Building Bridges

Researchers on their experiences with interdisciplinary research in the Netherlands

RMNO, KNAW, NWO, COS
2006

Ymkje de Boer, Alice de Gier, Marije Verschuur and Bert de Wit

Colophon

ISBN 90-72377-65-6
Title
Building Bridges
Subtitle
Researchers on their Experiences with Interdisciplinary Research in the Netherlands
Published by
RMNO, KNAW, NWO and COS

Author
De Boer, Ymkje
Interviews, co-editing
Alice de Gier, Marije Verschuur and Bert de Wit
Translation
Marilyn Hedges
Design
A10plus
Illustrations
Sybren Vlasblom

1163

RMNO
The Advisory Council for Research on Spatial Planning, Nature and the Environment advises the government, either on its own initiative or in response to requests from ministries, on the content and organization of research concerning spatial planning, the environment, nature and landscape.

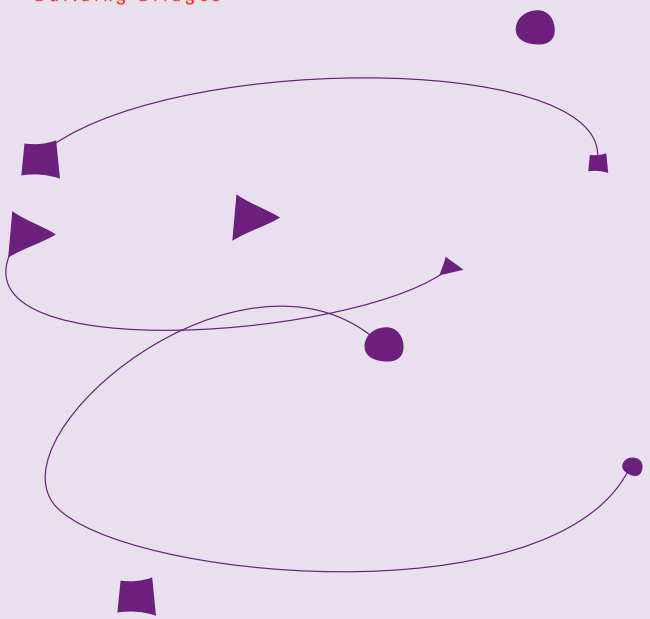
KNAW
The Royal Netherlands Academy of Arts and Sciences' mission is to ensure the quality of scientific research in the Netherlands. The fundamental research carried out today will provide a basis for the applied research of tomorrow and, in turn, for the practical application of science in the future. Main functions of the Academy are:

- advising the government on matters related to scientific research
- assessing the quality of scientific research (peer review)
- providing a forum for the scientific world and promoting international scientific cooperation
- acting as an umbrella organisation for the institutes primarily engaged in basic and strategic scientific research and disseminating information.

NWO
NWO has the following statutory mission. The Netherlands Organisation for Scientific Research:

- is responsible for enhancing the quality and innovative nature of scientific research as equally initiating and stimulating new developments in scientific research
- mainly fulfils its task by allocating resources
- facilitates, for the benefit of society, the dissemination of knowledge from the results of research that it has initiated and stimulated
- mainly focuses on university research in performing its task.

COS
The COS is an umbrella organization of cooperating Sector Councils and other exploratory institutions which operate under the legislative framework relating to Sector Councils for research and development. In addition to serving as a consultative platform, it is also the objective of the COS to stimulate cooperation between members involved in exploratory and (programming) studies (including by means of financial contributions from Sector Councils' Coordination Funds), and to promote members' shared interests.



Content

Foreword 7

Motivation 9

1. On disciplines and 'disciplinarities' 11
   Five Types of Scientific Collaboration 12

2. A spectrum of experiences and sample projects 16

3. The added value of interdisciplinarity 19
3.1 Societal Impact 19
3.2 Scientific Innovation 19
3.3 Spin off in new projects 21
3.4 Personal development 22

4. Impediments to interdisciplinarity 23
4.1 Lack of prestige in classical academia 23
4.2 Limited opportunities for publication 25
4.3 Natural vs. social scientists and other paradigmatic confusions 26
4.4 Institutional barriers 28

5. Paths towards integration of scientific knowledge 30
5.1 Building bridges and creating common foundations 30
5.2 Learning to speak one another's language 32
5.3 The competences of the team members 35
5.4 The role of informal knowledge 37
5.5 Methods for integrating questions, results and data 38
5.6 Qualitative + quantitative = ? 44
5.7 Quality loss of data 45

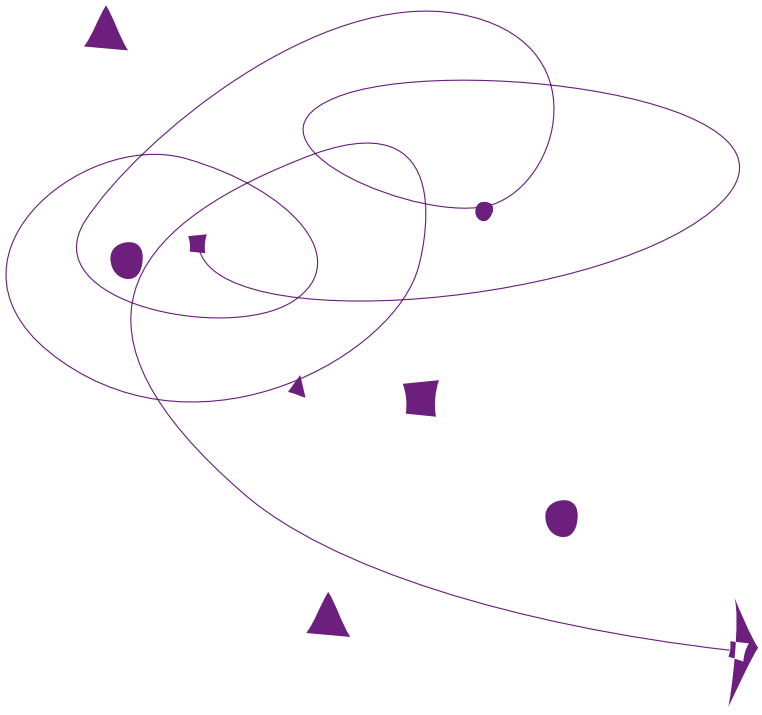
6. Directing and organizing interdisciplinarity 47
6.1 Interdisciplinary leadership 47
6.2 Competences of interdisciplinary leaders 49
6.3 Working plans 50
6.4 Agreements, progress meetings, communication 51
6.5 Physical proximity 52
6.6 Previous experience as factor for success 53
6.7 Reserving separate time, manpower and funds for coordination 54

7. Reflection 58
7.1 Building bridges 58
7.2 Some recommendations 60
7.3 Epilogue 61

Appendix 1 62
List of researchers interviewed 62
About the researchers interviewed 63

Appendix 2 68
Questionnaire used in the discussions with researchers 68

List of Abbreviations 71



Foreword

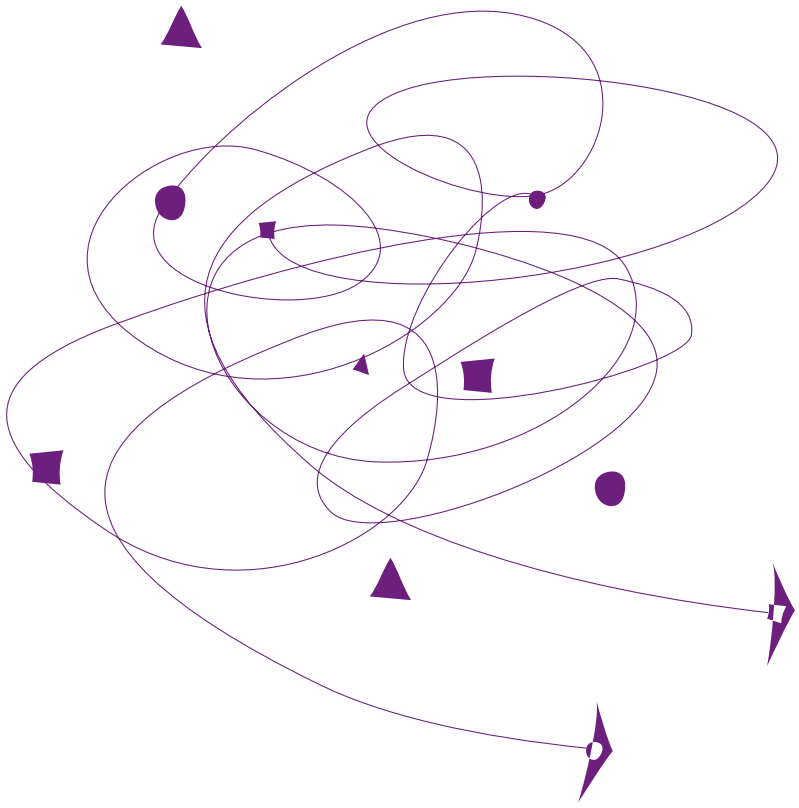
'Building Bridges' is a very 'constructive' title for a booklet that is intended to stimulate thinking about experiences with interdisciplinary research in the Netherlands. Building bridges is much more than merely 'getting to know the enemy' (i.e. the other disciplinarian), which is the last but one stage of interdisciplinary research according to Sjölander (see later).
There are intensive discourses in policy and in research organizations in favour of or against interdisciplinary research. These discourses are based on several convictions, for example that interdisciplinary research is needed to get a grip on complex reality. Or to produce results that are thought to be more relevant to policy-making. Frequently, interdisciplinary research is associated with innovations on the interfaces between disciplines.

Interdisciplinary research is often advocated, but in practice rather difficult to realize. One of the complicating factors might be that the award system and the quality control system in scientific institutions is based on the division in scientific disciplines. Interdisciplinary research is only a minority of the research carried out in the Netherlands. Considering this situation, the question presents itself what experiences researchers have gained and to what extent these experiences might be of use for those researchers who for one reason or another get themselves involved in interdisciplinary research. If we do not pay attention to these experiences, some people might say we do not spend research money in an efficient way, neglecting what we can learn from interdisciplinary research in the past. This is one reason for paying attention to interdisciplinary research and learning processes. The other, more interesting reason is that interdisciplinary research under certain circumstances may produce added value, in the form of new insights, new combinations, integrated views and specific knowledge.
So the central question in this booklet is: what can we learn from interdisciplinary research and individual interdisciplinary researchers? How did they deal with specific problems in the field of epistemology, methodology and organization? What kind of persons are best suited to carry out interdisciplinary research or fulfil the task of project or programme coordinator?
For this purpose, a series of interviews was held with fifteen scientists in the Netherlands by staff members of RMNO, KNAW and NWO: Bert de Wit, Alice de Gier and Marije Verschuur. Most, but not all of the researchers interviewed are engaged in environmental and climate change research. A minority of the interviewed do research on other topics like demography, social geography, nanotech and philosophy of science. The interviews have provided the basic information for Ymkje de Boer to compose this booklet.

We trust this publication will stimulate discussion, as differences of opinion clearly show up in the text. It may well be that a more profound analysis of certain problems and ideas is needed. As the results of recent surveys of

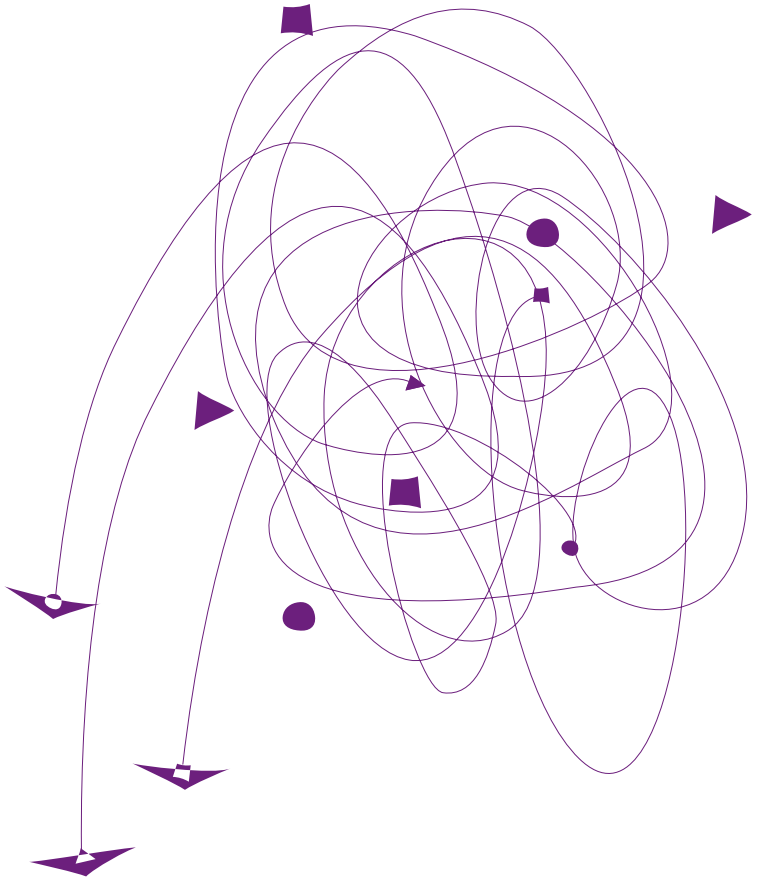
interdisciplinary research practice in Germany, the United Kingdom and the United States are available, a more intricate question is to what extent the Dutch research experiences are characteristic. Which cultural factors have a positive or negative effect on interdisciplinary research in the Dutch context? Last but not least, we hope the discussion will produce clear guidance and recommendations for those who carry out interdisciplinary research in practice.

For KNAW	For NWO	For RMNO
Prof. Frits van Oostrom	Prof. Peter Nijkamp	Prof. Roel in 't Veld



Motivation

This book has come about on the basis of thirteen discussions conducted by Alice de Gier (KNAW), Marije Verschuur (NWO) and Bert de Wit (RMNO) with a total of fifteen scientists. The discussions were based on a questionnaire and a written report was produced. The individuals interviewed have subsequently seen the report and made any necessary corrections. The reports of the discussions were then made available to Ymkje de Boer (YM de Boer Advies). She compared the different comments made by the interviewees by theme, and drew conclusions. In the description of the different subjects, she paraphrased and summarised versions of the opinions of the interviewees and in some instances also included them in the form of a (somewhat edited) quote. Placing the comments outside the context of the full report of the discussion may in a very small number of instances have led to the comments being ascribed a different meaning than that intended by the interviewee. The author has made every effort to avoid this.



1. On disciplines and 'disciplinarities'

TEN STAGES IN INTERDISCIPLINARY COLLABORATION

1. Everyone sings the old songs
2. Everyone on the other side is an idiot
3. Retreating into abstractions
4. The definition sickness
5. Jumping into tussocks
6. The glass bead game (Das Glasperlenspiel, Herman Hesse)
7. The great Failure
8. What happens to me?
9. Getting to know the enemy
10. The real beginning

Sjölander (1985)

Issues on a worldwide scale, such as problems relating to global change, demand the commitment of scientists with different backgrounds and knowledge. Take the example of climate change. Knowledge about natural processes, the technologies which may be applied, and human behaviour taken together, provide a better answer to the question 'how is the problem scientifically defined and what contributions can scientists make to resolve it?' than when considered in separate disciplines. At least, this assumption is frequently made. Not that this type of issue does not require any monodisciplinary research, the fifteen individuals interviewed for this book hasten to add. Also, interdisciplinary research does not by definition provide ready answers with which policy-makers are immediately able to work. Anyone who has experience of interdisciplinarity, moreover, knows that it is more easily said than done. It may be that the ten phases in interdisciplinary collaboration described by the researcher Sjölander in 1985 are all too recognizable.

Nonetheless, interdisciplinary collaboration generates something new or different, both in societal and academic terms.

More will be said later on the subject of the added value and the difficulties of interdisciplinarity, but let us start with the question: what exactly is interdisciplinary research and with what kinds of interdisciplinary research is there experience in the Netherlands? Does this type of research generate new, so-called integral knowledge, or is it rather a case of the (re-)combining or (re-)translating of insights? In other words: is it a matter of integration, interaction or maybe both?

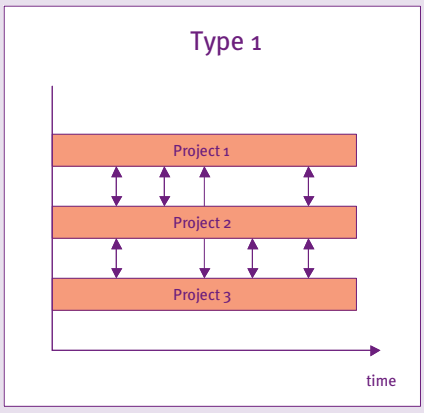
There may be different answers to this question, as is apparent from the experiences of researchers within and outside the Netherlands. Lisa Lattuca (University of Calgary) conducted interviews in 2003 with some forty researchers in four different American institutions. She applied the OECD definition:

> *'Interdisciplinarity is a noun describing the interaction of two or more different disciplines. This interaction may range from simple communication of ideas to the mutual integration of organizing concepts, methodology, procedures, epistemology, terminology, data and terms organized into a common effort on a common problem with continuous intercommunication among the participants from the different disciplines.'* [1]

The typology of different forms of interdisciplinarity which she applied further in her study are generally in line with the classification into five types made by the Dutch consultancy Ackers & De Vries in 2004.[2] These five types of interdisciplinary cooperation have been identified in the practice of some nine research projects financed by NWO/SenterNovem Incentive Programme on Energy Research. This programme aims at interdisciplinary collaboration – more specifically that between natural and social scientists.[3] In order to provide a common basis for the discussions with the researchers for this book, this classification into five types served as a reference framework for all the discussions.

Five Types of Scientific Collaboration

In the typology below an indication is given of how different researchers work together each with his or her own project in a common programme.



Type 1 – Mutual exchange of knowledge

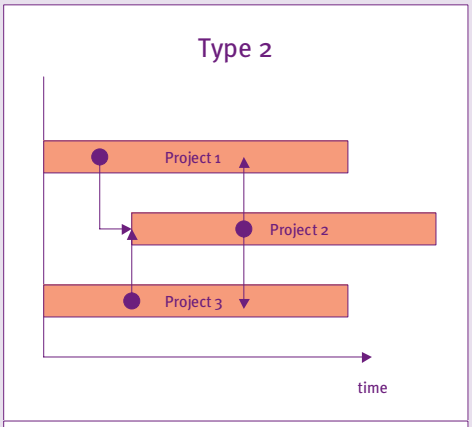
In type 1 integration, the different research projects are independent of one another. The progress of one project will not be determined by the progress of another. They share a common research domain, but they each approach the idea from a different perspective. Regular communication between the

1 *Creating interdisciplinarity: grounded definitions from college and university faculty, Lisa R.Lattuca, History of Intellectual Culture www.ucalgary.ca/hic/ISSN 1492-7810 2003, Vol. 3, no. 1.*
2 *Evaluation of NWO/Novem Incentive Programme on Energy Research, 2004, Ackers & De Vries, Bosch en Duin.*
3 *This programme started in 1999 and is still running. The evaluation by Ackers & De Vries related to an interim study into the progress of a number of programmes, whereby the interaction between natural scientists and social scientists was studied.*

researchers generates understanding for the other person's research perspective and the exchange of insights from the autonomous research projects.

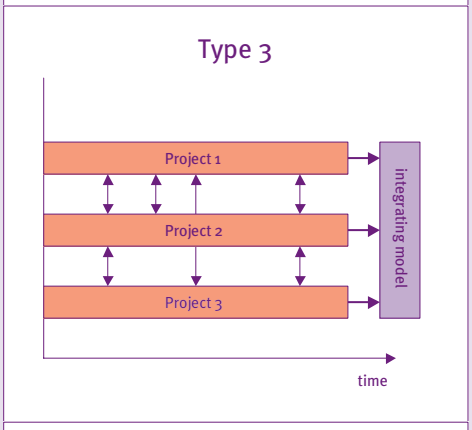
Type 2 – Reciprocal influence

Type 2 integration, in contrast to type 1, is typified by mutual dependence between the research projects. For example: project 2 is dependent on the outcomes of project 1 for its pre-conditions. The research projects need one another and influence one another in terms of content. Ideally, there is exchange inherent in the interaction, so that the projects do have real influence on one another.



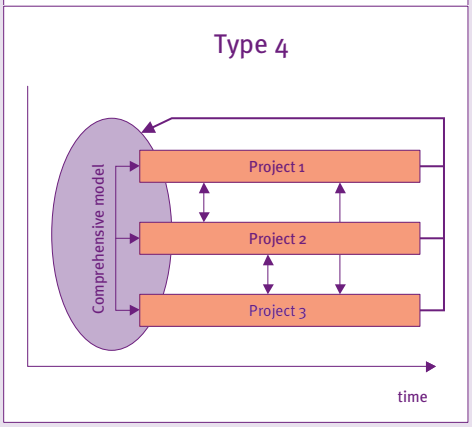
Type 3 – Integration of objectives

The concept of integrating objectives indicates that, in type 3 integration the different research projects will be combined at the end into one entity, which results in a separate model fed by the different projects. The interaction between the projects has a common goal: to fit into the joint result. In this method, the research projects do not originate from one model, but they jointly contribute to the final phase.



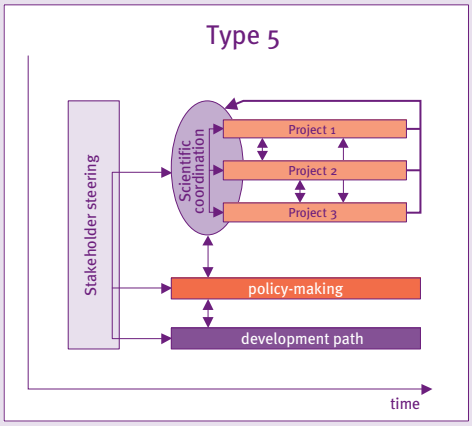
Type 4 – Integration of basis

The core of type 4 integration develops in the preliminary phase of the projects. Different disciplines relating to a subject are considered in relation to one another and are combined into a comprehensive research model. Research projects are initiated and founded on the shared basis, whereby the model indicates where the necessity lies for further development in the relevant fields. The results of these more penetrative projects are used as a repeat loop for improving and interpreting the basic model. The research question in this instance is multi-layered. There is a main question, which is formed in the basic model and each more in-depth research has its own question which is derived from this. In a multidiscipli-



nary programme the basic model is often a complex model. The scientific models of the subprojects may well be 'hard science' or in their turn complex science.

Type 5 – Directed integration



In type 5 integration, as well as internal integration (within the research programme), there is also external integration, whereby the scientific framework is combined with the frameworks of the other stakeholders (for example from policy, society and industry). The research programme is determined in interaction with the other stakeholders and is given a general interpretation, after which each stakeholder develops the issue in his/her own way. This leads to parallel tracks, whereby the scientist seeks further deepening of the issue, and the policy-maker, for example, prepares the policy documents. Ideally there is interaction between the different parallel tracks during the course of the process and the scientific result is integrated in the other tracks.

From: Evaluation of NWO/Novem Incentive Programme on Energy Research, May 2004, Ackers & De Vries, Bosch en Duin.

How does the five-type classification by Ackers & De Vries relate to these other forms of disciplinarity which are often mentioned in the same breath as interdisciplinarity? First there is multidisciplinarity. A commonly used description of this is that a question is looked at from several disciplines side by side, without this leading to integration of the different insights, which provides 'new' knowledge. According to this description, a great deal of what is termed interdisciplinary research meets this definition. There is then no clear difference between the two. What is clear is that in many cases with interdisciplinarity the intention is for a far-reaching form of interaction and integration, while this is not the case with multidisciplinarity.

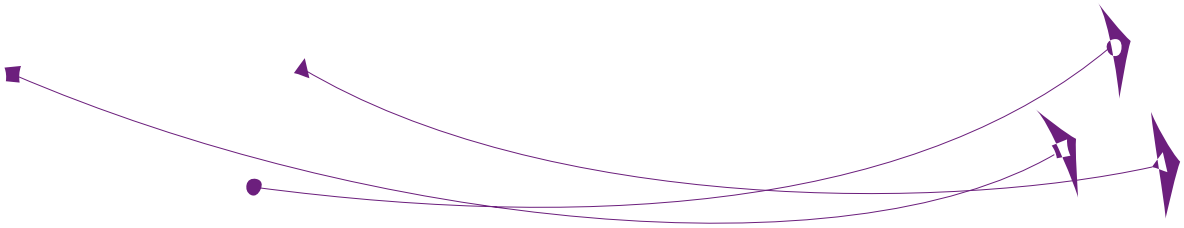
A further concept is transdisciplinarity: academic researchers approach an issue in close cooperation with stakeholders from outside the university who are involved in this issue. Different types of knowledge are thus combined: both academic knowledge and, for example, experiential knowledge.

' With transdisciplinarity, the relationship between science and society and policy is in fact redefined. The context in which knowledge is deve-

loped and applied thereby gains greater emphasis than in traditional monodisciplinary and fundamental research.' [4]

Transdisciplinarity is still a relatively young shoot on the scientific tree and is by no means regarded everywhere as a responsible way of conducting science.

In terms of Ackers & De Vries' five-type classification, 'mutual exchange' (type 1) and 'reciprocal influence'(type 2) could be considered as forms of 'multidisciplinarity' and 'directed integration' (type 5) possibly as 'transdisciplinarity', depending on how the knowledge of the actors is used. In any case, 'integration of objectives' (type 3) and 'integration of basis' (type 4) remain as forms of 'pure interdisciplinarity', if you will.



4 *Advisory Council for Research on Spatial Planning, Nature and the Environment: project on Transdisciplinarity and relevance to policy.*

2. A spectrum of experiences and sample projects

In order to verify the experiences of Dutch researchers with interdisciplinary projects and programmes, a number of interviews were held in 2006.[5] The researchers were selected for their experience with interdisciplinarity. Most of them have experience with all five forms of interdisciplinarity distinguished by Ackers & De Vries, whereby 'integration of basis' is mentioned slightly more often than the other types.

According to Faaij, research which falls into the 'integration of basis' category is often an element of a programme that can be regarded more as the 'directed integration' type.

Remarkably enough, Priemus and Hillebrand state that 'basic integration' research is very rare in their specialist area in the Netherlands or outside.

> *'Type 4 research is too mechanistic. If you want to achieve something within a particular time ('Man on the moon in 1970'), then it is a good model. It assumes a particular hierarchy. This type does not often occur, except for secret research, for example for the armed forces, which assumes a strong organisation.'*

Berk and Kok see a historical development, representing the increasing desire to be more in line with the problem formulation by policy-makers.

> *'The NOP I[6] was a type 1 programme (mutual exchange of knowledge). In the course of time there have been an increasing number of research programmes of types 3, 4 and 5: integration of objective, and of basis, and directed integration.'*

The *Millennium Ecosystem Assessment* [7] and the research work for the IPCC[8] are mentioned by Leemans as examples of types 1, 2 and 3 research. He mentions IMAGE (RIVM)[9] as an example of type 4 research. The COOL programme[10] was mentioned by a number of different researchers as an example of type 4 or 5 research.

5 *The questionnaire which was used can be found in Appendix 1. It was inspired by the Bioconsult report on interdisciplinary cooperation in the DEKLIM climate programme (Bioconsult, 2005).*
6 *National Research Programme on Global Air Pollution and Climate Change; the first phase ran from 1989 to 1995 (in Dutch: NOP I).*
7 *Millenium Ecosystem Assessment, an international programme which highlighted the consequences of the changes in the ecosystem, 2001-2006.*
8 *Intergovernmental Panel on Climate Change, started approx. 1990.*
9 *The Integrated Model to Assess the Global Environment, see www.mnp.nl/image.*
10 *Climate OptiOns for the Long Term, see box.*

COOL

Climate OptiOns for the Long Term

COOL was intended to explore long term options for climate policy in the Netherlands within a European and worldwide context. The programme was to generate information for policy-makers by pooling and applying scientific knowledge from different disciplines. One element of COOL was a dialogue with different stakeholders. A second aim was by nature more scientific: to contribute to the development of methodologies for participative approaches to '*integrated assessment*' studies such as COOL, with a view to improving the effectiveness of decision-making processes. The COOL researchers used both analytical and participative methods. The project ran from 1996 to 2001 and was financed partly by NOP II.[1]

1 *National Research Programme on Global Air Pollution and Climate Change: the first phase ran from 1989 to 1995 (referred to as NOP I), the second phase from 1996 to 2001 referred to as NOP II).*

Other examples of 'directed integration' research are:

- *ATEAM project*[11]
- *Corpovenista*[12]
- *The work of the Scientific Council for Government Policy*
- *TransForum Agro & Groen*[13]

Verbong remarks of type 5 research that this is a different type of integration than with the other types.

> *'... because here the integration should be expressed in the response to the question and/or solution to the problem. This type of integration is almost only possible with policy issues and even then there is an area of conflict between the short term of societal demand and the long term of scientific research.'*

An intriguing consideration is the question whether the integration will be of a different order once it is no longer integration (or interaction) between scientists among themselves, but when other actors are involved in the issue; more will be said on this subject later (see paragraph 5.4).

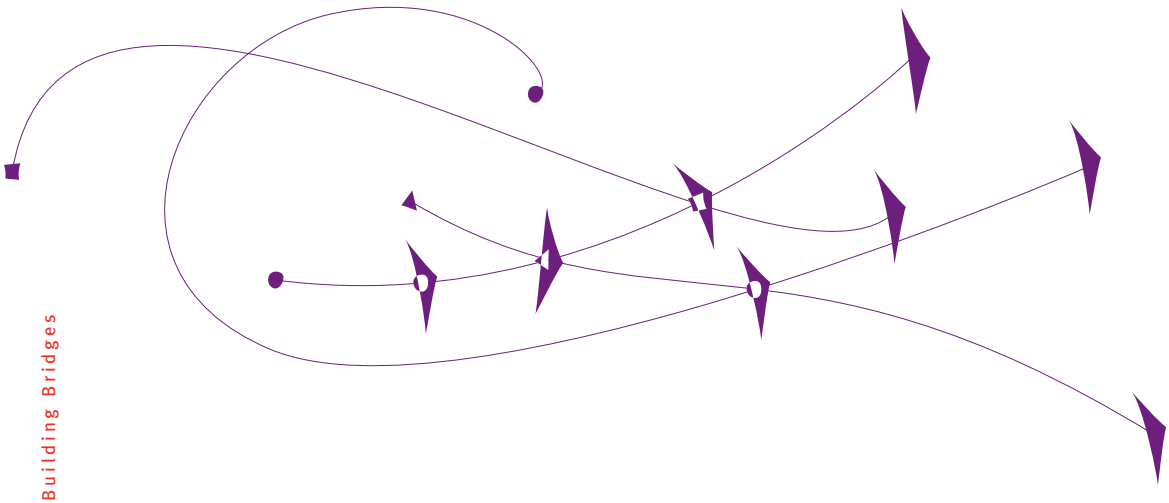
Hillebrand wonders whether transdisciplinary research can always be characterized as a form of interdisciplinarity.

11 *Advanced Terrestrial Ecosystem Analysis and Modelling, see www.pik-potsdam.de/ateam.*
12 *CORPOraties VerNIeuwen de STAd, (Corporations renew the City) a partnership programme by different housing corporations, Aedes and the OTB Research Institute, 2004-2007.*
13 *Knowledge network of researchers and professionals from practice, focused on sustainable business in the agro and food sector and in the vital countryside.*

‘You can work in interaction with the environment, and still do mono-disciplinary research. The majority of the research projects in ‘directed’ research can be monodisciplinary.’

Van Asselt has some experience with transdisciplinary research, but is somewhat sceptical about it.

‘We don’t yet know how it should be done. If stakeholders participate, expectations will often be raised which cannot be met by the scientist. The consequence may be disillusionment and mistrust of academia.’



3. The added value of interdisciplinarity

According to those interviewed, interdisciplinary research has added value in at least four different respects: societal, scientific, organizational, personal. Societal, because very complicated issues can best be dealt with by interdisciplinary knowledge. Scientific because interdisciplinary cooperation (sometimes) leads to new concepts, models and methods. Organizational because interdisciplinary cooperation can generate new partnerships, projects and research funding. Finally, there is also a 'personal' or more competence-related aspect. Different researchers have indicated that interdisciplinary work means an enrichment of academic life.

3.1 Societal Impact

Almost all the researchers interviewed indicate that interdisciplinarity is particularly appropriate when resolutions are sought for complex societal problems. In these instances, considerable policy relevance is often attributed to interdisciplinary research.

Van Asselt states, for example:

> *'There is frequently more social interest in interdisciplinary research than in monodisciplinary research. It also has the aura of being more broadly applicable.'*

Cooperation between different disciplines is required for such issues as climate research, even though there is no guarantee that it will generate precisely those results which you are seeking, postulate Berk and Kok:

> *'If no opening is made in the programming phase for a broader perspective, some issues will not be researched. The vulnerability to climate change in Africa, for example, cannot be researched without involving social scientific researchers.'*

3.2 Scientific Innovation

Although it is by no means a firm rule, interdisciplinary cooperation can lead to scientific innovation. Even more so, this is in certain instances the motivation to apply this form of cooperation. Kuhlmann is head of the CREA project *(Creativity capabilities in science and technology)*.[14] In this project, the emphasis is placed on nanotechnology and life sciences. Kuhlmann verifies under what conditions researchers become creative.

14 *See http://www.crea.server.de*

Interdisciplinarity is very productive here. Van Asselt also considers interdisciplinary research important, because it stimulates creativity. Moreover, researchers are forced to define their terms more clearly; the usual jargon will not do any more.

It is however not always the case that interdisciplinary cooperation generates new concepts or methods, says Faaij. Sometimes, a well-known method is actually needed to combine the results.

The ideal situation is when one discipline literally complements the other. Hooimeijer:

> *'The ideal situation is, for example, where one discipline researches a variable which needs to be explained, which for the other discipline is an explanatory variable, or vice versa. Physical geography specialists explain 'run off' using vegetation cover, biologists explain vegetation based on the characteristics of the soil. When feedback mechanisms are considered, you have to be able to combine the two fields of expertise in order to make progress. In such an instance, there is a scientific interest, and not just a societal interest, to arrive at 'neue Kombinationen'.*

According to Hooimeijer, interdisciplinary insights can convey understanding from one discipline to another or change the conceptualization of other disciplines.

> *'Interdisciplinary research can generate methods or systems which can be enlightening for the other discipline. Natural scientists (β-researchers[15]) who believe that social scientific research should in particular relate to the application of the knowledge and policy developed, may well discover that their view is not correct.'*

What Hooimeijer is sketching here fits with Verbong's experience. He related that he sometimes tires of the ever-recurring question of how new, sustainable energy options can best be implemented – as if the only right to existence of social sciences were to support technological development.

Interdisciplinarity can lead to new research questions, even to subjects which had not previously been thought of.[16] Also, new thematic areas and other innovations develop on the borders of disciplines.[17] According to Rip, an example of this is physical chemistry. A further example is molecular

15 *In the Netherlands natural scientists are called β researchers. Social scientists are called γ scientists and linguists and philosophers are called α scientists. This division into α, β and γ sciences is often used in the Netherlands.*

16 *From the discussion with Prof. D r J.C.M. van den Bergh (VU).*

17 *From the discussion with Prof. Dr Ir M.B.A. van Asselt (UM), Prof. Dr S. Kuhlmann (UT) and Prof. Dr Ir F.J.C. Willekens (NIDI)*

biology, which, partly influenced by Warren Weaver of the Rockefeller Foundation, took the direction of a new discipline in the nineteen-thirties.

Reflecting on the five-type classification of Ackers & De Vries, one might ask what type of research will be most innovative in a scientific perspective. The interviewees made no comment on this. For some of them it is also questionable whether innovation is always necessary. The scientific added value may lie elsewhere, according to Faaij.

> *'The combination of perspectives from natural and social sciences is very valuable, but I see this more as a compilation of insights and not really as an innovation.'*

The comment was also made that innovations do not necessarily arise from an interdisciplinary cooperation project. It is more complex than that, explains Verbong.

> *'Innovation seldom emerges as a result of one research study, or cannot be attributed to one piece of research. Innovation or innovative products often develop over a longer period of time. In other words, one should not be blinded by the claims of researchers. On the other hand, it is also necessary for scientists to claim inventions and discoveries, including the (potential) relevance.'*

3.3 Spin off in new projects

A number of researchers have the experience of interdisciplinary projects leading to new (interdisciplinary) projects; one project will precipitate another. Two researchers who are involved in NWO/SenterNovem Incentive Programme for Energy Research indicate that there is a lot of spin off. Paradoxically enough, some elements in this programme were in fact monodisciplinary. Faaij explains:

> *'In this incentive programme, fundamental research is carried out which now generates new projects. Many stakeholders are unwilling to pay for these fundamental projects, but they do want to reap the short-term benefits. Because you frequently work together with the practical environment, the projects can be translated into projects funded by third parties.'*

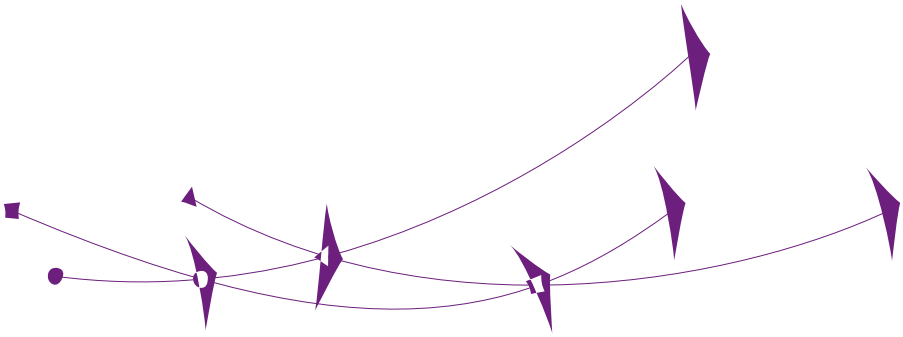
Verbong relates that he has developed research proposals which build directly on the interdisciplinary programme which he is currently implementing.

Rip explains that for some (monodisciplinary) researchers, interdisciplinary projects may primarily present a route towards (new) research financing. Researchers who have had experience of interdisciplinary cooperation more often go on to other interdisciplinary projects, whereas previously they had to revert to relying on monodisciplinary research funding.

3.4 Personal development

There is a further type of spin off: the more experience researchers gain in interdisciplinary work, the better the quality of such work becomes. Researchers build up experience which can be re-applied. But, according to some of the researchers interviewed, the question is whether this experience or these competences are always valued. For a number of them it is evident that interdisciplinary cooperation enhances personal development. Van Asselt, for example, says:

> *'In this type of research, it is primarily the personal competences of the researcher which are enhanced. You are challenged to use your social and communicative skills.'*



4. Impediments to interdisciplinarity

Although not specifically asked, very many impediments to interdisciplinarity were mentioned in the discussions with the researchers, although, according to some of those interviewed, we should qualify them as 'implied' impediments. Not everyone is in agreement about how firm or inevitable these impediments are. Prestige, publication opportunities, the gulf between natural and social scientists and institutional barriers are mentioned, in that order.

4.1 Lack of prestige in classical academia

Most of those interviewed agree that interdisciplinary research is generally not regarded as prestigious in the (predominantly monodisciplinary reward structure of the) academic world.

> *'Interdisciplinary research is sometimes regarded as superficial research. But people also say this out of a kind of opportunism because they see their research budget disappearing in favour of interdisciplinary research. Interdisciplinary researchers can generally present their research in a more understandable way because they have learned to explain their research to different disciplines.'* [18]

> *'It is true that people at the top do not see any distinction between disciplinary and interdisciplinary publications, but it is without doubt the case that disciplinary research schools have higher status than their interdisciplinary counterparts. 'Business administration is not science,' is a commonly heard statement and sometimes environmental science is included in this. Some natural scientists look at social sciences very simplistically.'* [19]

Willekens comments that the added value of interdisciplinarity cannot always easily be distinguished.

According to Van Asselt, there is not only a lack of prestige, but there is also a real pitfall for interdisciplinarity which can lead to qualitatively inferior research.

> *'Sometimes, weaker students and researchers escape into 'breadth'. This means less depth and at times also leads to the wrong contribution of disciplinary knowledge which cannot always be recognized in an interdisciplinary forum. On the other hand, there is also a group of top researchers, who are very good in their basic disciplines. Who consider*

18 *From the discussion with Prof. Dr L. Hordijk (IIASA).*
19 *From the discussion with Prof. Dr Ir F.J.C. Willekens (NIDI).*

interdisciplinarity as an intellectual challenge and who are exceptionally skilled in integrating disciplines. There is almost no middle group.'

In addition, both Rip and Willekens remark that the academic reward structure is not designed such that problems are analysed from the viewpoints of different sciences.

'If people can only publish via disciplinary channels, it is difficult to keep the research together. It helps if there is a clear purpose in working together using interdisciplinary methods, for example having an expectation of follow-on projects and financing. An alternative reward system strategy is to start one's own journal.' [20]

Verbong, too, has the experience that scientists are primarily evaluated on their publications. In his opinion, they for this reason often opt for the simpler method of monodisciplinary development. He does not believe that this is beneficial for science because the challenges are often to be found on the borders between disciplines.

'Everyone says that interdisciplinary research is important, but the stimulus to do it as a scientist is not great, because it costs much more effort and commitment and will not by definition benefit one's scientific career. On the other hand, interdisciplinary research does lead to new fields and research questions. For example: previously, energy research was only related to technical aspects, while it is now clear that social issues are also important.'

In the policy world, undoubtedly as a result of the assumed policy relevance of interdisciplinary research, the status of interdisciplinary research is different. Berk and Kok:

'Policy-makers do have regard for people who dare to look over the disciplinary fences. Researchers then have the idea that something will actually be done with their research findings.'

At the very world top of science, other values and norms apply, according to Van den Bergh:

'Nobel prize-winning research is often at the interface between disciplines – take for instance Tinbergen and Kahneman. This last is a psychologist who won the Nobel prize for economy. He conducted research into economic behaviour and has published articles in many leading journals. His work has been extremely influential.'

20 *From the discussion with Prof. Dr A. Rip (UT).*

Van den Bergh also feels something might be said against the prestige of monodisciplinary research. From a multidisciplinary perspective, monodisciplinary research seems relatively 'simple': it has limited scope and works with simplifying assumptions. Faaij, too, has a different perspective. He states that in the better cases of interdisciplinarity there really is a common product and common insights. The very combination of these insights may be a reason to have more confidence in the scientific outcomes of such a project than those of monodisciplinary projects.

4.2 Limited opportunities for publication

A frequently mentioned impediment for interdisciplinary cooperation (or at least one which used to be heard) is the lack of opportunity to publish at a high level. The top scientific journals are thought not be interested in interdisciplinary research projects. This assumption now seems to be outdated.

> *'To say that it is more difficult to publish interdisciplinary research is rubbish. Truly innovative research will always be given space in Nature, for example. Those people who claim that these journals only operate on reductionistic principles are wrong.'* [21]

> *'It is not more difficult to publish interdisciplinary work, because you have several channels simultaneously, such as magazines and conferences.'* [22]

Although publishing can be problematic, according to others.

> *'Interdisciplinary research does have more publication opportunities than for example fifteen years ago, but the interdisciplinary magazines do not have such good figures in the international rankings. The journals ought to have a higher ranking because the assessments of researchers are at least in part based on their citation indexes and magazine rankings.'* [23]

> *'It is difficult to publish in fields which fall between several disciplines. But if you manage to publish once via different channels, then you can publish more. And it is still the case that with universities and in academia, people are evaluated on their publications and there are not many interdisciplinary journals.'* [24]

---

21 *From the discussion with Prof. Dr Ir R. Rabbinge (WUR).*
22 *From the discussion with Dr A.P.C. Faaij (UU).*
23 *From the discussion with Prof. Dr L. Hordijk (IIASA).*
24 *From the discussion with Dr G.P.J. Verbong (TUE); Van den Bergh formulated this in almost the identical words.*

Rip advises: if publishing along existing (monodisciplinary) paths is difficult, then publish the interdisciplinary work as a separate book.

Copyright is a separate issue here. According to Hooimeijer, this only plays a role if there are also private parties involved in the publication. Leemans prefers to mention the whole team as authors. Faaij believes that copyright issues are subsidiary. What is important is that you have the common intention to produce something collectively. It is in his opinion only difficult that scientists to a strong degree are evaluated on the quantity of their output. This is not always to the benefit of such partnership projects.

4.3 Natural vs. social scientists and other paradigmatic confusions

A 'classical' barrier for interdisciplinary cooperation is that natural scientists and social scientists have difficulty understanding one another. Some of the researchers interviewed endorse this, albeit reluctantly. Priemus and Hillebrand, for example, have experienced that it is difficult to relate economists and sociologists to developmental research. The large gulf between the two has origins in tradition. In order to bring them closer together, there needs to be a common construction of the research object. The formulation of the research question must invite interdisciplinary research.

The majority of the researchers interviewed are of the opinion that the contrast between natural and social scientists is charicatural by nature. Where there is a will, there is always a way. Leemans remarks that it does take time. Willekens says that:

> *'Between natural and social scientists there is often the idea that the natural scientists first analyse the problem and that it is only after this that the social scientists have their turn. In order to work together on a problem it is necessary for researchers to be willing to work with other disciplines on formulating problem issues and research design.'*

Hordijk and Van den Bergh state that it also depends on how much experience researchers have with interdisciplinary working, i.e. how much they know of other disciplines. The greater their experience, the fewer the problems between the different disciplines. Hordijk regards it as a 'misunderstanding' that natural scientists regard social sciences with a certain disdain and would only characterize them as 'political analysts'. But that there are differences to overcome, is obvious.

> *'On the social sciences side, more qualitative research is carried out, while natural scientists conduct more quantitative research. The data collection and processing are different in both branches of science. There*

is also conceptual confusion between both types of scientists, for example on sustainable development. This conceptual confusion can lead to heated discussions.[25]

'As a generalization you can say that natural scientists set high demands on the ability to replicate, to observe and to experiment. 'If there are no concrete results, then the research must be wrong.' Social scientists realize that you cannot experiment with people and that social reality changes at a fast rate. Social scientists therefore have little or no belief in patterns of regularity.' [26]

'Vulnerability is a term which is interpreted by natural scientists very differently from social scientists. These last tend to think more in terms of social resilience.' [27]

Moreover, as a number of different researchers remark, there are not only important differences *between* social and natural scientists, but also *within* the social and natural sciences. Rabbinge sees, for example, a difference in attitude between different social scientists.

'There is a difference between conducting policy research and making politicizing statements. Some social scientists make statements which are politically determined. They should not do this. A social scientist can make the political contrasts visible, but should not give political advice.'

Rip states that at times natural scientists do not completely understand one another. Yet, strangely enough, this does not necessarily have to impede interaction. From a thesis with which he was familiar on different visions of Nuclear Magnetic Resonance (NMR) held by researchers from different disciplines, it appears that:

'... physicists try to gain further understanding of basic mechanisms and chemists see NMR, for example, as an instrument to localize hydrogen. Chemists and physicists do not, in fact, understand one another, but the mechanism functioned as a lever to bring them together. NMR also plays an increasing role in more domains, such as, for example, in material science. A kind of interaction arena has been created between different disciplines.'

Rip comments that the nature of different fields of science is characterized by Richard Whitley.[28] Whitley distinguishes on the one hand the degree of

25 *From the discussion with Prof. Dr L. Hordijk (IIASA).*
26 *From the discussion with Prof. Dr J.C.J.M. van den Bergh (VU).*
27 *From the discussion with Drs M.M. Berk and Drs M.T.J. Kok (both from the Netherlands Environmental Assessment Agency).*
28 *The Intellectural and Social Organization of the Sciences, Whitley, 1984, second edition 2000.*

task-(un)certainty and on the other hand the dependence of other scientists as important dimensions of scientific work. He regards physics as being characterized by a high degree of mutual dependence on the part of researchers and a low degree of task-uncertainty, while political scientists have no drive to cooperate and in addition are highly task-uncertain. The dimensions formulated by Whitley could, in Rip's opinion, also be used to estimate opportunities and problems for specific combinations of interdisciplinary research. To date, this has never been done.[29]

4.4 Institutional barriers

When preparing this publication, the interviewers wanted to avoid the lament about institutional barriers. No specific questions were asked about this. A great deal has been published – including in the Netherlands – on this subject, for example, recently by Rotmans.[30] He indicates, for example, that universities do not cherish interdisciplinary ambitions to any great degree.

Rabbinge appears to share this view. He is of the opinion that, given societal development, greater attention should be paid to 'mode II science'.[31]

> *'The unfamiliarity of many people in the Netherlands with this concept is related to the way in which our knowledge institutions are structured. More incentives are needed for interdisciplinary cooperation and more interdisciplinary institutions. In practice, an interdisciplinary research school seems to be so successful that it has a multiplier effect in the order of 2 to 3.'*

In the experience of Priemus and Hillebrand, change is occurring in universities, but the ambition should actually stretch much further.

> *'The faculties of Delft Technical University have traditionally represented particular disciplines. The Board of Governors has realised that social issues disregard disciplinary borders. The Delft Interdisciplinary Research Centres – or simply the Research Centres – are by definition partnerships between different disciplines, focused on a particular problem. This is as far as the breadth of vision of the Board goes. People are not yet ready for, for example, cooperation between Delft and Wageningen University and Research Centre.'*

29 *In this regard, it may be relevant to mention the dissertation of J.P. Birnholtz (2005) entitled: 'When do researchers collaborate?' Birnholtz states: 'Cultural factors such as competition for individual recognition and concerns about intellectual property were not perceived as significant impediments to collaboration. Instead, characteristics like resource concentration and the need for coordination were more important in determining collaboration propensity.'*

30 *In 'Transitiemanagement, sleutel voor een duurzame samenleving', J. Rotmans, 2003, Van Gorcum, Assen. (Transition Management, Key to a Sustainable Society).*

31 *'Mode II Science' (Transdisciplinary cooperation which generates primarily 'socially robust' knowledge) was contrasted with 'Mode I science' (traditional, academic knowledge development) by Gibbons et al in 1994 and later.*

A further impediment is the assessment system, which is primarily oriented towards monodisciplinarity, whereby promising and innovative interdisciplinary research often fails in an early stage of evaluation. A number of different researchers interviewed confirm this image. Rabbinge states, for example:

> *'What is needed is for heads of research organizations to become convinced of the value of and necessity for interdisciplinary cooperation. The 'peers' are generally purely discipline-focused.'*

Also with the KNAW institutes, in a sense, two different standards are applied. On the one hand people want to promote interdisciplinarity within the institutes; on the other hand it is difficult for new (inter)disciplines to become established there, according to Willekens. As an example of such a new discipline he mentions business administration.

> *'Why does business administration have such low status in the Netherlands? Can a company not be a suitable subject for research? Or is it because business administration does not apply the economic paradigm, but tends to be close to economy?'*

Verbong, too, sees a problem with regard to the assessment of research proposals. There are enough opportunities to submit such proposals, but the assessment:

> *'... is mostly done by individuals with a monodisciplinary vision and then the interdisciplinary proposal is often rejected.'*

In addition, the organizational embedding of interdisciplinary research is considered to be difficult. This image is confirmed by a number of researchers. Berk and Kok are of the opinion that interdisciplinarity has been a difficult issue for many years. At times it appears as if scarcely any progress has been made. They state:

> *'This may be because people have interpreted the phenomenon of interdisciplinarity too much as an ad-hoc arrangement.'*

Hordijk also emphasizes the importance of continuity:

> *'Interdisciplinary cooperation increases as people spend more time together. Both university groups and institutions have the tendency to drift apart after a few years of working together, mainly for financial reasons. This represents a loss of capital, because it takes a long time before people understand one another and build up a good cooperation.'*

5. Paths towards integration of scientific knowledge

The researchers were asked to make comments on a number of relevant scientific aspects of interdisciplinarity. The formulation of problems and objectives, finding a common language and other elements of interdisciplinarity are dealt with in the next paragraphs, as are frequently used methods of integration and the role of informal knowledge.

5.1 Building bridges and creating common foundations

In order to promote mutual understanding and fruitful cooperation, scientists have to know how to build bridges to one another's knowledge. This starts as early as the stage of problem perception and the formulation of the research question. According to almost all those interviewed, it is important that this formulation is a joint process. Only Verbong is of the opinion that an interdisciplinary programme can start without any joint problem formulation in advance. A research project can start from a joint issue, but with the question being formulated by the individual disciplines, in order to then merge in the course of the project.

Berk and Kok emphasize that in interdisciplinary research it is not only a matter of bridging the gap between different scientists, but also between scientists and (for example) policy-makers. In their opinion it is an iterative process and 'programming rather than conceptual'. Although, Berk and Kok stress that building too many bridges is also not good. Striving for the greatest common denominator should not be the purpose, but rather maintaining the potency of one's own knowledge.

Faaij is of the opinion that making an attempt towards bridging gaps is always beneficial: this is how people understand one another's concepts, reference frameworks, methods and limitations. But, in his view, top down management plays a role here. With the joint approach to a research project – certainly if it is a basic integration or directed integration – ideally there is a joint formulation of the problem or object. Faaij:

> *'Objective and question formulation are important. You shouldn't have three objectives which relate to separate disciplines, but a cohesive set of objectives from which emerges that you want common products.'*

Faaij also comments that people are generally successful in coming to such a definition of the research. But:

'The problems only crop up when you express the expectations of the research, when you actually start the project.'

Van den Bergh has commented that finding common ground may remain a constant problem.

'There has to be clarity and consensus about the problem to be researched. It may happen that during a project this consensus is more difficult to achieve. This also depends on the people who are involved. Are they really suited to interdisciplinary research? Sometimes people casually join a research programme at the start, without realizing that interdisciplinary research requires a high level of commitment.'

If a PhD researcher experiences problems with the progress of his dissertation, this has to be given priority instead of the interdisciplinary cooperation, in his opinion.

Berk and Kok state that it is important in an interdisciplinary project to be able to handle different problem perceptions. If necessary, more time has to be devoted to this.

Kuhlmann, too, is of the opinion that the start of good cooperation lies in the joint definition of the problem. He advises participants to come up with common questions and to research what these questions can contribute to the total project. It is not a matter of abandoning your own conceptual background, but adding something new, he says. He explains further that this generally takes new staff at his institute[32] a year. It also often means starting at a low level of academic recognition.

Rabbinge emphasizes that an open attitude and a certain degree of purposefulness on the part of the researchers is needed to find common ground.

'What is necessary is: an absence of prejudice and a certain degree of respect relating to methods and techniques from different sciences. The purposefulness of the research generally ensures that people work on a common problem construction.'

Leemans advocates flexibility to allow the dialogue between the parties to take shape.

'With the Millennium Ecosystem Assessment, we lacked a conceptual framework. For two years attention was paid to achieving an acceptable conceptual diagram. This meant that a much better integration and acceptance of the different disciplines was achieved.'

32 *Fraunhofer Institute for Systems and Innovation Research in Karlsruhe.*

Hooimeijer relates that sometimes status differences between disciplines get in the way ('hard' natural scientists versus 'soft' social scientists for example). The solution to this is to bring talented researchers into contact with one another. In no time they gain respect for one another, in his experience. A joint formulation of the question helps, preferably for a single subject. This question should be aimed at connection between disciplines. As an example Hooimeijer mentions the step from the likelihood of flooding to the experience of risk. This is also the step from natural to social science. In the research into vulnerability to natural disasters such as earthquakes and tsunamis, for example, you need geological knowledge (about probability and physical impact), economic knowledge (about damage and investment potential for prevention) and administrative knowledge (about institutions which organize the solidarity between different population groups in early warning systems, support for victims, etc.).

> *'Often these interests are closely related; geography specialists are interested in house-moving behaviour per se and as an underlying process for segregation. Sociologists are also interested in segregation, but then in the effects which it has on the social position of the inhabitants, without regarding the house-moving behaviour as a significant phenomenon in their discipline. The social position is again important for the possibilities for moving and is therefore important for the geography specialists.'*

Hooimeijer remarks that it is difficult for researchers to report back on results from interdisciplinary projects to their own disciplinary research groups. Educational programmes should, in his opinion, pay more attention to this aspect.

According to those interviewed, it is true to say that creating a shared basis can mean that researchers lose disciplinary focus. Leemans feels that this loss is compensated by the added value offered by the cooperation.

> *'New ideas crop up, new applications for existing technology, increased/enhanced understanding, particularly with the involvement of stakeholders.'*

In Van Asselt's opinion, interdisciplinary cooperation sometimes has a 'focusing' effect on one's own discipline. Researchers have to be able to continue to demonstrate depth and quality to their peers.

5.2 Learning to speak one another's language

To what extent do scientists working in interdisciplinary partnerships understand the key concepts of the different participating disciplines? And

how can researchers from different disciplines avoid talking at cross-purposes? Is it necessary to develop a common vocabulary? Or does this develop automatically in the course of time anyway? The researchers interviewed are not fully in agreement on this.

According to Faaij it is a question of teaching one another. Particularly in the initial phase the opportunity has to be made for this. Kuhlmann also states that understanding is mainly achieved through training. Hordijk locates the crucial moment for acquiring mutual understanding of one another's discipline earlier in the process:

> *'Writing research proposals together is important and ensures that as you are involved in the writing you learn one another's concepts.'*

In his opinion, it is above all a case of use of language and definitions of concepts. An interdisciplinary research proposal which is written in a one-sided fashion is in Hordijk's opinion often doomed to failure.

Van Asselt states that she regularly acts as bridge-builder in interdisciplinary projects, whereby her prime role is as a 'translator'.

> *'Sometimes I observe disturbances in communication. They can often be traced back to different interpretations of specialist jargon. Also, there are sometimes concepts which sound identical, but where the meaning differs with different disciplines. Both the hydrologist and the psychologist know the term 'water consumption', for example. For the hydrologist, the term means 'evaporation' and for the psychologist 'water usage by households'.'*

Rabbinge and Van den Bergh are not completely convinced that there is always real understanding.

> *'Often, scientists have picked up a certain amount of knowledge while researching concepts and methods of other disciplines but it is still difficult to answer the question of towhat extent there is mutual understanding.*[33]*'*

A number of those interviewed are firmly convinced of the importance of previous experience with interdisciplinarity in terms of understanding one another's language.

> *'With groups which have worked together for a long time, there are always a few people who carry the terminology. With new relationships, you have to be aware of this problem and give it a lot of time.'* [34]

33 *From the discussion with Prof. Dr Ir R. Rabbinge (WUR).*
34 *From the discussion with Prof. Dr L. Hordijk (IIASA).*

'With interdisciplinary programmes, it is wise to involve people who have demonstrated they are well versed in other disciplines. It is crucial for people to be up to date with classical articles, textbooks and one another's jargon.' [35]

As regards the development of a common language or vocabulary, some of those interviewed (Leemans, Verbong) believe that this will develop automatically. Verbong remarks that the process can be disrupted by changes of people during a project. Van Asselt is of the opinion that it should be a conscious and deliberate process, which stretches further than just cooperation within one project. It also relates to the context within which the project takes place. She mentions two examples:

'The title 'Biodiversity' of an incentive programme attracted far more biologists than social scientists. The social scientists were not stimulated or challenged by this title. Different titles for broad programmes or projects may be more useful here. Another example is where KNAW's Young Academy discovered after the event that a symposium on 'cognition' could better have been entitled 'thinking'.'

There are also examples of conscious efforts to develop a common conceptual framework. Berk and Kok mention the efforts of Biesiot, a researcher within the NOP. He developed a glossary of terms which are used in climate research. Berk also mentioned the effort to achieve integration of knowledge by means of a risk approach. This effort has, in his opinion, not been successful. On the use of particular central concepts, Berk and Kok say:

'The concept of vulnerability works as a kind of link between the different sciences. Some concepts have the potential of acting as a link, others are so fossilised that it is not possible to make the transition to research practice.'

Van den Bergh says that there is certainly a common vocabulary within environmental science, whereby disciplinary origin is sometimes unclear. Something similar applies, in his opinion, for terminology from the ecological and evolutionary discipline such as 'resilience', 'selection', etc. These words are being used increasingly within social sciences.

Other researchers interviewed are of the opinion that it is not so much a matter of a common list of terms or something similar. Priemus, Hillebrand and Rabbinge attach greater importance to the mutual understanding of what are important concepts and terms in the other disciplines.

35 *From the discussion with Prof. Dr J.C.J.M. van den Bergh (VU).*

'Clarifying core concepts is a considerable achievement. Often, very counter-intuitive matters have to be included. An example would be the law of diminishing returns from economy. For natural scientists this is not so convincing.' [36]

According to Hillebrand, mutual understanding is achieved through the problem which is being jointly researched. Priemus mentions fulfilling dual roles as an important factor for mutual understanding.

'As a member of a SER commission[37]*, I am presented with policy proposals at an early stage, which are then discussed in detail in subsequent meetings. Then you do understand where the conflict and possibilities for consensus lie. In other words, researchers have to be part of society. Then we really are talking about a good joint formulation of the question.'*

Hooimeijer, finally, mentions the importance of developing 'generic concepts.' (See paragraph 5.5)

5.3 The competences of the team members

The researchers were asked whether integration of knowledge is primarily encyclopedic (gathering without a specific integration framework), interpersonal (product of cooperation between different scientists) or intrapersonal (integration by one person with multiple qualifications). Insofar as the researchers have expressed any opinions on this, 'intrapersonal' was mentioned slightly more than the other two methods (with encyclopedic being mentioned least often).

The success of interdisciplinary projects therefore seems to be largely dependent on the competences of (mainly senior) researchers, who are able to implement the integration themselves, or at least are able to keep an overview and to estimate what different chunks of knowledge are needed to achieve the required end result.

Several researchers have made statements about what they expect from participants in interdisciplinary projects. Kuhlmann illustrates this using the personnel policy from the Fraunhofer Institute (FI).

'We only hire people with an excellent track record in their own discipline and who have the will to bridge the gap between disciplines. In the FI they are directly confronted with the opportunities and threats of interdisciplinary cooperation. If they are unable or unwilling to do this,

36 *From the discussion with Prof. Dr Ir R. Rabbinge (WUR).*
37 *SER: Social and Economic Council (in the Netherlands).*

they are advised to become a consultant, for example, or to go to a classical university.'

Van Asselt emphasizes the importance of communications skills and an open and flexible mind. Interdisciplinary researchers have to be sufficiently self-assured to admit that they do not always know everything. Respect for the other discipline is inherent in this, but in practice it is sometimes difficult to achieve. Everyone at times has particular prejudices against others. The only way of avoiding this is to work together. This is also helped in Van Asselt's opinion by so-called diagonal careers (a change of social function to lecturer and vice versa) and active networking outside the university (for example, via consultancy work). She gives a typology of four types of researchers:

- pure disciplinary researchers;
- researchers who are open for other disciplines, but do not themselves take part in interdisciplinary projects;
- researchers who can take part in interdisciplinary research;
- researchers who in themselves represent an interdisciplinary research.

It is also her impression that as a result of their training, the present generation of students often think and work more in interdisciplinary terms than their lecturers.

Hordijk indicates that he would advise PhD researchers to take their doctorate based on monodisciplinary research with a professor who is not averse to multidisciplinary cooperation.

'It is important that you have a monodisciplinary education in order to be able to develop from this basis in an interdisciplinary direction. If you do not start in a monodisciplinary environment, you will be superficial and there is the likelihood of loss of quality and credibility.'

Faaij indicates that many people who have had a monodisciplinary training like to develop in an interdisciplinary direction. Some later leave academia and go into the policy field, for example. Good interdisciplinary scientists have a sound monodisciplinary depth which they are able to put into practice with interdisciplinary issues. Conversely – a broad training and then specializing – often causes problems, in Faaij's experience. Individuals trained in monodisciplinarity are in a particular way skilled in analysis, while broadly trained people can often remain very superficial in their analyses.

Van den Bergh, also, emphasizes the importance of a disciplinary basis. He advised people to continue with monodisciplinary publications because in this way it is possible to remain up to date with one's own field.

'It is important that people do not lose touch with what is going on in their own field. You have to continue to be known to fellow specialists

because this is how you test your work against that of your colleagues. People have to continue to work in two fields and that takes time and effort.'

Berk and Kok consider the attitude of researchers as more important than the fact of whether one has a background in the natural or social sciences. Researchers have to be open for societally oriented, demand-focused research. One then also has the tendency to take knowledge from other disciplines seriously.

5.4 The role of informal knowledge

The researchers were asked to what extent attention was paid in interdisciplinary projects to the integration of non-formal knowledge, such as experiential knowledge, contextual knowledge, etc. In the responses to this question, it became obvious that some researchers think in this respect mainly of the knowledge *of* other actors (which is introduced into the project by them), while other researchers seek this kind of knowledge more in their own research group; it is often knowledge *about* other actors.

A number of those interviewed state that knowledge which is introduced by societal actors is integrated into the research project, and they give examples of this, such as the previously mentioned COOL project, whereby this was explicitly the case.[38] Hordijk mentions 'contextual knowledge' in particular as being important:

' The knowledge of certain people from the business sector was very useful in terms of sensitivities between businesses themselves and between businesses and ministries.'

Leemans indicates that, in view of the problem-focused character of interdisciplinary research, non-formal knowledge often plays a role, but that in his experience this is never documented.

Faaij considered contextual knowledge important within the individual research group, for example with combined social scientific and natural scientific research that is related to policy. He remarks that this requires senior researchers, because PhD assistants 'often have problems with this kind of knowledge'.

Priemus and Hillebrand also consider informal (namely 'tacit') knowledge important, just as contextual knowledge, also for spatial issues.

38 *Both Berk and Kok, as well as Hordijk, mention COOL.*

'The solution for case A is not directly applicable to case B.'

They wonder in this context whether new categorization is possible to make knowledge more generally applicable. This would be possible by thinking in typologies or dependencies, remarks Priemus.

In the discussions with Hordijk and Verbong, contextual knowledge was related to the capacities of researchers to relate their research to the relevant societal context, and for example also to transfer their research effectively to societal actors. Hordijk says that PhD researchers in the SENSE research school[39] are given the task of writing an article about their dissertation in relation to the societal context. Within Verbong's specialist field, prominence is given to providing integration training, focused on allowing the integration of knowledge, insights and methods from different disciplines. He tries to teach his students to learn to make use of all types of knowledge in solving problems. But a student has to be open to this. Verbong considers contextual knowledge important for every researcher. It occasionally happens that a scientist is excellent in his own field but is unable to explain his knowledge in public to people outside his field.

Hooimeijer brings up the problem that non-formal knowledge (experience, intuition) is always picked up by individual researchers, but is difficult to build into projects which are focused on acquiring scientific knowledge. He considers research at the interface between science and practice to be useful, but in his opinion there is no reason to designate this type of knowledge as a comprehensive alternative to acquiring scientific knowledge.

Willekens finally emphasizes that contextual knowledge also, like norms and rules of behaviour, should be approached as scientifically as possible. A way of passing on this knowledge is by making use of 'voices', to illustrate the scientific information. He cites the example of research into women's careers. Statistical analyses among highly educated females, with and without children and/or a job, can be supplemented with stories from practice. In life course research there is growing interest in supplementing statistical analyses of life histories with life stories.

5.5 Methods for integrating questions, results and data

The researchers interviewed who were cooperating in interdisciplinary projects are familiar with different methods of achieving the integration of different elements of disciplinary knowledge.

39 *SENSE is the environmental research school in the Netherlands.*

Actor/Agent-based modelling[40]

According to the experience of Berk and Kok, scientists are faced with the question of how human behaviour should be represented in their models: via activity levels, or as economic actors, as economists advocate, or in some other way which does justice to the broader understanding of human behaviour ascribed by social scientists? With *actor-based modelling* it is possible to couple/link the physical world to the 'human world'. Berk and Kok believe that this is better than simply linking between economic and natural scientific models. They do comment, however, that the question remains of precisely what aspect of societal complexity can be captured in what models. It is Kok's impression that not enough is invested in these developments by social science. There are more opportunities than some people realize. There are already spatial models, for example, which include particular behavioural and decision-making rules.

System Analysis and Process Analysis

As well as agent-based modelling, Willekens also mentions the following methods:

- system analysis
- complexity analysis
- computational economy, computational biology, computational demography, etc.

Willekens explains that according to complexity theory, people regard developments in systems as developmental processes: economic, biological and social. It is about the actors and the interactions between the actors. The ageing of the population, for example, is not an isolated problem. For this reason, NIDI (Netherlands Interdisciplinary Demographic Institute) puts it in a broader context, such as the life course system, within which 'health' can be placed. In Willekens' view it is essential that researchers gain an understanding of different concepts from other disciplines, otherwise they give up. Complexity theory, in his view, offers such a framework for combining inputs from different sciences at a higher level of abstraction.

Priemus and Hillebrand also mention system analysis as a good integration method: it helps to link different disciplines with one another and also to place spatial research in a broader context. The plans themselves can also be a unifying factor. The attitudes of planners do have to be attuned to this; that is, they have to want to try out alternatives, according to Priemus and Hillebrand.

Dialogue

A further method of promoting integration is the dialogue method, according to Kok and Berk, again mentioning the COOL project. During workshops, researchers, policy-makers and other stakeholders who have an interest in

40 *Berk and Kok use the word 'actor' here; Willekens, who also mentions this method, uses the word 'agent'.*

the central problem exchange views, visions and experiences. In the case of COOL a so-called 'Global dialogue' was organized whereby the method of back casting was used to explore the short term consequences of long term options.

Case studies

According to Berk and Kok, case studies offer an opportunity to integrate knowledge. Rip, too, mentions case studies as a method for integration (within social sciences).

Triangulation

Hooimeijer comments that integrating different types of data not only plays a role in interdisciplinary research, but also, for example, in monodisciplinary social scientific research. Triangulation is frequently applied here. This is a method in which the researcher combines administrative information, survey data and interviews by testing the interpretation of one type of information against the other two.

Generic concepts

Hooimeijer also mentions generic concepts, such as, for example, the concept of 'neighbourhood effects'. These play a role both in physical and social geography. It also appears that flocking algorithms, which were developed for the deposition of sand in river estuaries, can give a good description of flows of pedestrians from streets to open squares. And the hydrological cycle plays a significant role in physics, biology, chemistry and geology. And flow concepts occur in a large number of disciplines. These kinds of concepts can be used to develop interchangeable concepts.

Narratives with quantitative testing

Leemans gives as an example the case of IHOPE (Integrated History of People in Earth), an element of the GAIM-AIMES project[41], in which archeologists, historians, paleo-ecologists, geographers and ecologists work together. The first projects were primarily descriptive, based on narratives. The quantitative approach of economists and/or ecologists can test the plausibility of these narratives.

Oral history, surveys

Rip mentions oral history and surveys as commonly used methods of integration.

41 *See: http://www.aimes.ucar.edu/. AIMES is the Earth System synthesis and integration project of the International Geosphere-Biosphere Programme (IGBP). It builds on the foundation of the Global Analysis, Integration and Modeling (GAIM) task force. The challenge for AIMES is to achieve a deeper and more quantitative understanding of the role of human perturbations to the Earth's biogeochemical cycles and their interactions with the coupled physical climate system.*

Unifying concept, unifying method, unifying approach

Rabbinge explains that at the C.T. de Wit Graduate School for Production Ecology and Resource Conservation in Wageningen is founded on a number of important interdisciplinary concepts. These include:

- a unifying concept, relating to growth and factors which influence growth.
- unifying methods: a large number of explanatory models.
- a unifying approach: integrating from a basic knowledge to a higher level.

The explanatory models were to an extent already available, also with interaction between natural and social sciences, but they have since been broadened, they are constantly being improved and attempts are made to falsify them using the well-known Popper principles. Rabbinge refers to the GOAL model of the Scientific Council for Government Policy. In 1992, this Council developed four scenarios for land use in the European Union aiming towards the year 2015 (in the report 'Ground for Choices'). The GOAL model was developed for this purpose: General Optimal Allocation of Land use. In this scenario study different quantitative methods were used to gain insight into policy relevance for economic, social and environmental policy.

Inventing the wheel for yourself, working on methodology

Leemans comments that there is no well-equipped toolkit for interdisciplinary research. Many tools have to be developed ad hoc. Van Asselt, too, states that there is a lack of 'interdisciplinary methodology'. In the Netherlands in any event little attention is paid to methodology (except in statistics), although the necessary experience has now been built up through the cooperation of social scientists. NWO should reward extra attention to methodology in interdisciplinary projects, according to Van Asselt. The final report should include a critical reflection on methodological aspects in such a way as to benefit subsequent interdisciplinary projects. Van Asselt indicates that this will not always be an easy task.

> *'Often, the methodology cannot be presented when the project is first instigated, but is developed along the way. The most difficult aspect of this is the paradigm differences. There is also the aspect of disciplinary superiority. Researchers fail to recognize the plurality of paradigms and consciously or subconsciously establish their own paradigm as the norm and the benchmark. In this situation, dogma can be very restrictive. You need researchers with an open mind, who can recognize that it is possible to do things differently. Not everyone can do this; it requires flexibility and the preparedness to take risks.'*

In Faaij's experience, too, finding ways towards integration is custom-work. He mentions further:

> *'Combining disciplinary **concepts** is not really possible, it gets stuck at management level. What is important is the integration of **results**. You*

*have to carefully plan and monitor how you handle this. **Data** are in principle separate from one another.'*

Van den Bergh is of the opinion that it is possible to integrate data.

'It is essential that people have the relevant data on both sides of the disciplinary spectrum, and can integrate this. It is then, of course, extremely useful if integrating concepts and models can be used which are available in advance.'

Verbong also states that integration of data is important and that it takes place. The way in which it takes place is a difficult issue within interdisciplinary research.

Priemus and Hillebrand are aware that a range of different integrating methods are used, but they themselves do not develop such methods. According to them, there is an 'implementation gap'; information on methods is published, but it is nonetheless not widely known.

Rip is of the opinion that people should not rely overly on methodology books.

'There should first be a shared concept, within which integration can take place. Methodology should be useful, rather than being prescriptive.'

According to Rip, there are considerable differences in the evaluation of methodologies in scientific research. In Germany methodology is emphasized as an integration instrument. Rip comments that this should be seen in the light of the greater importance which German scientists in general ascribe to methodology. English project proposals, on the contrary, often only focus on case studies which will be carried out (and this is indeed accepted), while such a project proposal would not be approved in a Dutch context. To illustrate this, Rip mentions the project 'New modes of knowledge production'[42] in which he was involved. He wrote a paper for a conference in 2002 on a typology with twelve forms of knowledge production – some based more on the cognitive aspect, others on the organizational side. New types of knowledge production which are now accepted, appeared to have initially been disputed in the past. X-ray crystallography, for example, came into being because different disciplines were considered together.

Rip further states that methodology is not only a question of, for example, philosophy of science, but that social aspects are also involved. He mentions

42 *'Strategic Research, Post-Modern Universities and Research Training'. A. Rip, 2002, in CHEPS: Changing Modes of Knowledge Production and Labor Markets. Proceedings of an International Workshop', University of Twente, pages 45-54.*

as an example the 'Clinic of Knowledge', whereby students and lecturers from business schools were involved in diagnosing situations. This has gradually become a tradition. It serves both to help the 'patient' (client) and to increase knowledge.

Generally no structuring effect

Insofar as the researchers interviewed commented on the structuring effect of the integration methods adopted in projects which they had carried out, they state that there is no such an effect. Priemus and Hillebrand mention, for example, that the cooperation comes about in a much 'freeer, more unintentional' way. Only Rabbinge states:

> *'Interdisciplinary cooperation is strongly structured as a result of these integrating methods. But attitude and culture are also very important.'*

In Faaij's experience, methods do not structure cooperation, but the working method can be modified in the course of time according to the phase and the content of the research. Phases and forms of cooperation can also merge into one another.

Integration requires attention from start to finish

Insofar as the researchers interviewed commented on the need for continual attention integration during the course of a project, they consider it essential for attention to continue to be focused from start to finish on the integration of knowledge. Faaij:

> *'You can work separately, but if the results have nothing to do with one another, you will not get any integrated findings and your programme will also not be successful. In spite of a good, joint problem definition, projects can still fan out. You can prevent this by keeping the objective as a central focus, using effective project management, regular discussions, and understanding for one another's project. Attention to a joint objective is in fact a key issue in an integrated programme. The integration action can take place at the end of the project, or during the project.'*

Rabbinge warns of the danger of overdoing it. In his opinion the research findings have to be harmonized, but not such that no response is ever given to the original question.

Integration of knowledge is often linked to the (possible) application of research results (perspectives for action). On this subject, Verbong comments:

> *'The question during the whole research is: what can you do with it? The research may provide a response to societal questions, but it may also*

lead to other research questions. This is a dynamic and slow process which lies directly below the surface of the research.'

Nonetheless, the societal usefulness of the research is not the only motive for integration of knowledge, according to Faaij.

' You have almost purely scientific objectives for interdisciplinary activities, and sometimes these lead to spectacular fundamental insights.'

5.6 Qualitative + quantitative = ?

The researchers were asked to what degree there is a problem in combining qualitative statements with quantitative statements and what solutions are adopted to deal with this in interdisciplinary projects.

Hooimeijer and Kuhlmann state that this is not a problem which is confined to interdisciplinary research. It also occurs within disciplines. Kuhlmann indicates, to illustrate this, that different schools can also be distinguished within economics. Considerable differences are also discernable in engineering. There are engineers who work on the basis of principles of natural science, but there are also those who work empirically, via trial and error. Kuhlmann believes that we should find a way of connecting these different approaches.

Other researchers recognize that combining qualitative and quantitative comments is a continual problem in interdisciplinary work. Verbong states that it can even lead to conflict within an interdisciplinary team, because qualitative research is regarded by some individuals as less scientific. Willekens ascribes this to a lack of knowledge on both sides:

' Integration of data, qualitative and quantitative research findings, is a recurrent problem. People who are focused on quantitative research often have no knowledge of qualitative techniques, and vice versa. Calculations based on statistical relationships say little about causal links. Focus groups with five to ten people are not representative, as every statistician knows.'

According to other researchers, the problem is not insurmountable. Rabbinge states that there are always solutions to this recurrent problem. Faaij believes that the point in time when the different types of information become available heralds a good juncture in the research: combining the different data can provide useful knowledge.

'Quantitative information can constitute a good foundation for policy. Policy can provide the framework for quantitative information.'

Priemus and Hillebrand are aware of different ways in which 'quality' and 'quantity' can be combined. Statistics can become more meaningful through frequent discussions with those involved. A further method is the use of maps, whereby they mention the spread of cholera in the nineteenth century as an example.

5.7 Quality loss of data

In the summing up and processing of one another's data, cooperation can result in loss of quality of the data. How do interdisciplinary researchers handle this?

In Hooimeijer's view, this is not a problem which is confined to interdisciplinary research. It also occurs in other projects. Otherwise, the researchers are somewhat divided on the issue of loss of quality.

Faaij states that the combination of knowledge from different disciplines often has the effect of raising quality.

'If your work is merged into a larger body of work, there is often less need for specific details in this larger body of work. But if you cooperate effectively and you have knowledge of details available, then you are better able to interpret and incorporate these details. The combination of different forms of monodisciplinary knowledge provides a much better interpretation of a model or of conclusions.'

Priemus and Hillebrand, also, do not believe there is any loss of quality. Although they do add that there are hardly any integrative models in the field in which Habiforum operates.

Rabbinge also has the impression that there is no loss of quality as a result of integration of knowledge. But on the other hand people should not be under the impression that a particular model can be applied everywhere: explanatory models cannot, for example, be used to make predictions. Scientists have to have adequate knowledge of how models work so that they can choose the right method for the right purpose, according to Rabbinge. Scientists are often not aware of these basic principles. The elementary principles of simulation are apparently little known, whereby oscillations occur in model calculations.

Hordijk too, mentions in this connection the requirements which have to be placed on the development of models. If researchers construct models from

elements of different disciplines, they often come up against the difficulty that the information from one discipline is suited for a detailed level, while the data from the other discipline is more suited for an aggregated level. Good cooperation is therefore needed, according to Hordijk:

'In scaling up the information, you need to involve monodisciplinary scientists to test whether you may use their data in your model outside the context in which the data was acquired and verified. This is important for the credibility of your research. As long as you do this, I don't see any problems with such forms of research. You get more answers with interdisciplinary research than with monodisciplinary research and not just one aspect of the problem.'

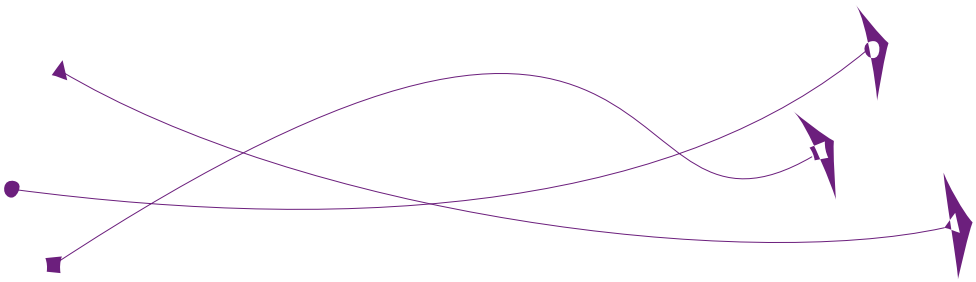
Kuhlmann is also concerned about erroneous model constructions. The more elegant the model, the greater the danger of misunderstandings and unreliability, he says.

'The likelihood of an artifact looms up if data is naively adopted without knowing the background or the context.'

Van den Bergh and Verbong state that a degree of quality loss from the viewpoint of the discipline is inherent in interdisciplinary research. Van den Bergh considers that this particularly applies to loss of depth.

'People are always trying to capture a system in a particular complexity, and this complexity should not be too great. People on both sides of the disciplines have to be prepared to compromise.'

Verbong again queries whether all interdisciplinary research should start with a joint problem definition, because this already involves a loss of depth.



6. Directing and organizing interdisciplinarity

What is more important: that interdisciplinarity is well designed in *scientific* terms, or that projects are arranged well in *organizational* terms? The researchers hold very different views on this. Berk is of the opinion that the organizational aspects are most important, because this is what shapes the basic conditions for interdisciplinary cooperation. A solution will be found later for methodical problems. Most of the rest of those interviewed see this differently and place the emphasis on such aspects as the personal competences of the project leader and the team, and the methodological aspects. Rabbinge states that it depends on the project.

> *'If there is a high degree of purposefulness in the research, organizational and methodological aspects become more important. If there is less purposefulness, epistemological and person-related aspects are more important.'*

And Verbong considers all the aspects mentioned important, but in different ways.

> *'**Organizational** aspects create the conditions, **methodological** aspects are necessary to shape the research, **epistemological** aspects relate to the content or the meaning of the knowledge and **personal competencies** are the lubricant or the 'enabling factor' of interdisciplinary research.'*

This section deals with the organizational conditions for effective interdisciplinary research, including the role and competences of researchers who direct interdisciplinary projects and different aspects of cooperation and financing.

6.1 Interdisciplinary leadership

How should an interdisciplinary project be managed? What type of leadership is needed? Those interviewed stressed different aspects.

Strict framework, clear structure

Hooimeijer is of the opinion that strict project management is crucially important. Frameworks have to be specified for the cooperation. A high degree of communication is needed, people do not automatically connect with one another, in his experience. A clear structure which makes this possible, will help. Hooimeijer mentions in this context a geographical partnership in which there was a lack of interaction as a result of an overly layered structure. The lecturers involved were too distant from the doctoral

researchers, while the senior researchers had insufficient authority to enforce interdisciplinarity. This meant that there was too much opportunity for disciplinary preoccupations.

Free-thinking and charismatic leadership

According to Hordijk, good leadership is essential to the success of interdisciplinary projects. Dogmatic or inflexible leaders can cause a project to fail. What is difficult is that the type of characteristics which are necessary for interdisciplinarity cannot actually be trained. It is above all a question of attracting the right people. He also indicates that the fruits of interdisciplinary research often occur later than with other projects. The programme leader has to work in a more product-oriented way; it costs him more effort to get the researchers to cooperate well.

Van den Bergh believes that a coordinator should have charisma, because he/she has to be able to bring people together. It can happen that an interdisciplinary programme is too ambitious. Then the coordinator also has to be prepared to make the necessary interim adjustments. In his experience, the management of a project takes place ad hoc and not according to any detailed plan agreed in advance.

Management dependent on complexity and attitude of researchers

Priemus states: the more differentiated the groups, the greater the requirements which are placed on the programme management. Faaij, too, is of the opinion that the nature of the project management is dependent on the size of a project, on the number of partners and on the number of products.

> *'If you have a team where researchers carry out purely monodisciplinary work, it is very difficult, even with strong project management, to have them work in line with interdisciplinary principles. In such instances you have to apply strong management. And the implication of this is that you have to know in advance what you want to do with the monodisciplinary knowledge and then you have to really know what you are asking of the monodisciplinary researchers.'*

The manager himself has to be a researcher

Leemans is sceptical about the phenomenon of 'project managers'. Managing a project should preferably be done by the researcher involved in the specific discipline.

Create a team culture

Leemans and Rabbinge both emphasize elements such as ambiance, attitude, culture and team-feeling. In Rabbinge's opinion, most people want to organize too much. Those aspects which are less easy to organize are more important. An important shared principle which can facilitate this is that people do not see mutual influence as a threat, but as an opportunity.

Leemans considers that project leaders should ensure transparent communication, that justice is done to all participants and that a clear common objective is established.

Allowing cognition and organization to go hand in hand

Rip considers it important that a project should start with cognitive and conceptual agreement. This is followed by organizational embedding. In his opinion, an organizational leader is needed as well as an intellectual leader. At the point when the project starts to progress, methodological reflection is needed. It may then be appropriate to modify the cognitive aspects. The most important success factor for interdisciplinarity, according to Rip, is then to ensure cognitive integration (being able to look beyond the borders) and on the other hand to see that the project runs well in organizational terms.

Not too much management, a lot of communication / joint learning / reflection

Willekens states that communication, the framework for thought and language are the most important considerations in directing an interdisciplinary project. With interdisciplinary research, Verbong considers project management slightly more important than with other research, but it is important not to exaggerate. He sees interdisciplinary projects and project management within this as a learning process, in which communication in particular is important. But in addition to communication, reflectiveness is also important, the ability to consider what has taken place in a particular situation or between people. Van Asselt, also, prefers not to have any heavy management, but above all a lot of time and attention to communication.

6.2 Competences of interdisciplinary leaders

In response to the question about which specific competences leaders of interdisciplinary projects and programmes should possess, experience and knowledge of integrative methods and working procedures are most frequently cited. Rabbinge, for example, believes that authority only exists when linked to content.

> *'Programme leaders have to stimulate, but cohesion works on the basis of content and not on the basis of power. Charismatic leadership cannot be learned. Often people have to manage with content alone.'*

Van den Bergh is very precise about the knowledge required:

> *'A programme leader should have a good methodological background, experience in constructing models, and statistical knowledge. In addition, he should also have good theoretical knowledge, be able to conceptualise and be able to penetrate abstractions.'*

According to Leemans, there is a need for researchers who are actually able to integrate.

> *'It seems to be easier for many researchers to research more and more details, than to bring the overall picture (helicopter view) together. In proposals you still see lists of detailed case studies which seldom contribute to the overall insights. Cohesive models would make a contribution to this.'*

But substantive knowledge is not the only requirement; attitude and communication skills are equally necessary, according to other researchers. Qualities mentioned are openness for other disciplines, the ability to listen to others, being able to communicate, respect, giving latitude to other people, the ability to learn, being able to put their own discipline into perspective or being able to distance themselves from it, and being focused on creating connections.

> *'Interdisciplinary cooperation requires a different type of authority: a project leader does not have to possess the knowledge himself at all levels. He does have to understand and be able to make connections, not always being a follower, not being focused on overseeing activities, but on making the connections.'* [43]

> *'Openness towards other disciplines, respect and the willingness to listen and learn are important. It is possible to screen applicants for positions as project leader on these qualities.'* [44]

Finally, the importance of training. Faaij states that programme leaders should be trained in interdisciplinarity. Hooimeijer and Willekens are of the opinion that interdisciplinarity should be an element of all educational programmes.

6.3 Working plans

The researchers interviewed do not agree about the extent to which there should be fixed working plans. According to Hooimeijer, a working plan is the first priority. Hordijk's experience is that devoting a lot of time to a working plan at the start can sometimes give the best results in the end.

> *'In the COOL project, which was made up of three sub-projects, one project team chose to take a great deal of time for preparations. In my view at the time, far too much time, but it meant they had a very good working plan. This eventually became the project with the best results.*

43 *From the discussion with Prof. Dr P. Hooimeijer (UU).*
44 *From the discussion with Prof. Dr Ir F.J.C. Willekens (NIDI).*

So, sometimes you need to devote more time to preparation so that you can implement the project better. Depending on what kind of project it is, of course.'

Other researchers consider a detailed working plan unnecessary or even impossible. Faaij says:

'Cooperation has to grow and you should be able to shape it together. You should preferably choose for an open approach. You need to have just the right people who have an overview to be able to write an overall approach. As a specialist you cannot write a good working plan for a very broad programme.'

Leemans considers that working plans are more likely to be a restriction to interdisciplinary cooperation than a useful tool. But a clear objective and planning (with deadlines which are not too far in the future) are necessary, in his opinion.

Priemus and Hillebrand see no importance in a working plan. The attitude of the researchers is much more important. They should, for example, take stakeholders seriously. In some (policy) processes a powerful learning environment develops because conflicts between empiricism and policy assumptions emerge. There is no opportunity for such a valuable learning opportunity in predetermined plans, according to Priemus.

Verbong considers that working plans are more appropriate in the policy world where people have to be accountable, than in the research world. The working method crystallizes into a programme during the course of the research.

6.4 Agreements, progress meetings, communication

With interdisciplinary cooperation, by no means everything can be agreed in advance, according to the researchers interviewed, although Priemus is in favour of agreeing definitions to be applied mutually in order to avoid misunderstandings. But good discussions on progress, and open communication at the start of and during the project are most important – even if only to understand one another better. Leemans:

'People with little experience have to ask about the jargon. Time should be made in the discussions for explanations; you have to be open.'

Van den Bergh also emphasizes the 'introductory function' of the progress meetings.

> *'It is important to get to know one another, but also to learn one another's jargon, concepts and theories. That takes a lot of time; sometimes people have to explain even trivial things from their field to aid cooperation. People also have to be prepared for these kinds of discussions to recur during the course of the research.'*

According to Van den Bergh it is useful for researchers to hold many discussions with one another before starting interdisciplinary research. If people do not know one another or one another's field, they have to be encouraged to do so. But it is in his opinion less necessary in the case of research in the field of 'global change'. The people involved often already know one another and the different disciplines well.

Faaij also considers that there should be more opportunity for discussion in an interdisciplinary project: 'training time' to understand one another. But this has to be determined by the dynamics of the research process: no set discussions, only if and when necessary. Van Asselt, too, emphasizes that a great deal more communication and reading time is needed in interdisciplinary projects. Berk and Kok are also of the opinion that it is important for adequate time and money to be budgeted for regular discussions. They state that the Dutch consultation culture may be an advantage in this respect.

Verbong, too, considers the working discussions important since they benefit interdisciplinarity. But it is simply not always possible. Rip favours a major workshop once a year involving all the research assistants. Hillebrand considers communication between researchers and with people from *practice* as being extremely important, namely in order to generate timely results which are also desirable at that point in time.

6.5 Physical proximity

To what extent is it important for the success of a project that the partners are located in close proximity to one another? Insofar as those interviewed commented on this, they are of the opinion that this is very important and can have considerable benefits. Only Faaij is not of this opinion. Physical distance is in his view not a barrier.

Hooimeijer states that physical proximity is important because much of the working discussion takes place informally. He believes that researchers should, if necessary, be located close to one another if they are not already nearby at the start of a project. Also, Van den Bergh mentions in this connection 'accessibility' as a factor. He prefers to avoid ambitious cross-

disciplinary projects whereby the researchers also work at different universities. It is better if the researchers' offices are on the same floor, but this is often not possible. Van Asselt advises in any event having researchers from different disciplines spend a week together.

Hordijk has mixed experiences with this. He was once involved in a project (the Dutch Acidification System in 1987) which did not work because, as well as geographical separation, the cooperation was also hampered by a kind of administrative separation. He brought all the researchers involved together in one location. This gave an impetus to the project, which it apparently needed, because afterwards the project progressed well. He had the same experience with IIASA during the RAINS project where he held weekly meetings with the participants to discuss any problems. This allows the different scientists to learn from one another and to hear what the other participants are involved in. Hordijk also indicates that, given the possibilities of electronic exchange of information, geographical separation may no longer play such an important role. Sometimes, geographical distance is not an issue, but it is more the *priorities* of the different departments which play a role.

6.6 Previous experience as factor for success

Almost all the researchers interviewed consider that it certainly helps if researchers in the team have previous experience with interdisciplinarity, or at least have a feeling for it. On this point Faaij says:

> *'The type of experience and type of attitude of people who take part in interdisciplinary research are different from those of monodisciplinary specialists. It is difficult to involve monodisciplinary experts ad hoc in an interdisciplinary team. In the coordination there should at least be people with previous experience with interdisciplinary research. It is crucial to have researchers who know how to handle an issue along interdisciplinary lines.'*

Hordijk, too, considers that experience may be more important in one case and attitude in another. The interdisciplinary research at IIASA (in the eighties) was successful because the participants were all young researchers, who were good in their own specialist field, but were keen to learn a lot more, and were open to knowledge from other fields. Hordijk believes that these kinds of researchers, also later when they have acquired standing in their own field, still have this flexibility and openness, which makes them very capable scientists.

Kuhlmann explains that within his institute some 40% of the researchers are natural scientists and 40% are social scientists. The researchers carry out

projects in mixed teams, which often address technological developments and their influence on economic developments. The appointment policy of the Fraunhofer Institute is to appoint monodisciplinary researchers who are placed in interdisciplinary teams which also include people with more interdisciplinary experience.

In addition to previous positive experience with interdisciplinarity, Priemus and Hillebrand also consider the attitude held by scientists important. In Habiforum's scientific steering group people trust one another on the basis of the qualities of the individual researchers in their own field. This creates a relaxed and straightforward atmosphere. Researchers should then never relinquish this quality. Researchers should be good in their discipline but should also have an understanding of what others are involved in. A 'T-bone education' is interesting in this respect: becoming an expert in one discipline but also gaining an orientation on another discipline.

According to Priemus and Hillebrand, not everyone is suited to interdisciplinary cooperation.

> *'You have to be prepared to show your vulnerability in order to achieve good interdisciplinary cooperation. To gain an idea of the doubts experienced by the other researchers. A questioning attitude is always good in academic research.'*

Rip has had experience of an interdisciplinary project which worked well partly due to the fact that the people already knew and respected one another.

Van den Bergh, too, considers it useful if people have already gained experience with interdisciplinarity because they then know the pitfalls and are prepared for the amount of time it will take to learn one another's language. He selects post-docs in particular on their experience. With the other team members this is not the prime criterion; he considered intelligence a more important selection criterion.

6.7 Reserving separate time, manpower and funds for coordination

There is no consensus among those interviewed as to the necessity to reserve separate time, manpower and funds for coordination.

Separate time, manpower and funds should be reserved
Van den Bergh has occasionally experienced that when a programme leader is also project leader, his or her own project is often prioritized above the programme as a whole. He considers that more structured planning would be beneficial in such a case although it is difficult to precisely define these

kinds of matters in advance. It can make a difference if the programme leader receives an allowance for this so that there is more opportunity for thorough programme management.

Berk and Kok are of the opinion that planning of resources and capacity within a project is necessary, but that this often does not happen in practice. The research world benefits from certainty. People have to know that a particular relationship will last for at least two years.

Faaij, Hordijk and Verbong also indicate that interdisciplinary research always takes extra time and resources. Faaij states that if no time and resources are made available, there is no point in starting on the project. He considers it unrealistic for financiers to stipulate that the staff in a project have to be 'matched' for a few hours a week because working in interdisciplinary projects takes more time than this. If the financiers want this, then they also have to actually partly fund the senior researcher in the project. Hordijk, too, states that the overhead costs of interdisciplinary research are much higher and that the funding institutions have to take this into account.

Kuhlmann only considers a good coordinator with time for integration worthwhile in large projects. Van Asselt, also, says that it is only necessary to reserve time for coordination with larger projects. Leemans, on the contrary, believes that these kinds of aspects should be a fixed element in all research projects.

Separate time, manpower and funds need not be reserved

Hooimeijer states that no separate time needs to be reserved. Priemus and Hillebrand also consider this unnecessary. However, they do add that the financial restrictions are less stringent in Habiforum's programmes than with other research programmes. There are often slightly more generous budgets for interdisciplinary programmes. Priemus indicates that he does not believe in the necessity for separate time to be reserved, although interdisciplinary research is generally more complex and more time for discussion is needed.

Rabbinge explains that within WUR[45] separate funds have been established to develop interaction between natural and social scientists within and between research schools. At the same time he is of the opinion that people should not in advance include in the budget the necessity for separate funds for interdisciplinary cooperation. This would be fatal, according to Rabbinge.

Rip says on the one hand that it would be useful if those involved in interdisciplinary projects within the university could more easily obtain a privileged status and be selected more readily as the focal point for research. In this case, it is important to make sure that one's interdisciplinary capabilities

45 *WUR: Wageningen University and Research Centre.*

and interests remain visible. On the other hand he regards interdisciplinarity as something that should remain 'unorganized'.

> *'Interdisciplinarity comes as an extra. It is not institutionalized and also should not become institutionalized, because this is fatal. There is a lot to be said for organizing interdisciplinary cooperation as an ad hoc construction.'*

Rip gives a very precise indication of why interdisciplinarity should preferably remain 'unorganized'. A first reason is argued from a negative viewpoint, as he himself says.

> *'If one takes interdisciplinarity as a criterion in the assessment of research proposals as well as scientific quality and relevance, then (on the basis of Gibbon's first law) one can predict that the indicators developed will work as guidelines to earn 'i points'[46]. Introducing an assessment criterion seems to be an obvious solution, but it works counterproductively if it subsequently becomes a tactic to acquire funds. One should look for connections in terms of the content.'*

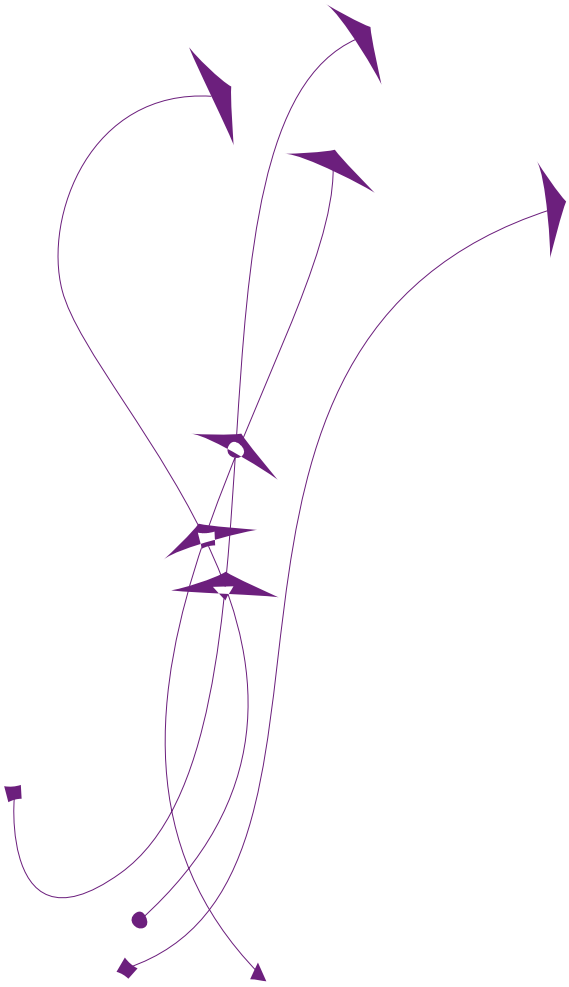
Secondly, there are according to Rip a large number of disciplines which are not so monodisciplinary at all, but offer openings for interdisciplinary cooperation. In the social sciences, for example, different methods do not necessarily have to be seen as excluding one another; interpretive methods, surveys and rational choice models can be used as complements to one another. Such possible combinations should be actively investigated.

> *'An example is the TIN20 project on the history of technology in the Netherlands in the twentieth century, partly funded by NWO. The main line of this is collaboration between sociologists, historians and philosophers of science. So, there is room, there are openings within disciplines. Rather than thinking in terms of 'i points'[46], it should be about research design, cognitive integration. So, take the openings which are already available and exploit them. Don't complain about interdisciplinarity and try not to institutionalize it.'*

A third development which is increasing in recent times and offers opportunity for interdisciplinary cooperation is the emergence of research centres of excellence and relevance. Rip refers here to different centres in the UK and Australia and MESA+ in the Netherlands and BMTI. It is frontier research often involving different parties: TNO[47], Technological Institutes, sometimes NGO's, sector organizations and such like.

46 *Imaginary 'interdisciplinarity points'.*
47 *TNO is a Dutch Research Institute, especially for Applied Research.*

'All kinds of interesting things happen there, but we're not talking specifically about interdisciplinary cooperation. It is about cognitive and organizational integration. Moreover, the premise is that within these centres of excellence people learn from earlier experiences to arrive at integration.'



7. Reflection

In this chapter, a number of conclusions will be drawn: on what issues are the researchers in agreement, and on which do they disagree? What are now the important (follow-up) questions for effective interdisciplinary cooperation?

7.1 Building bridges

If there is one thing on which the researchers interviewed are in agreement, then it is about the fact that truly effective interdisciplinary research can have societal, scientific and personal benefit, and is largely dependent on the goodwill of the participants. Everything starts with the right attitude. Even if there are fundamental differences between natural and social scientists and within the different disciplines: where there is a will there is a way.

A great many chasms have to be bridged on the way. At times there are well-worn paths and the bridges are firmly anchored. Experienced researchers work effectively together; they are respected, etc. At other times it appears as if the bridges are fragile constructions on which the researchers have to try to balance in order not to fall into the ravine of (institutional) impediments, prejudices based on monodisciplinarity, methodological issues, lack of time and paradigmatic confusions. And in yet other situations, the image of the drawbridge is more appropriate: the intentions are good, but the bastions of the different participants do not always seem accessible and the bridge is regularly open.

Difference of opinion on the bridge

The researchers interviewed agree on the importance of building bridges. But then the question is what is the best 'operating mechanism' for the bridge. Some researchers sketch the image of a charismatic and experienced leader who can create the proper atmosphere in his group without too many extra resources and facilities. In this case, the bridge is formed by knowledge, experience and authority, which together function as a natural counterweight, whereby the bridge can more easily be raised or lowered. Other researchers are of the opinion that the lifting or swinging mechanism of the bridge could use some extra power in the form of extra time, money and manpower, and separate positions and institutions. In other words, there appears to be a lack of agreement among the researchers in terms of the degree to which interdisciplinarity should be further shaped institutionally.

Different assessments of the climate

Some researchers hardly mention the impediments to interdisciplinarity. Although interdisciplinary research often lacks the prestige of monodisciplinary research it is sufficiently valued, respected and published, etc. It seems primarily to be a matter of persisting and doing your best. The fact that a number of top publications and Nobel prizewinners can be considered interdisciplinary, gives cause for hope. In short, there is not so much wrong with the climate in which the bridges have to be built, although it is not always plain sailing.

Other researchers take a more pessimistic view and are of the opinion that the climate is against them. There may be signs of a change, but it will take a long time before interdisciplinarity runs smoothly. These researchers mention, for example, that it would for a start make a difference if the assessment systems of funding institutions such as NWO were more attuned to interdisciplinary research.

The team

Different researchers have indicated that it is important that participants in interdisciplinary projects should have a monodisciplinary training, and that they do not lose contact with their own discipline. At the same time, some researchers indicate that from the start university education should pay more attention to interdisciplinarity than is currently the case. To what extent does this represent a conflict? And should a distinction be made in the required competences of project leaders versus the competences of others who participate in an interdisciplinary project?

This does not alter the fact that researchers consider that the team should above all be enthusiastic, should believe in the mission and can also consist of less experienced participants so long as there is some experience in the leadership or in other participants.

The contents of the toolkit

There is considerable consensus on what the contents of the toolkit of interdisciplinary researchers should be:

- A great deal of extra time for knowledge transfer and discussion – particularly at the start of a project or programme when the problem definition is formulated.[48]
- Knowledge of different disciplines and integrative methods (because they are there!), or the willingness to work together on new methods (because this is necessary!).
- Non-formal knowledge (also that of the stakeholders).
- Opportunity to be located close to one another.[49]

48 *Although Verbong considers that researchers can also begin with their own, more monodisciplinary problem definition and come closer to one another in the course of the project.*

49 *Although Faaij considers at the present time that this is no longer a necessary condition.*

The final destination, but also the route itself

There are also similar images of the fruits of interdisciplinary cooperation. This cannot in all cases be precisely that knowledge which society or even academia can put to immediate use – this is inherent in scientific practice. But very often there is benefit in other aspects:

- The seed for new disciplines.
- New knowledge questions, new project ideas and finances.
- Personal enrichment, a broader view, more experience, more competences.
- Adjusted images about 'the other' disciplines (and therefore having a better idea of what your value is for one another).

7.2 Some recommendations

In the previous chapters a number of wishes and complaints of the researchers can be read between the lines. In this paragraph we mention a number of recommendations which have not yet been addressed explicitly.

Funding of interdisciplinary projects

Van den Bergh advises research-funding institutions to above all encourage people in interdisciplinary research to be creative and not to impose too many bureaucratic questions and rules – particularly with preliminary applications. His first preference is to give free rein to the participants' ideas. The funding institutions should then base their initial selection on creativity and relevance, and only in the second round on quality.

Hordijk recommends greater flexibility in organizing the financing of interdisciplinary projects.

> *'Interdisciplinary research also often takes longer than the standard four years. This is undesirable for the financing institutions but the interdisciplinary knowledge would often benefit if such projects were handled with more flexibility.'*

Assessment, rewards, incentives

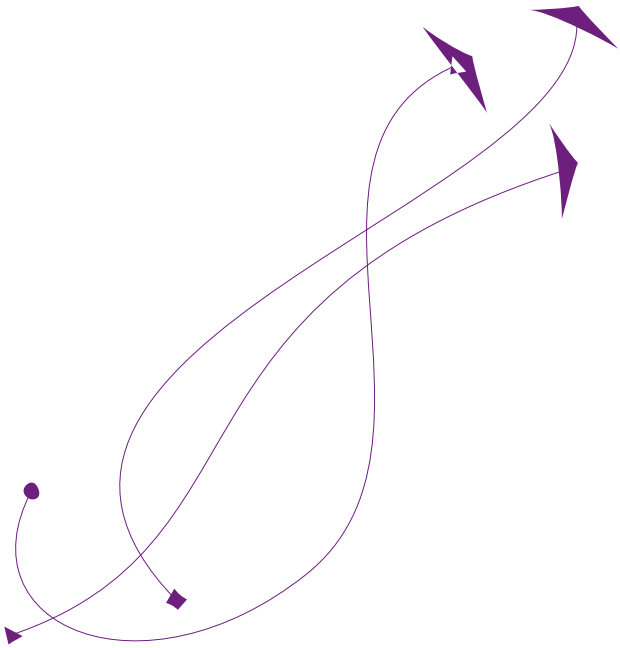
Never allow interdisciplinary research to take the place of monodisciplinary research, but ensure there is greater recognition of this type of research and researchers, advises Verbong.

According to Van Asselt, such institutions as KNAW and NWO play a role in solving the issues relating to reviews and visitations of interdisciplinary research. There need to be more researchers in the Netherlands who can assess projects.

Rabbinge advocates greater incentives for interdisciplinary cooperation. Rip mentions in this respect the MESA+ structure (the Twente institute for nanotechnology). Within this institution there are a number of 'strategic research orientations (SRO) which have been formulated along main lines, independent of any disciplines. The driver of an SRO is sometimes very active towards other disciplines, particularly if there are (personal, academic) rewards. A further incentive can be the external demand for unifying narratives, says Rip. People are then motivated to do something internally in order to be able to present a good story externally.

7.3 Epilogue

The issues raised in the chapters before clearly give way to different opinions that deserve further discussion. We hope this publication serves well in giving an impression of learning experiences of different researchers in different contexts and will also act as a starting point for a more profound analysis of cases of interdisciplinary research.
It might even bring about an agenda for further research.



Appendix 1

List of researchers interviewed

Prof. Dr Ir M.B.A. van Asselt (University of Maastricht, Young Academy of KNAW)
Prof. Dr J.C.J.M. van den Bergh ('Vrije Universiteit' in Amsterdam)
Drs M.M. Berk (Ministry of Housing, Spatial Planning and the Environment)
Dr A.P.C. Faaij (University of Utrecht)
Dr J.H.A. Hillebrand (Habiforum)
Prof. Dr P Hooimeijer (University of Utrecht)
Prof. Dr L. Hordijk (International Institute for Applied System Analysis)
Drs M.T.J. Kok (Netherlands Environmental Assessment Agency)
Prof. Dr S. Kuhlmann (University of Twente)
Prof. Dr H.B.J. Leemans (Wageningen University and Research Centre)
Prof. Dr Ir H. Priemus (Habiforum)
Prof. Dr Ir R. Rabbinge (Wageningen University and Research Centre)
Prof. Dr A. Rip (University of Twente)
Dr Ir G.P.J. Verbong (Technical University Eindhoven)
Prof. Dr Ir F.J.C. Willekens (Netherlands Interdisciplinary Demographic Institute)

About the researchers interviewed

Prof. Dr Ir M.B.A. van Asselt (University of Maastricht)
Marjolein van Asselt (1969) is Professor Extraordinary (Dr Tans rotating professorship) at the Faculty of Cultural and Social Sciences of the University of Maastricht and member of the Board of the Young Academy of the KNAW (Royal Netherlands Academy of Arts and Sciences). She followed a combined information technology and sociological sciences training in Twente and has considerable experience with interdisciplinary research. She has worked for RIVM (the National Institute for Public Health and the Environment), EAWAG (the Swiss Federal Institute of Aquatic Science and Technology) and the ICIS (International Centre for Integrated Assessment and Sustainable Development) research centre, and was a member of RMNO for a number of years. She conducts research into the interaction between science and policy, her specific area of interest being issues where uncertainty, risk and the future are important factors. In 2001 she was awarded an Innovation Incentive prize by NWO (Netherlands Organisation for Scientific Research).

Drs M.M. Berk (Ministry of Housing, Spatial Planning and the Environment)
Marcel Berk now works for the Directorate of International Affairs of the Ministry of VROM (Housing, Spatial Planning and the Environment). Previous to this he worked for the programme office of the Dutch National Research Programme on Global Air Pollution and Climate (NOP II) at RIVM (National Institute for Public Health and the Environment).

Prof. Dr J.C.J.M. van den Bergh ('Vrije Universiteit' in Amsterdam)
Jeroen van den Bergh (1965) is Professor of Environmental Economics at the Faculty of Economic Sciences and Business Administration and Professor of Nature, Water and Spatial Environment at the Institute of Environmental Issues, both at the Vrije Universiteit ('Free' University). He studied Econometrics in Tilburg, obtained his doctorate at the Vrije Universiteit and works for the Tinbergen Institute Research School and NAKE (Netherlands Network of Economics). He is member of the General Energy Council, Chairman of NWO VAM programme (on social scientific aspects of climate change) and Chairman of NWO's Sustainable Earth programme.

Dr A.P.C. Faaij (University of Utrecht)
André Faaij (1969) is Senior University Lecturer at the Copernicus Institute for Sustainable Development and Innovation (University of Utrecht) and coordinator of the research cluster Energy Supply & System Studies. He studied Chemistry and Environmental Sciences and obtained his doctorate in 1997 based on his dissertation on energy from biomass and waste matter. Faaij is actively involved in multidisciplinary (international) energy research, part of which is conducted in cooperation with policy-makers and industrial partners. He works for such organizations as IEA (International Energy Agency), IPCC (Intergovernmental Panel on Climate Change), UN (FAO (Food

and Agriculture Organization), UNCTAD (United Nations Conference on Trade and Development) and is a member of a number of national and international working groups.

Dr J.H.A. Hillebrand (Habiforum)
Hans Hillebrand (1956) studied Economic and Social History and obtained his doctorate in 1991 based on a historic-demographic research subject. Later he held a number of different research positions in the 'green' sector. He is currently involved with the Habiforum practical programme and is a member of staff of the Innovation Network, an organization which is committed to groundbreaking innovations in agriculture, agribusiness and rural areas. Over the course of his career he has built up expertise in the fields of employment, spatial developments, recreation and demographics. His passion is implementing innovations.

Prof. Dr P. Hooimeijer (University of Utrecht)
Pieter Hooimeijer (1955) is Professor of Social Geography and Demographics within the Department of Social Geography and Planning at the Faculty of Geosciences. He is also Director of NETHUR (the Netherlands Graduate School of Urban and Regional Research), a member of RMNO and Chairman of the KNAW Social Scientific Council. His expertise is at the interface of demographic developments and public housing and spatial planning, in particular on the relationship between the development of households and migration on the one hand and the functioning of the housing market and the development of urban systems on the other.

Prof. Dr L. Hordijk (International Institute for Applied System Analysis)
Leen Hordijk (1946) is Director of IIASA (International Institute for Applied System Analysis) in Austria. His original field was econometrics, from which he pioneered the forging of relations between economy and environmental pollution. He also worked for IIASA from 1984 to 1987, when he set up the RAINS model, which for many years provided the scientific foundation for a European Air Pollution Policy. Hordijk was co-founder of the Netherlands Environmental Assessment Agency, formerly a division of RIVM (National Institute for Public Health and the Environment), and board member of SENSE (Research School for Socio-economic and Natural Sciences of the Environment). He was also involved in the NOP (National Research Programme on Global Air Pollution and Climate Change) and COOL (Climate Options for the Long Term) projects.

Drs M.T.J. Kok (Netherlands Environmental Assessment Agency)
Marcel Kok (1968) has been Senior Policy Adviser with the Netherlands Environmental Assessment Agency (MNP) since 2001. Previous to this he worked as Academic Secretary for the programme office of the Dutch National Research Programme on Global Air Pollution and Climate (NOP II). He studied General Social Sciences and Environmental Sciences at the

University of Utrecht. He is currently involved in projects focusing on the relations between development and climate and sustainable development and vulnerability.

Prof. Dr S. Kuhlmann (University of Twente)
Stefan Kuhlmann (1954, Germany) holds the position of Professor of Foundations of Science, Technology and Society at the University of Twente since the autumn of 2006. Prior to this appointment he was Director of the Fraunhofer Institute for Systems and Innovation Research in Karlsruhe; he also held the part-time position of professor at the Utrecht Centre for Natural Science and Innovation Management, where he was involved with innovation policy. He is editor of *Research Policy* and is also involved with other scientific journals. He is a member of a number of different Dutch and international academic networks. His original fields of study were political science and history.

Prof. Dr H.B.J. Leemans (Wageningen University and Research Centre)
Rik Leemans (1957) is Professor of Environmental Systems Analysis at Wageningen University and Research Centre (Environmental Sciences Department), Chairman of the Board of SENSE (Research School for Socio-Economic and Natural Sciences of the Environment) and heads a number of inter- and transdisciplinary projects constructing and applying integrated models for assessment of climate change, biodiversity and the vulnerability of ecosystems. He acts as chairman of the Netherlands Global Change Committee of the KNAW. He was educated as an ecologist (Universities of Nijmegen and Uppsala) and was senior researcher for IIASA (International Institute for Applied Systems Analysis in Austria) and RIVM (National Institute for Public Health and the Environment). He is actively involved in the Intergovernmental Panel on Climate Change (IPCC) and the Millennium Ecosystem Assessment, and participates in a number of different international partnerships on global change.

Prof. Dr Ir H. Priemus (until 1 October with Habiforum)
Hugo Priemus (1942) studied Architecture in Delft and General Economics in Rotterdam. Having held a number of positions at Delft University of Technology, he was appointed Professor of Public Housing and Director of the Delft Research Institute OTB (Research Institute for Housing, Urban and Mobility Studies). He has held a number of different international visiting professorships. He is honorary member of NIROV (Netherlands Institute of Housing and Planning) and is an honorary doctor of the University of Uppsala. Priemus is a member of the SER (Social and Economic Council) committee on Spatial Planning and Accessibility and was research coordinator of the parliamentary enquiry commission on Infrastructure Projects (the Duivesteijn Commission). He is also Professor of System Innovation in Spatial Development, and Dean of the Faculty of Technology, Administration and Management of Delft University of Technology.

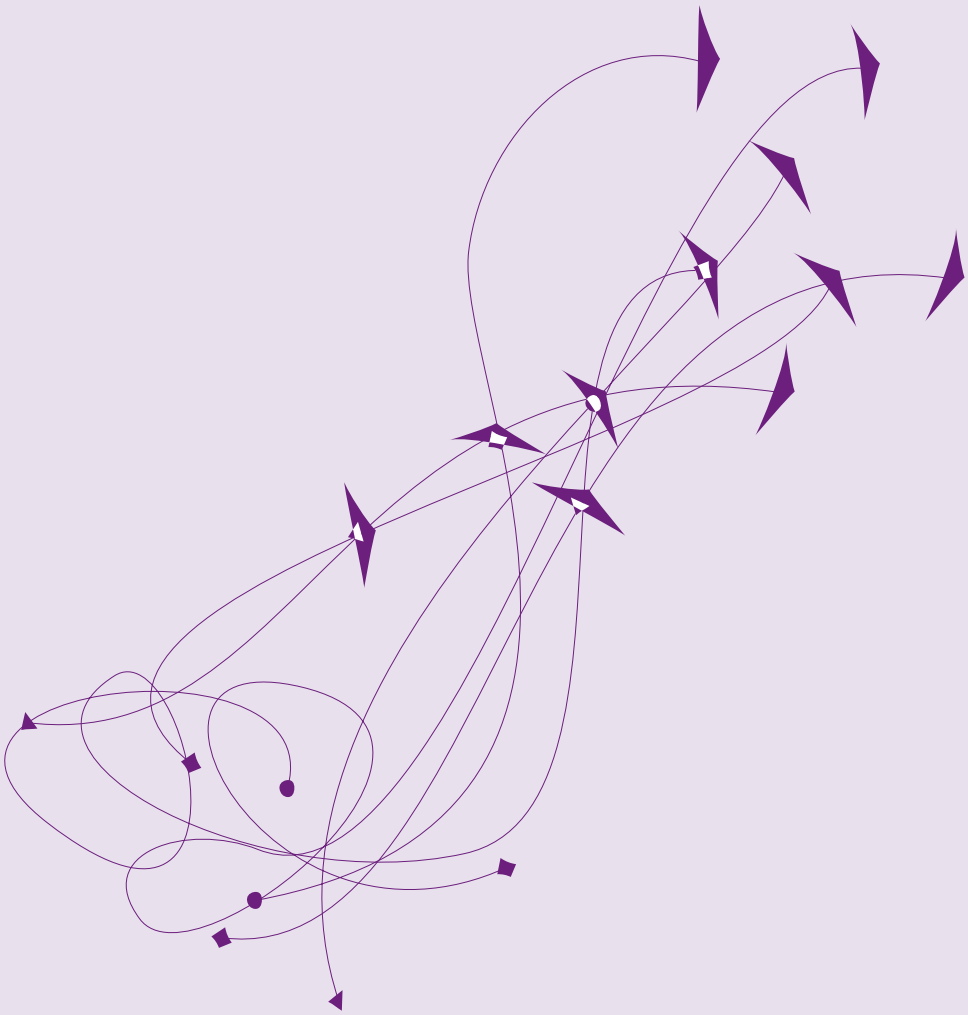
Prof. Dr Ir R. Rabbinge (Wageningen University and Research Centre)
Rudy Rabbinge (1946) is an agricultural scientist and is Professor in the field of Sustainable Development and System Innovation at Wageningen University and Research Centre. Prior to this he held a number of different scientific positions, including as a member of the Scientific Council for Government Policy. He is involved in a number of different national and international scientific partnerships in the area of nature, environment and agriculture, including the Millennium Ecosystem Assessment. He is one of the founding fathers of the transdisciplinary Para Limes Institute. Furthermore, he holds several management and advisory positions. Rabbinge is also Member of the Upper House of the Dutch Parliament on behalf of the PvdA (social democratic party).

Prof. Dr A. Rip (University of Twente)
Arie Rip (1941) studied Chemistry and Philosophy in Leiden. From 1970 he was involved in developing educational programmes and research in the field of chemistry and society. The study of science and technology in society became his specialist field. From 1987 to 2006 he was Professor of Philosophy of Science and Technology at the University of Twente. He published and continues to publish on the dynamics of science and technology development, science policy, innovations and constructive technology assessment. He recently instigated a research programme on technology assessment and societal aspects of nanotechnology as part of the Netherlands Research Consortium NanoNed.

Dr Ir G.P.J. Verbong (Technical University Eindhoven)
Geert Verbong (1955) is Senior University Lecturer in Transition and Sustainability within the Faculty of Technology Management of the Technical University Eindhoven. He studied Technical Physics in Eindhoven and became historian of technology and innovation researcher specialising in energy systems, sustainable energy and Strategic Niche Management. He is a participant in the Netherlands Knowledge Network on System Innovations and is also a member of the Tensions of Europe project, particularly with regard to the role of infrastructures in the European integration process. He currently head of an interdisciplinary programme on energy transition (see: www.transitionstudies.org).

Prof. Dr Ir F.J.C. Willekens (Netherlands Interdisciplinary Demographic Institute)
Frans Willekens (Belgium, 1946), is Director of NIDI in The Hague and is Professor of Population Studies at the University of Groningen. He set up the Population Research Centre there in 1991, which conducts research into demographic trends all over the world, reproductive health and the cohesion between population and development. Willekens studied Agricultural Science, Economy and Sociology at the University of Leuven and Urban Planning and Demography in the United States, where he also obtained his

doctorate. He has worked in Zaire and Austria and prior to his appointment as Professor at the University of Groningen in 1989, he was Professor at the University of Utrecht and Co-Director of NIDI.



Appendix 2

Questionnaire used in the discussions with researchers

1. Do you have experience with cooperation between scientists from different disciplines, and if so, which disciplines? (Reference to the five types of Ackers and De Vries, 2004)

2. To what extent do you agree with the statement that project management in interdisciplinary cooperation is crucial, even more so than with monodisciplinary projects? How important is communication in interdisciplinary cooperation in comparison with monodisciplinary research projects?

3. What organizational conditions are important for good interdisciplinary cooperation?
   a) Detailed working plans? Who should draw these up (core team or not?) and are special competences needed?
   b) Agreements on handling overlapping areas between disciplines?
   c) Agreements on planning of time, modus of delivering interim results, etc?
   d) Agreements on copyright relating to publications?
   e) Regular progress meetings for project participants?
   f) Physical proximity of the different researchers who participate in an interdisciplinary project?
   g) Is previous experience with interdisciplinary cooperation of the team a factor for success?
   h) To what extent is it important to separately reserve specific time, manpower for and resources for coordination and integration? (Unimportant, important, very important?)

4. What methodological aspects are important for good interdisciplinary cooperation?
   a) Are integrative models used to arrive at:
      - a joint formulation of the question?
      - an integration of the results generated by scientists from different disciplines?
      - integration of data?
   b) Have (already existing) integrative concepts been used or developed for interdisciplinary cooperation?
   c) To what extent have the integrative methodologies applied structured the cooperation? To what extent were the working method of the researchers and the presentation of the research findings adjusted?
   d) To what extent is there a problem in merging qualitative statements with quantitative statements and what solutions were adopted for this problem?

e) To what extent is there a loss of quality of the data in integrating this into integrative models and how is this handled?
f) What other, as yet unmentioned, methodological aspects are important?

5. To what extent is minimizing or bridging the differences in knowledge between different disciplines a condition for successful interdisciplinary cooperation?
   a) To what extent was there a 'joint construction of the research object'? Was a common basic concept formed, explicitly or implicitly? What is needed to arrive at a common basic concept of the problem from different disciplines? Is loss of disciplinary acuity unavoidable here?
   b) Can (Could) any problems be discerned between natural scientists and social scientists with regard to the question in the research?
   c) To what extent do the scientists understand the key concepts of the different participating disciplines? Is previous experience with interdisciplinary cooperation an advantage here?
   d) Were efforts made towards the development of a common vocabulary? Was this a conscious decision, or was this regarded as a dynamic process?
   e) To what extent is the aligning of research findings with one another an issue for attention? Is integration of knowledge relevant for the whole project or only for the end?
   f) To what extent is the integration of knowledge from different disciplines linked to the (possible) application of research results (perspectives for action) or does it arise from other motives?
   g) How does integration of knowledge take place: encyclopaedic (gathering data without a specific integration framework) or interpersonal (the product of cooperation between different scientists) or intrapersonal (integration by one person with multiple qualifications)?
   h) What type of integration of knowledge applies for which projects of interdisciplinary cooperation where you are (were) involved and what kinds of problems occur in terms of paradigmatic differences (and consequently probably methodological fixations)?
   i) To what extent is attention paid in these interdisciplinary projects to the integration of non-formal knowledge (experiential knowledge, contextual knowledge and such like) and how does that work?

6. What competences do project leaders in interdisciplinary cooperation need to possess?
   a) To what extent do project leaders require specific competences, in addition to general skills for good project leadership (coordination and cooperation)?
   b) Are these specific skills related to methodological qualifications or familiarity with integrative methods?

c) Do these specific skills relate to knowledge of backgrounds, paradigms of different scientists (for example, the individual's multiple qualifications)?
d) Are these specific skills related to experiential knowledge from previous projects?

7. In your opinion, what added value does interdisciplinary cooperation generate in the projects where you have been involved?
   a) Added value in the form of a better applicability of research, i.e. greater policy relevance?
   b) Added value in the form of the development of new concepts or methods?
   c) Added value in the form of innovative concepts, innovations?
   d) Added value as a result of spin off in the form of new projects?
   e) Added value in the form of experiential knowledge relating to interdisciplinary cooperation which can be applied elsewhere?
   f) Added value in the form of prestige, respect?
   g) Added value in the form of (more) publications?
   h) Added value in the form of competences for interdisciplinary cooperation?
   i) .....

8. Which of the above-mentioned four aspects: organizational, methodological and epistemological aspects, or person-related competences, do you consider important in interdisciplinary cooperation?

9. To what extent do you agree with the statement that interdisciplinary cooperation is not in direct opposition to disciplinary specialisation, but is a status which is developed ad hoc?

10. Are there any other matters relating to interdisciplinary cooperation which you consider important which you would like to put forward, and if so, what?

List of Abbreviations

COOL	Climate OptiOns for the Long Term - Project
COS	Committee for the Sector Councils
FI	Fraunhofer Institute for Systems and Innovation Research
GAIM-AIMES	Global Analysis, Integration and Modeling task force of the Earth System Synthesis and Integration project of IGBP
GOAL	General Optimal Allocation of Land Use - Model
IIASA	International Institute for Applied Systems Analysis
IHOPE	Integrated History of People on Earth - Project
IPCC	Intergovernmental Panel on Climate Change
KNAW	Royal Netherlands Academy of Arts and Sciences
MESA +	Institute for Nanotechnology (UT)
MNP	Netherlands Environmental Assessment Agency
NGO	Non-Governmental Organization
NIDI	Netherlands Interdisciplinary Demographic Institute
NOP	National Research Programme on Global Air Pollution and Climate Change (from 1989-2001)
NWO	Netherlands Organisation for Scientific Research
OECD	Organization for Economic Co-operation and Development
RIVM	National Institute for Public Health and the Environment
RMNO	Advisory Council for Research on Spatial Planning, Nature and the Environment
SENSE	Research School for Socio-Economic and Natural Sciences of the Environment
SenterNovem	Agency for the implementation of government policies on innovation, the environment and sustainable development in the Netherlands
SER	Social and Economic Council
SRO	Strategic Research Orientation
TNO	Dutch Organization for Applied Research
TUD	Technical University of Delft
TUE	Technical University of Eindhoven
VU	'Vrije Universiteit' ('Free' University)
UM	University of Maastricht
UvA	University of Amsterdam
UT	University of Twente
UU	University of Utrecht
VROM	Ministry of Housing, Spatial Planning and the Environment
WUR	Wageningen University and Research Centre

What are the difficulties researchers face in interdisciplinary projects? And what can we learn from their experiences? What is the added value of interdisciplinary research? Fifteen researchers in the Netherlands give their opinion about epistemological, methodological and organizational aspects of interdisciplinary research. Their ideas are presented in this publication by four Dutch organizations engaged in science policy: KNAW, NWO, RMNO and COS.