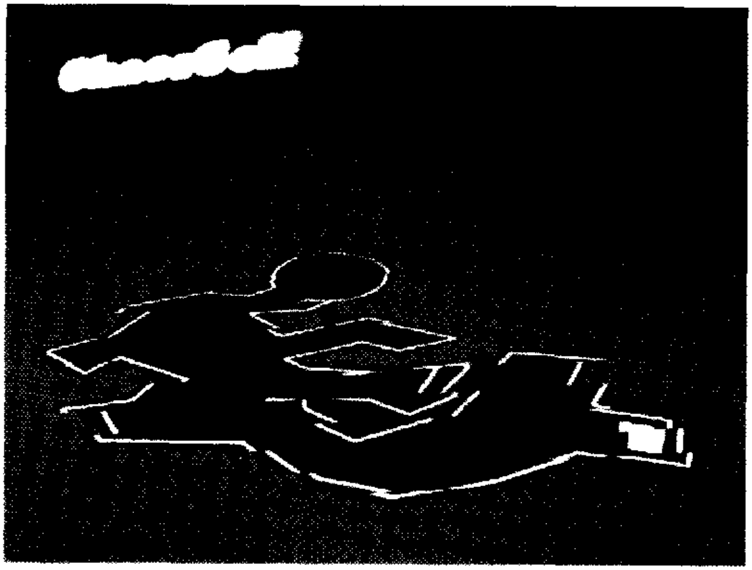

Figure C.1: Chaosgolf concept showing dynamic landscape

Analysis

*Strengths and weaknesses:*Chaosgolf gets high marks for a number of communication challenges, but in terms of the complexity challenges it shows an interesting problem because the player navigates, rather than deals with, the challenges of the dynamic landscape the game goals are not as intricately tied up with the challenges of complex systems as in the other games. The game would also require a lot of extra information about the meaning of the system dynamics, because they are open to interpretation.

*Practical usefulness:*ChaosGolf can easily and accessibly serve a modest function - quickly introduce a sense of dynamic system equilibria and changing contexts in an intuitive and engaging way. It could be a key introductory exercise in many interdisciplinary courses and workshops on complex systems dynamics.

Feasibility of implementation: This game would not need to look spectacular, but instead rely on game-play for its engagement. As a web-based casual game, its game dynamics can be fairly easy to develop.

Spaceship Earth

A scenario storytelling game using a global perspective where the player pilots the planet. A moving globe is located within a tension field of axes that represent the different ways

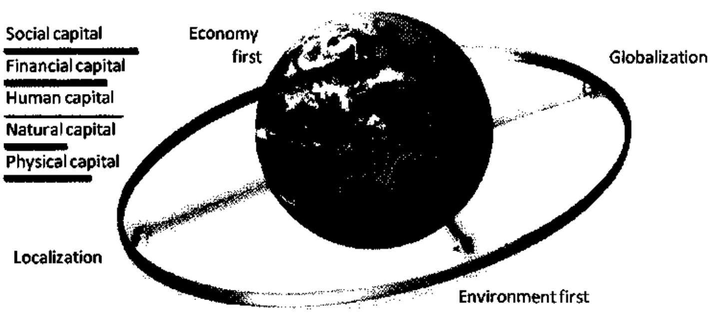

Figure C.2: Simplified example of basic Spaceship Earth elements. Navigating the world through different global change challenges can be done by navigating to a different future, but such a transition has costs, in this example in terms of different types of capital.

in which visions of the future are polarized in scenario assessments: proactive world vs. reactive world, globalization vs. localization, economy first versus environment first, and so on.The player starts out with quantities of several different types of credits (financial support, public engagement, knowledge, technology etc.) that can be used to steer the world towards one variable or another. Different transitions will cost different ratios of these credits. The world itself will mirror the state it is in depending on its position, through a storyline told on its surface. The earth is also the place where (impending) disasters or rapid positive developments can be seen. These developments will be consistent with the kind of world the player has steered toward at that moment: a strongly localized world will have problems with issues on the global level, while a strongly globalized world has to deal with the consequences of global governance schemes that are insensitive to the local scale. In this game, the player creates his/her own vision of the world but it is not a static vision, and they have to deal with the consequences of their choices. They also get a sense of the costs and challenges of making global transitions along these dimensions.

Evaluation by expert panels:

- The communication panel members appreciated this game for its accessibility, engagement and clarity.
- Members of the science panel judged this game concept to be highly informative, clear, engaging and intuitive. They saw its main communication being on non-linearity and feedbacks, with scale issues and perspectives not being prominent in this game.
- Suitable contexts: high-school, college, on-line.

Analysis:

Strengths and weaknesses: This game was valued for its accessibility, engagement and intuitive design. The complexity panel gave this game an exceptionally high rating for its ability to convey the right amount of information. At once problematic and a strong point is its focus on a single (global) scale: it largely ignores scale interactions, but paradoxically allows for consciousness of the global integration of system changes. The complexity panel was very divided on this game's ability to capture a sense of strategic knowledge: some panel members felt that the global focus of the game undermined the possibility of inhabiting specific systems.

Practical usefulness: Spaceship Earth serves a different function from the more abstract games in this selection it aims to develop understanding of the challenges of global governance, and of future uncertainties. It could therefore be useful in educational settings as well as policy/workshop settings. It would be valuable to focus on developing the possibility of choosing between sets of axes for the 'scenarios' in the game, so these could fit actual scenarios exercises.

Feasibility of implementation: Spaceship earth could be fairly simple to design if it used relatively few variables and rigid categories of information tables for its scenario combinations. If the goal was to create a more continuous interaction of game elements that would generate much uncertainty in their possible outcomes, a full model would be needed to drive the game.

Group interaction concepts

Breathing feedbacks

Concept: a group of people has to do a short physical exercise, like walking up and down some stairs. Then, they are brought to a room where multiple microphones have been installed. Each individual does nothing but breathe into a microphone. The sound of the group's breathing is amplified throughout the room, providing individual and group feedback on the breathing. In the beginning, the breathing is chaotic and asynchronous, but after some time, people unconsciously sync up. This exercise works as a metaphor for a complex adaptive system, like an ecosystem or a society, transitioning from a state of relative chaos to a state of relative equilibrium and synchronicity, because of system agents syncing up. Also, the breath is a bodily function that can switch between unconsciousness and conscious control, which extends the metaphor into the subject of adaptive management. The sound is recorded and analysed and discussed further.
Evaluation by expert panels:

- The media experts thought this concept was very engaging, accessible and clear, but not strong in terms of the amount of information communicated.
- This concept was judged by the science panel to be very highly accessible, offering

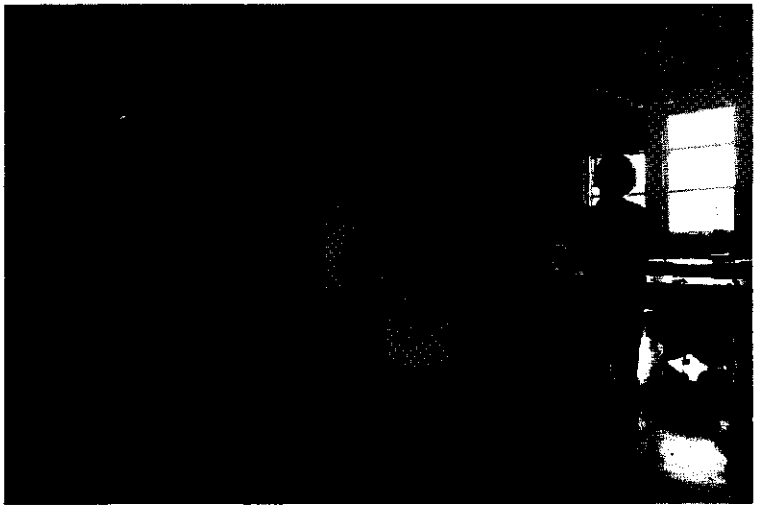

Figure C.3: A successful trial run of Breathing Feedbacks.

a great combination of transparency and maintaining the complexity which makes it very clear and intuitive. A criticism was that it focuses almost exclusively on nonlinearity and feedbacks.

- Suitable contexts: high school, college, workshops, possibly online.

Analysis:

Strengths and weaknesses: Like the Ouija Drawing concept, Breathing Feedbacks received very high ratings for nearly all communication challenges. The amount of information communicated was again seen as low by the communication experts, but as solid by the complexity panel. Most problematic is the ability of this concept to take on the complexity challenges the complexity panel saw its communication limited to the understanding of feedbacks an non-linearity.

Practical usefulness: Breathing Feedbacks is an immersive and pervasive experience of interacting system elements, and as such can be used in educational or workshop settings as an engaging and direct intervention to quickly give a sense of the role of feedbacks and non-linearity in complex systems. Participants literally 'step into the system'.

Feasibility of implementation: The need for a space and the right electronic equipment makes this concept a little more difficult to implement, if far from impossible. As figure C.3 shows, this concept was tested in the workshop, and produced the intended immersive effect.

Social media storytelling concepts

Indicators

Concept: a series of Youtube (2008) videos that shows a person bragging about his capacity to capture the gist of a language in 30 minutes sufficiently to talk and understand native speakers. He then demonstrates his method over a series of videos: a simple, box-relationship model that summarizes a handful of key words and relationships/grammar. This person proceeds to interact with different people using his model of the languages, and the video subtitles show him failing miserably and comically. The video then goes on to show how governments, companies etc. develop indicators for ecosystem health etc., building on the metaphor of what is left out in language Evaluation by expert panels:

- The media panel members were very divided about the accessibility of this concept, but otherwise rated it positively on all fronts.
- The science panel was divided but mostly positive about the accessibility of this concept, but all found it to be engaging and informative. They saw it as mostly communicating on the limits of knowledge.
- Suitable contexts: high school, college, workshops, on-line

Analysis:

Strengths and weaknesses: The complexity panel saw Indicators as being somewhat indirect, but communication panel praised it for its ability to translate the complex concept of uncertainty and lack of knowledge to an understandable metaphor. However, in communicating a main idea rather than displaying system dynamics as some concepts in previous categories, Indicators was not evaluated as able to capture many aspects of complex systems well, apart from an understanding of uncertainty. In short, then, Indicators was seen as a creative and powerful concept, but limited by its single focus.

Practical usefulness: This concept could be useful to quickly make its point in a wide range of settings including educational and workshop settings but also as a general 'social marketing' device, given its great web-based accessibility.

Feasibility of implementation: Great- a first version of this project was already developed during the workshop. The web architecture for its presentation and dispersal through social networks is already available.

Appendix D
Glossary

The following definitions are based on or directly derived from the referenced authors.

Adaptive capacity: The capacity of actors in a system to influence resilience (Folke et al. 2010).

Analytic communication: The sending and receiving of information that is handled by humans' analytic processing mode, such as schemas, statistics, large data sets(this thesis, Marx et al. 2007).

Change agents: Actors who exert their individual agency to innovate and create sustainable, accepted change in the systems in which they operate (Anderies 2008)

Communication: the sending and receiving of information between individuals and groups moderated by forms and modes of presentation, reflecting and creating shared realities (Craig 1999; Barnlund 2008).

Complex adaptive systems: Systems that are irreducible to their constitutive parts; are made up of dynamic networks of interactions; have the ability to adapt to their development history; are sensitive to their initial conditions (Levin 1999).

Complexity (in social-ecological systems): A system can be characterized as complex if its future state cannot be deduced from the functioning of its parts (Levin 1999).

Dimension: A bare aspect of reality or phenomena to which scales are applied. Examples are time, space, temperature (this thesis).

Engagement: The affective involvement with content (Xiang and Clarke 2003)

Experiential communication: The sending and receiving of information that is handled by humans experiential processing mode, such as direct experience, vivid imagery, engaging stories (this thesis, Marx et al. 2007).

Feedback loops (positive or negative): The output of the system directly or indirectly changes the input of the system; in positive feedback loops, output amplifies input; in negative feedback loops, output attenuates input (Levin 1999).

Framing: Cultures, groups and individuals structuring and delineating how the world is perceived and interacted with (Tversky and Kahneman 1985).

Interactive visualization: Visualization that allows for and responds to changes by users (Thomas and Cook 2007).

Knowledge visualization: The study of abstract schemas, concepts and metaphors as accessible, clear and intuitive carriers of information (Thomas and Cook 2007)

Landscape visualization: The part of digital geographic visualization that deals with 3D visuals (Sheppard 2005).

Level: A position on a scale. Examples of levels are countries, watersheds, ecosystems and households (Gibson et al. 2000).

Multi-modal communication: Communication employing multiple senses such as hearing, sight and smell (Sharma et al. 1998).

Myths of Nature: Alternative conceptualizations of how natural systems react to disturbance (Holling 1979).

Non-linear change: Output in a system is not directly proportion to its input (Levin 1999).

Participatory/ multi-stakeholder scenarios/visions: Plausible or desired futures developed by multiple stakeholders with distinct goals, perspectives and societal positions (Kok et al. 2006; Wilkinson and Eidinow 2008).

Personal scenarios/visions: Alternate plausible/desired futures developed by an individual rather than a group (this thesis).

Resilience: The capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure and feedbacks, and therefore identity, that is, the capacity to change in order to maintain the same identity (Folke et al. 2010).

Scale: A measure used to structure a dimension (time, space, power), such as the Julian calendar and the metric system(Gibson et al. 2000).

Scenario communication: Communication strategies associated with the development of alternative futures (this thesis)

Scenarios: Descriptions of possible futures that reflect different perspectives on past, present, and future developments (van Notten et al. 2003)

Serious gaming: A computer-based contest with an artificial intelligence or other players that uses game enjoyment for training purposes (Greitzer et al. 2007)

Social-ecological systems: Integrated system of ecosystems and human society with reciprocal feedback and interdependence. The concept emphasizes the humans-in-nature perspective (Folke et al. 2010).

Time orientation: The basic structuring of an individual's time experience: the relative importance placed on past, present and future (Zimbardo and Boyd 1999)

Time perspective: The composite cognitive structures that characterize the way an individual projects, collects, accesses, values, and organizes events that reside in the past, present and future(Hoogstra and Schanz 2008)

Uncertainty (in a futures context): Lack of certainty and knowledge that make it impossible to predict the future. Three levels can be distinguished: technical uncertainty (inexactness), methodological uncertainty (knowledge limited by methods, values, framing) and epistemological or fundamental uncertainty (full knowledge is fundamentally impossible) (Funtowicz and Ravetz 1993).

Visions: descriptions of desired futures (Robinson et al. 2011)

Visual analytics: The science of analytical reasoning supported by a highly interactive visual interface (Thomas and Cook 2007)

Visualization: Any communication that uses visual structures to represent objects, concepts and relationships (Pylyshyn 2003).

Appendix E

Nederlandse samenvatting

Gedurende de laatste decennia is via verschillende wetenschappelijke disciplines het besef gegroeid van de complexiteit en onzekerheid die verbonden natuurlijke en menselijke systemen of sociaal-ecologische systemen kenmerken. Maar dominante maatschappelijke beelden, mentale modellen en discoursen schilderen deze complexiteit op over-simpele en bevooroordeelde wijzen af. Nieuwe, interactieve media hebben de potentie om maatschappelijke communicatie over social-ecologische complexiteit voorbij deze beperkte vormen van communicatie te helpen. Het doel van het onderzoek in deze Ph.D. dissertatie is het gebruiken van interactieve media voor het vangen en communicaren van een grote verscheidenheid aan maatschappelijke perspectieven op verandering in sociaal-ecologische systemen.

De dissertatie gaat in op twee fundamentele uitdagingen: 1. Het vangen en delen van verschillende analytische perspectieven (besproken in hoofdstukken 3 en 4) en 2. Het combineren van analytisch systeembegrip met experientieel engagement (hoofdstukken 5 en 5). De uitdagingen worden besproken in hoofdstuk 1. De onderzoekers pakken deze twee uitdagingen uit door het ontwerpen, inzetten en evalueren van een serie van nieuwe communicatiemiddelen. De toegankelijkheid, flexibiliteit en haalbaarheid van tools zijn criteria die door de hele dissertatie worden gehanteerd.

Om het onderzoek te kaderen gebruikt hoofdstuk 2 de uitdagingen uit het eerste hoofdstuk om tools en strategieen te identificeren die momenteel worden ontwikkeld en gebruikt in verschillende onderzoeksvelden die verbonden zijn aan communicatie over omgevingswetenschappen. Het hoofdstuk begint met communicatie over toekomstscenarios en onderzoekt daarna landschapsvisualizatie, serious gaming, visual analytics en informatievisualisatie. Een evaluatie van deze velden concludeert dat op de manier waarop ze nu gebruikt worden de verschillende tools en strategieen uit deze vakgebieden ieder hun krachten en zwaktes kennen as het gaat over het communiceren over social-ecologische systeemverandering. Om voorbij deze limitaties te komen stelt het hoofdstuk een ontwerp-framework voor dat verschillende elementen uit de voorgaande evaluatie combineert. Allereerst wordt web 2.0 technologie voorgesteld voor het integreren van verschillende platforms. Daarnaast worden design methodes uit pervasive gaming gebruikt om inhoud gegenereerd door gebruikers in te zetten om analytische communicatie en engagement te faciliteren.

Hoofdstuk 3 brengt verslag uit van onze eerste strategie voor het vangen en delen van verschillende analytische perspectieven op social-ecologische systeemverandering. De System Perspectives Scope is een tool die verkent hoe participatieve modellen kunnen worden gebruikt om perspectieven van verschillende maatschappelijke actoren te vangen op de ruimtelijke en temporele dimensies van complexe systemen. Het gebruik van deze tool in twee case studies laat zien dat het mogelijk is om expliciet te richten op ruimtelijke en temporele systeemniveaus en hun interacties, verschillende manieren om temporele verandering te begrijpen en verschillende basisperspectieven op hoe social-ecologische systemen veranderen. Dit alles gebeurde door een vrij simpele tool in een toegankelijke on-line context. Resultaten van dit onderzoek wijzen op significante relaties tussen verschillende perspectieven op ruimtelijke en temporele systeemniveaus en verschillende perspectieven op systeemdynamiek.

Hoofdstuk 4 verkent een andere analytische strategie waarmee de mentale modellen van sleutelpersonen meer volledig en fundamenteel gevangen zouden kunnen worden. We beginnen met de aanname dat change agents in social-ecologische systemen in dit geval de landbouw-innovatoren in het TransForum project- ervaring moeten hebben met het verbinden van een grote hoeveelheid conceptuele dimensies in hun pogingen om geaccepteerde veranderingen te creeeren. Hierbij zullen zij niet alleen kijken naar de biofysische dimensies maar ook naar institutionele dimensies, netwerken, kennisdimensies, machtsdimensies enzovoort. We stellen ook dat deze dimensies, en de schalen die agents of change gebruiken hen in staat stellen om volgens hen cruciale systeemdynamiek in kaart te brengen die tussen die schalen afspeelt. We hebben daartoe een serie diepte-interviews afgenomen met een methode genaamd de Scale Repertoire. Deze methode hielp om multi-dimensionele perspectieven van change agents te vangen die interacties tussen schalen weergaven binnen een project of regio. Het onderzoek in dit hoofdstuk bevestigt dat change agents inderdaad in staat waren om een brede verzameling aan schalen te gebruiken om cruciale multi-schaaldynamiek bloot te leggen. Op basis van deze bevindingen pleit het hoofdstuk voor het betrekken van sleutelfiguren buiten de wetenschap in interdisciplinair onderzoek naar de rol van schaal in het beheren van complexe systemen. Verder zou bewustzijn van dimensies, schalen en schaalniveaus in maatschappelijke debatten moeten worden gestimuleerd.

In hoofdstuk 5 onderzoeken we de tweede uitdaging: het combineren van analytisch begrip met experientieel engagement in communicatie over sociaal-ecologische systeemverandering. We hebben daartoe twee workshops georaniseerd met locale groepen die zich richten op duurzame ontwikkeling in het kader van een case study in de county Oxfordshire in het Verenigd Koninkrijk. We gebruikten een live versie van de System Perspectives Scope uit hoofdstuk 3 samen met ScenarioCommunities, een interactieve tool voor het vertellen van verhalen uit toekomstscenarios. ScenarioCommunities bleek in staat om engagement op te wekken, werd als levendig ervaren en was in staat de participanten te motiveren om hun eigen levendige verhaallijnen te schrijven. De System Perspectives Scope ving de individuele mentale modellen van participanten en faciliteerde analytische reflectie bij hen op deze modellen. Deze positieve resultaten van beide tools zijn complementair en werden ook zo gezien door participanten. Het sterk participatieve karakter droeg bij aan zowel de ervaring van het process door participanten en de capaciteit van de tools om resultaten te genereren. De workshop die begon met de tool gericht op experientieel engagement werd als succesvoller ervaren en genereerde meer resultaten dan de workshop die begon met de analytisch-georienteerde tool. Hoewel de case study klein was, zijn de resultaten over dit verschil consistent genoeg om te suggereren dat de transitie van engagement naar analytische interactive natuurlijker is dan de tegenovergestelde transitie.

Een alternatieve aanpak van de uitdaging om analytisch begrip te combineren met experientieel engagement was het richten op een volledige fusie van deze twee communicatiemodi. Om deze richting te verkennen brengen we in hoofdstuk 6 verslag uit van een samenwerking met multi-media designers en kunstenaars van buiten de wetenschapscommunicatie doormiddel van een serie workshops. Deze samenwerkingen genereerden ideeen voor serious games, interactieve groepsopstellingen en storytelling op sociale media. De game concepten en interactieve groepsopstellingen bleken het beste in staat om complexe systeemdynamiek te vangen. Deze concepten werden ingeschat als goed in staat om engagement te genereren en richtten zich op het ontwikkelen van strategische kennis. Waar de interactieve groepsopstellingen fysieke ruimten gebruikten waren de games door hun on-line implementatie bijna onbeperkt inzetbaar. De storytellingconcepten op sociale media werden hoog gewaardeerd op het gebied van engagement en intuitief ontwerp, maar scoorden minder hoog in hun geschatte capaciteit voor het vangen van complexe systeemdynamiek. Het exploratieve karakter van dit onderzoek betekende dat we niet in de gelegenheid waren om alle concepten uit te testen. In plaats daarvan vertrouwden we op de opinies van experts voor een beoordeling van het potentieel van de concepten. Met deze beperking in acht genomen suggereren de resultaten van dit project dat experientieel engagement en analytisch begrip geheel samen kunnen gaan en dat games en interactieve groepsconcepten kunnen bijdragen aan de ontwikkeling van strategische kennis bij hun deelnemers. Tenslotte geeft deze case study een sterk argument voor collaboratieve initiatieven tussen wetenschapscommunicators en multi-media designers en kunstenaars.

In de synthese (hoofstuk 7) concluder ik dat interactieve visualizatie kan worden ontwikkeld op zon manier dat het zich direct kan richten op het vangen en communiceren van analytische perspectieven op sociaal-ecologische systeemverandering. Ook kunnen analytisch begrip en experientieel engagement worden gecombineerd door het gebruik van gescheiden methoden of door de volle integratie van deze modi, waarmee op het ontwikkelen van strategische kennis kan worden gericht. De vereisten van flexibiliteit, toegankelijkheid en uitvoerbaarheid veranderden van beperkingen in richtlijnen die ons in staat stelden het design van de verschillende tools te richten op complexiteit zonder ingewikkeld te worden. Onze op design gerichte onderzoeksaanpak levered specifieke inzichten op en een diepe leerervaring. Ik wil stellen dat het richten op de diversiteit van perspectieven in een multi-stakeholder context een sterke basis biedt voor meer op consensus gericht werk. Door onze samenwerking met kunstenaars en designers werd het duidelijk dat verschillende modi van communiceren zelf ook nieuwe ruimtes voor perspectieven kunnen inhouden. Ik raad aan dat wetenschaps-communicators zich direct richten op de karakteristieken van complexe systemen, en dat er gericht wordt op het combineren van analytische en experientiele vormen van communicatie maar ook van communicatie die zich richt op praktische en conceptuele niveaus van content. Beperkingen door de noodzaak tot toegankelijkheid, flexibiliteit en haalbaarheid moeten in sterktepunten worden veranderd. Wetenschappers en kunstenaars zouden moeten samenwerken aan communicatie over complexe systemen; daarvoor moeten kunst en designgemeenschappen worden geinformeerd en geinspireerd. Daarbij moet de communicator zich bewust zijn van zijn of haar rol en doelstellingen. Als laatste moeten mogelijkheden worden gezocht om communicatievormen die bewustzijn over complexiteit en onzekerheid bevorden te institutionaliseren en hun impact op te schalen.

Appendix F

Acknowledgements

As the years went on during my Ph.D., I heard many, many horror stories about thesis supervisors. Lab environments in particular seem to be designed as cruel follow-ups to the Stanford prison experiment. I always felt very lucky when I heard these stories. My supervisors Kasper Kok, Tom Veldkamp, Ron van Lammeren and for a large part of the Ph.D. - Arnold Bregt introduced me to a world of great research, gave me all the freedom to chase my ideas, while tactfully reining me in and making sure my work stayed more or less within the boundaries of feasibility. Even when time was running out they still green-lighted two research projects, confident that I could pull them off. I'm very grateful that they did, these projects have turned to be some of the most interesting research in the thesis and allowed me to gain great new experiences. Kasper, thanks for being so supportive over the years and for the many, many hours you spent with me to discuss ideas, science and the wider world and in particular, music that makes other people draw back in horror. I'm glad we are able to continue working together and I'm looking forward to many more opportunities for us to talk ideas and music! Tom, somewhere in the mass of literature I consumed over the years I read that the true mark of generative leadership is the ability of the leader to leave his people energized and inspired whenever they meet. I always left our meetings that way, and with clear ideas of how to move forward. Thanks for your vision and support - and for bringing us along on a fantastic trip to Kenya! Ron, it was a pleasure to be able to discuss my work with you because of your background and interests, you were always able to connect my ideas to great areas of research and tantalizing new options to explore. Your enthusiasm for this type of work is contagious! Arnold, thanks very much for your continued engagement with my research even after your work as official supervisor had ended I appreciate your sharp and honest but constructive view.

My team of supervisors were part of a wider group of great colleagues. I'd like to say thank you to all my colleagues at Land Dynamics, particularly my roommates Dirk van Apeldoorn and Frans Hermans. Between the three of us we developed a kind of micro-innovation arena where many disciplines met while we got to know each other. Dirk, you're an exceptionally insightful and grounded guy and I really hope we can set something up together under the CCAFS flag, they need you! Frans, your skeptic, highly critical approach to research and healthy pessimism has been a great (and funny) antidote to my sometimes unrealistic can-do mode of operating. Thanks for your key input into the Scale Repertoire work, and for not killing me in Embu when I was too drunk to stop laughing. Special thanks also go out to Henny van den Berg and Mieke Hannink for dealing with my endless questions and to Jetse Stoorvogel for giving me a break and letting me go to Phoenix after all. Mathijs van Vliet, my scenari-bro! Thanks for the time teaching classes together and swapping tips and literature. I still remember when we met in Duivendaal and we decided to go and chase away some annoying kids throwing snowballs. Good introduction! Derek van Berkel, thanks for being hardcore in Kenya and drinking Tuskers night after night discussing research, religion and the role of violence in the world until your feeble digestive system put an end to the fun. In the wider world of Wageningen UR I would like to thank Marjanke Hoogstra for finishing her Ph.D. at just the right day which led to some inspiring work together on the System Perspectives Scope. Last but not least, thanks to my students Wim Joost van Hoek and Jery Hsu for great enthusiasm, hard work, and some interesting travel together.

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A few months before I finished this Ph.D. thesis I started work at the Environmental Change Institute at the University of Oxford. Working in this great environment gave me a new perspective on my work just before the finish line. Before I was even invited for an interview I had already met the extraordinary miss Ariella Helfgott. Thank you for being an atomic force of warmth, energy and inspiration. Thanks also dr. John Ingram for being so appreciative of the difficulties of doing a full-time job and a thesis, for being a real example in your tireless dedication to doing great and relevant work, and of course, your talent at putting the right person in the right position. Anita Ghosh, I have survived the thesis/CCAFS trial partly because of your great help. Angela Wilkinson, I feel very privileged to benefit from your insights and experience, thanks for bringing me into the Oxford scenarios fold. Meeting Jerry Ravetz and Rafael Ramirez has also been a delight, thanks for some great re-framings of research, academia and life in general. The last months of my Ph.D. have taken me to other places than Oxford, most notably Nairobi and the CCAFS teams over there. Polly Ericksen, Wiebke Foerch, Moushumi Chaudhury, Patti

Kristjanson, Philip Thornton, Mario Herrero, thanks for being such great colleagues, the fruits of our work together are sprinkled over this thesis.

When I realized the challenges I would be facing in this highly interdisciplinary research project I immediately turned to my friends, many of whom were talented and experienced in areas crucial to the project. Even back in the early days of the Ph.D. journey when I still needed an hour to explain what my project was about, these friends were very interested in where things were going and eager to help out. Rolf Janssen, you have been part of this work from the beginning. Thank you for all the late weekend hours you have put into the various tools we designed together and for the many discussions and plans that we came up with as we went along. Thanks especially for your patience with my constant requests for last minute changes! Tim Bakker, it was great working on the scenario material together you've got great skill at interpreting and synthesizing information into strong imagery, and that is a rare gift. Lucas Rutting, it's been a long journey from 'de vibe' to 'in recent decades'! Thanks a lot for your part in the Scale Repertoire research, I hope we can continue to cook up and experiment with new stuff for a long, long time. Richard Japenga, even though we never found the time to take some of our on-line concepts as far as we would have liked, thanks for a lot of great machine-gun-speed chats and some key work on the design of the interface we did end up using. Paul van der Aalst, Demian Snel, cheers for giving me your opinions and serving as test bunnies. Thanks a lot to Larry Kendrick for providing staggeringly good vocals for our Oxfordshire scenarios!

Ever since we were little kids, Bram Spoor and I have shared a hunger to learn - about science, philosophy, history, literature, music, martial arts. Our careers have brought our expertise and interests even closer together to the point where we have been able to discuss systems complexity, the roles of power and knowledge and even scenarios practice. I know we will end up doing great work together at some point. Fantastic to have you as a paranymf. Charissa de Bekker motivated me to do a Ph.D. years ago thanks for the sharing of woes and advice! Oceans are stupid. I also spent many an evening talking with Wouter Kouwe about new ways to view our lives, jobs and ambitions. Cheers! Karel Terlaak, you're the walking definition of resilience. Thanks also to Jayant Makhan for some sorely needed discussions that always quickly cut through the veneer of every day routines and hit the weird phenomenon that is existence. Cheers to the rest of the old Vught crew (Miel, Thijs, Gijs, Ron, Nils, Bjorn) and their significant others, here's to lifelong friendship.

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Throughout my Ph.D., I have lived another life a life of practice sessions, gigs and recording studios. I have my bandmates to thank for some of the best moments of my life. A fair part of this Ph.D. thesis has been written in a tour van. My first practice session with the band that was to become Terzij de Horde was on the eve of the interview for the Ph.D. position, and there has been a parallel progression with band and work since then.

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Curriculum vitae

Joost Vervoort holds an MSc. in Natural Resources Management from Utrecht University. Aside from his Ph.D. research, he has helped co-ordinate a researchers' training and discussion platform 'Stakeholder Participation in Scientific Research' from 2008 to 2010.

Joost has recently taken up the position of Scenarios Officer for the CGIAR Core Research Programme 7, CCAFS (Climate Change And Food Security), at the Environmental Change Institute, University of Oxford. He divides his time between the Netherlands (where he lives with his girlfriend Elisabeth van de Grift), Oxford and the CCAFS regions. Joost is vocalist for the band Terzij de Horde, who have just released a vinyl EP with US-based label Antithetic Records.

PE&RC PhD Education Certificate

The C.T. De Wit Graduate School PE&RC PRODUCTION ECOLOGY & RESOURCE CONSERVATION

With the educational activities listed below the PhD candidate has complied with the educational requirements set by the C.T. de Wit Graduate School for Production Ecology and Resource Conservation (PE&RC) which comprises of a minimum total of 32 ECTS (= 22 weeks of activities)

Review of literature (6 ECTS)
- Stepping into futures: exploring the potential of interactive media for participatory scenarios on social-ecological systems

Writing of project proposal (4.5 ECTS)
- Thresholds to the future: envisaging regime-shifts in social-ecological systems

Post-graduate courses (7 ECTS)
- Complexity in and between social and ecological systems; PE&RC (2007)
- Getting to the bottom of Mount Kenya; PE&RC (2010)
- Scenarios development: SCENES (2008)
- Geo-visualization; LGIRS (2008)

Invited review of (unpublished) journal (2 ECTS)
- Landscape and Urban Planning: serious gaming (2010)
- Agronomy for sustainable development: participatory cropping systems development (2011)

Deficiency, refresh, brush-up courses (3 ECTS)
- Advanced programming in Java; WUR ITC (2008)

Competence strengthening / skills courses (1.5 ECTS)
- Mobilizing your scientific network; PE&RC (2009)
- Facilitation skills workshop; Stakeholder participation in scientific research PE&RC Group (2010)
- Collaboration of workshops at PLUK social innovation: personal skills for co-sensing, co-presencing, co-creating in multi-actor work; PLUK (2011)

PE&RC Annual meetings, seminars and the PE&RC weekend (1.2 ECTS)
- PE&RC Weekend (2007)
- PE&RC Day (2009)

Discussion groups / local seminars / other scientific meetings (5 ECTS)
- Stakeholder participation in scientific research (2007-2010)
- SPAM (2010)
- Seminar on greensport shanghai (2009)
- Seminar on affective responses to environments (2010)
- Centrum Landschap meetings (2009)

International symposia, workshops and conferences (8.2 ECTS)
- Resilience alliance conference; Stockholm (2008)
- Fifth international conference on multimedia and ICT in education; Lisbon (2009)
- Scaling and governance; Wageningen (2010)
- Resilience alliance conference; Phoenix (2011)

Lecturing / supervision of practical 's / tutorials (6.6 ECTS)
- Frontiers of land science; 2 days (2009)
- Supervision BSc thesis; 5 days (2010)
- *Metamedial swarms; 5 days (2010)*

Supervision of 1 MSc student; 6 months (2 ECTS)
- Interaction design for scenario development tools
- Stakeholder perspectives on cross-scale dynamics