

# Nanoscience and Nanotechnology Research Case Study

The practical benefits resulting from  
collaboration between social scientists  
and nanotechnology researchers

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Research, Science and Technology



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## Summary

This case study used qualitative research methods, to investigate the key themes listed in the project brief. Input came from social and biophysical scientists working in the areas of nanotechnology and biotechnology both in New Zealand and in the United Kingdom.

Within the developing fields of nanotechnology and biotechnology in New Zealand, collaboration between biophysical scientists and social scientists is relatively uncommon. However, recognition that these areas of research are viewed by the public as somewhat contentious has helped raise interest and promote collaborative work. In the area of biocontrol for pest management in New Zealand, consultative work is more well established, with research done into possum and rabbit control by Fitzgerald et. al (1994, 1996 & 2006), and the Parliamentary Commissioner for the Environment (2000). Social science involvement in the area of pest control is ongoing within the National Research Centre for Possum Biocontrol, and through the Australian Co-operative Research Centre on Invasive Animals.

In the area of nanotechnology, collaborative work with social scientists seems to be in its infancy. Formative work has been done by two of the interviewees in this study who prepared a seminar paper and research proposal together, and by Andrew Cook (2005) who investigated the ethical and social issues around nanotechnology using a series of focus groups. In the UK, collaborative work with social scientists into nanotechnology appears to be more common including work on public deliberation processes.

Inter-disciplinary collaboration was found to be a challenge for the participants involved. Issues included: overcoming the barrier of disciplinary specific language, approach and methodology, coming to terms with your own and your collaborators underlying philosophical assumptions, maintaining a level of autonomy when working closely within another discipline, coming to a mutual understanding of each others role in a project, maintaining an open mind, and allowing the time necessary for a successful collaboration.

Collaborative work was found to be beneficial for the participants on a number of levels. Benefits included; building new networks, opportunities for further collaborative work, increased knowledge, improved capacity for cross-disciplinary communication, insight into the broader social context (including public viewpoints of the technologies), more reflexive research practice, heightened awareness of disciplinary assumptions, appreciation for different research methods, and producing outputs that are more robust.

Linked to the benefits are the achievements of having social scientists engaged in nanoscience and biotechnology research. In the area of biotechnology these included: the identification of society's performance standards for biocontrols and the consequent re-shaping of research priorities, and the development of communication and risk management strategies. In Nanotechnology the benefits were: the increased knowledge of how to conduct a constructive public debate around the development of a potentially controversial technology, improved arrangements for sharing facilities, strengthened links with science stakeholders, establishment of collaborative arrangements, participation of fundamental science practitioners in policy debate, and the development of a more reflective, critical and socially aware approach to nanotechnology research.

Social science work and public engagement have the potential to help shape the somewhat contentious areas of nanotechnology and biotechnology in a positive and socially constructive manner. The NanoJury UK involved the public through putting the UK government nanotechnology policy 'on trial'. Expert witnesses were involved, and a citizen jury produced

a number of recommendations regarding the development of nanotechnology and nanotechnology policy. In New Zealand, social scientists and PCE investigators engaged the public in a series of focus groups, interviews, and hui around the issue of possum biocontrol. The findings of this research have directly influenced the shaping of research priorities.

As part of the interviews, participants described lessons they had learned through the collaborative work they had done, and offered advice for researchers planning collaborative work, and institutions promoting these collaborations. Suggestions included: investing time into informal conversations with your collaborator, incorporating research of social, ethical and cultural issues into the project design (rather than 'tacked on' later), promoting research into collaborative models and strategies, investment into monitoring of collaborative work, explicitly recognising the work of collaboration in project funding, valuing cross-disciplinary teams, and the promotion of a positive attitude to collaboration within funding bodies. Strategies for collaboration were suggested by two participants, and the process of selecting appropriate individuals for a collaborative team was considered important. Basic attitudes, such as having an open mind and being prepared to listen and debate were considered useful for successful collaboration.

In general, participants regarded collaborative work as interesting and fruitful, both in terms of individual or institutional capacity development and in terms of outputs produced from their research. Collaborative work was regarded as more challenging than intra-disciplinary work, however these challenges were, for the most part, overcome and meant that future collaborations could run more smoothly. Collaborations between social scientists and scientists working in the areas of nanotechnology, or biotechnology seemed to be uncommon, and the potential for collaborative work to produce new research in these areas seems relatively untapped.

# 1. Introduction to the case study

## 1.1 Background

The Ministry of Research, Science and Technology, (MoRST), is commissioning a set of case studies which will inform and illustrate themes for the biotechnology, nanotechnology, energy and environmental roadmaps. Roadmaps are documents that provide an overview of an area of science activity important to Government and to New Zealand and outline the desired directions for that science activity into the future.

This report describes the findings of a brief case study on nanotechnology with specific reference to collaboration between social scientists and nanotechnology researchers.

## 1.2 The brief for this case study

In its brief for the case study, the Ministry of Research, Science and Technology stated the broad issue to be explored in this case study is “*the practical benefits resulting from collaboration between social scientists and nanotech researchers*”. The Ministry has indicated that the rationale for examining this “*is that there is a recognised need for nano-scale R&D to meet societal values and expectations, and practical guidance for social scientists and natural scientists [on how to do this] would be beneficial*”.

By looking at examples of where social scientists and biophysical scientists have collaborated or been closely involved with each other, especially in potentially controversial or contentious areas of science such as nanotechnology and gene-based pest biocontrol, the Ministry wanted to identify:

- the challenges that social scientists and biophysical researchers faced in coming to understand the perspectives and approaches of each other when they worked together
- the benefits and insights gained by the social and biophysical scientists involved
- the benefits of having a social scientist actively involved in the research programme/s
- how social scientist involvement and public engagement have informed or shaped the research direction.

## 1.3 Case study method

Three collaborative situations were used to explore the themes in the report brief. These included:

- a. a case where a social scientist and a materials nanoscientist came together to deliberately explore each other’s perspective and disciplinary culture in order to understand what social and physical science collaboration might actually involve.
- b. an experimental case where a social scientist was deliberately recruited to be actively engaged in the programme of a specialist nanoscience research centre.
- c. a case where social research and public engagement were used to inform the direction for research on possible biological controls for environmental pests in New Zealand, specifically the use of genetically modified organisms for possum control.

These three collaborative situations (so called, because they all involve more than one project), were investigated primarily through semi-structured interviews with four individuals closely involved. The participants in this case study included:

- A Nanoscientist and a Social scientist, both based in New Zealand (interviewed separately - face to face interviews).

- A UK based social scientist working in the area of Nanoscience,
- A New Zealand based biophysical scientist working in the area of possum biocontrol.

Additional comments and background information were also provided by social scientists working in the area of pest biocontrol. Background information was also obtained from relevant organisational websites, from papers provided by the interviewees, and through conversations with a range of social scientists working in New Zealand research institutions and the private sector.

The interview notes were key-worded according to the themes set by MoRST, then inputted into the qualitative data analysis tool 'AskSam'. Reports generated from AskSam processing were used in a more detailed thematic analysis which directly informed the final report.

#### 1.4 A note about 'collaboration'

The brief for this case study appears to assume that social scientists and biophysical scientists are possibly quite different in their approaches to research, their interests, and perspectives. It also seems to suggest that generating new scientific insights or products in particular areas of science (especially those which are potentially contentious) might occur if social and biophysical scientists are brought together to collaborate in a common endeavour. It also seems to suggest that doing so could be challenging to both groups, and to science managers.

Working together, as distinct from 'working for', can take a variety of forms. One typology ([Pollard, 2006](#)), notes, but distinguishes between, *coordination*, *cooperation*, and *collaboration*. The brief for this case study makes reference to collaboration, which is described in the New Oxford Dictionary of English as being "the action of working with someone to produce or create something" (Pearsall, 1998. pp. 358). Of central interest in this case study is, therefore, what social and biophysical scientists "working with" each other actually entails .

#### 1.5 A note about social science

Social science is a broad term covering a wide range of disciplines and sub-disciplines that take human beings, their interactions, and endeavours as their main object of research. Each of these fields has its own traditions, research practices, forms of interpretation, explanation, and literature. There is considerable debate about what constitutes a 'science' and whether these various areas of research can be considered sciences. Underpinning this debate is the issue of whether human action, interaction, and organisation are subject to 'scientific laws' in the same way that physical phenomena might be. However, while many social scientists recognise important differences between the social and biophysical sciences, they justify the use of the term science on the grounds that they use *systematic research methods* to gather their data along with various forms of *explanation* to help understand it.

In New Zealand the social sciences are typically thought of as including:

- psychology, which is largely focused on the working of the human mind, emotions, and behaviours at the level of the individual
- sociology, which is largely concerned with human collectives and how they work – ranging from quite small groupings (e.g. the family) through to whole societies or groups of societies
- geography, which focuses on the dynamic interrelation between humans and their terrestrial environment
- anthropology, which focuses on human culture (and cultures) and how they are expressed and maintained

- economics, which focuses on the human use and exchange of goods and services
- political science, which focuses on processes of influence and decision making within groups, organisations and the state.

It should be noted that understanding the human activity of ‘doing science’ and its organisation is largely a social scientific endeavour, and has given rise to a field of study referred to as ‘science, technology and society’ and to various sub-disciplines such as the ‘sociology of science’.

In the New Zealand context there are few social scientists (if any) working in physical or biological research programmes on an ongoing basis. Among the Crown Research Institutes (CRIs) social scientists are more likely to be found working in fields where a variety of disciplinary efforts are required, for example in environmental and resources sustainability, management, adaptation, and risk management. Employment of social scientists in New Zealand science institutions has been a relatively recent phenomenon, beginning with the Social Science Unit of the former Department of Scientific and Industrial Research (DSIR), and in the 1990s in some of the CRIs. In the universities social scientists are typically located in discipline-based departments and until relatively recently, their research has also been discipline-based.

Even when they are included in science institutions such as CRIs, social scientists do not appear to be engaged in studying the science that is occurring, or in conceptualising the science itself. Rather, they report that their work tends to be treated or seen as one or a combination of the following:

- an add-on to large biophysical research efforts and programmes rather than integrated into them
- an after-thought
- providing ‘social’ market intelligence, including of social risks and costs
- facilitating public and stakeholder engagement
- managing conflict, and
- technology transfer.

Efforts of biophysical scientists and social scientists to collaborate and inform each other’s work are therefore relatively rare.

## 2. What has the collaboration involved?

### 2.1 Nanoscience collaboration in NZ

The New Zealand nanoscience collaboration work was new and relatively short-lived. It was centred on the goal of preparing and presenting a seminar paper on the technology and the social and technical interface from the point of view of both a social scientist and a physical scientist. The collaboration was initiated by the social scientist who was looking to include a Nanoscientist in a research proposal. The collaboration began rather informally and worked up to the joint preparation of a proposal followed by the seminar presentation.

These two researchers would meet roughly once a week, talking and brainstorming key concepts, entering the discussion directly into a PowerPoint presentation. The physical scientist was new to this approach, stating that within their discipline work started with figures, diagrams and formulae, the verbal explanation came later. Relatively informal

conversations were important and email was also used in the later stages to review draft materials. Once a framework for the presentation was established the different (or not so different) perspectives were articulated to inform the finished product.

## 2.2 Nanoscience collaboration in the UK

The UK based nanoscience collaboration we examined was sponsored by a leading nanoscientist. Our study informant on this was the sole social scientist working within the nano-based organisation, which included many scientists and technologists.

This collaboration was for a medium length fixed term, and included running workshops to inform nanoscientists of the social and ethical issues of nanotechnology, talks and presentations at science festivals, and conducting social science research within a science setting. Another role of the informant has been facilitating public involvement in the NanoJury UK process, which was aimed at involving the public in Nanotechnology policy development.

## 2.3 Possum Biocontrol

In the area of biocontrol, collaboration began with the CRIs joining forces with an independent researcher on some early qualitative and quantitative research for MAF regarding public attitudes to possum and rabbit biocontrol (Fitzgerald, Saunders & Wilkinson, 1994 & 1996). Landcare Research and AgResearch were also involved with the subsequent investigation by the Parliamentary Commissioner for the Environment (PCE), published as 'Caught in the Headlights' (2000). The social research component of this investigation (stakeholder focus groups) was conducted by Fitzgerald & Wilkinson, and specifically looked at the question of fertility control and issues surrounding genetic modification (GM). Researchers attended the focus groups to both answer questions about the biocontrol research being conducted and to gain a firsthand appreciation of the viewpoints of the various stakeholders. PCE offices also conducted individual interviews, hui, and interest group discussions.

# 3. What are the challenges of interdisciplinary collaboration?

In interview discussions it became apparent that all participants encountered many challenges involved in interdisciplinary collaboration, and that these challenges depended on the nature and purpose of the collaboration. One of the most salient challenges was coming to terms with disciplinary specific language. This was mentioned by virtually all participants for whom it was necessary to be prepared to ask for clarification and take the time to build up some knowledge in another subject area. This gave rise to the challenge of having to articulate this new knowledge and language to other individuals and even community groups.

For a biophysical scientist, social science language can seem vague and imprecise. This was associated with an unfamiliar disciplinary approach and methodology. Some of our informants stated that biophysical scientists can be dismissive of social science methods, particularly qualitative methods. For a biophysical scientist used to a formal experimental method, dealing with less tangible qualitative data, methods and rationale can be difficult. Attitudes to these methods changed as the benefits of the social science approach were

demonstrated.

These challenges are linked to the deeper obstacle of understanding the differing philosophical assumptions which underpin disciplinary approaches or viewpoints. This seemed to be an ongoing challenge in any collaboration, but one that with continued effort yielded benefits in the form of an increasing awareness of the assumptions underpinning one's own discipline, alongside the development of a more fruitful collaboration. It was also stated that individual social scientists tended to have differing approaches.

Within interview discussions it was mentioned that a way to forge a more successful collaboration and help overcome disciplinary specific viewpoints is to orient work on research objectives and outcomes, as opposed to process and method. Deciding upon a set of research questions or goals can be a challenge, but should be done collaboratively. An open mind, and an acceptance that there are many ways to reach an end point, was seen as necessary here.

The UK based social scientist noted that another challenge was to maintain a level of separation in order to retain the differences in perspective upon which inter-disciplinary collaboration is based. This separation is threatened when the researcher becomes too "embedded".

Coming to a mutual understanding of the social science role, when working closely with physical scientists, can be difficult. For social scientists, finding concrete ways to contribute directly to nanoscience research projects and literature can also be challenging. The UK social scientist stated that "the big challenge was to reject the framing that public and social issues weren't connected to research practice and science work in general". This viewpoint seems to be related to a common assumption that the doing of science (in the laboratory) is value-neutral. Hence, the broader social and political context of the research is not often considered by biophysical scientists working within a given programme. Introducing public concerns around the development and deployment of a technology can therefore be difficult, since these are generally thought of as a matter for social science and beyond the typical scope of science and science literature.

It was generally noted that cross-disciplinary collaboration was time consuming (for many of the reasons stated above), and allowing the necessary time could lead to difficulties. Establishing a process was one of the tasks that consumed a large amount of time in the NZ nanoscience collaboration. This task is one that is more familiar to a social scientist, but less so to biophysical scientists, as a more concrete process is implicit in their work.

In the UK based collaboration the social scientist was included for a fixed term in an established nanoscience facility. It was suggested that an extended placement in the lab could help to overcome the social and technical complexity of the laboratory context, which can take a considerable length of time to understand. As an extension to this point, the social scientist regarded ethnographic methods as relevant and useful in this context. The social scientist in this case also noted an implicit assumption that involving a social scientist would lead to the development of less publicly contentious technology. This assumption was described as often being unrealistic and sometimes misleading when collaboration is seen as a "fix" to public questions about the governance of science and technology. The informants view was that "collaborations may be able to highlight tensions and provide a language for debate about the role of science and technology in society – but it cannot replace wider public deliberation".

#### **4. What have been the benefits of collaboration for those involved?**

For all the challenges that come with cross-disciplinary collaboration, the benefits of such work were often regarded as rich and unpredictable. It is these benefits which are the focus of this part of the discussion.

Participants found that collaborations helped to build new networks, both with people working in other disciplines, and with those working in the same discipline who share similar interests. For example, links were established between social scientists with an interest in studying science. Ideas and opportunities for further collaborative work were found to be by-products of collaboration.

Personal knowledge of another disciplinary area was increased in collaborative work, and this helped to build the ability to communicate in a cross-disciplinary setting. Social scientists were better able to articulate the community concerns about the technology and research to the biophysical scientists. This articulation enabled more considered decision making regarding which avenues of research to pursue, particularly in the area of possum biocontrols. Further, through the collaborative research, biophysical scientists gained an insight into what informs people's views and preferences regarding technologies, and why people make the decisions they do. This greater level of understanding helped to soften the sometimes dismissive attitudes of biophysical scientists to the public and its concerns.

Associated with this is a heightened awareness of the social and political context within which researchers operate at all times. Social science challenges the idea that society and its interests begin outside the laboratory door, showing that all scientific work has social implications. This heightened awareness of context was said to include science and technology policy and its formulation, public concerns and the politics of funding.

In general, cross-disciplinary collaborations were found to 'broaden the horizons' of those involved, a pleasant surprise for some researchers. This meeting of different viewpoints can encourage reflection upon one's own approach (whether social or biophysical in nature); which can unearth assumptions inherent in any discipline. These assumptions may be embedded in a researcher's choice of language when they write or communicate. One participant believed that through their collaboration they gained an ability to 'read between the lines' and deconstruct their own and others work.

In one case the biophysical scientist gained an appreciation of the value of qualitative research methods, having previously been very sceptical of such processes. Finally, cross-disciplinary collaborative work was said to produce more robust outputs.

#### **5. What outcomes have been achieved by having social scientists engaged in nanoscience and biotechnology research?**

Having social scientists engaged in nanoscience and biotechnology research has resulted in a wide range of outcomes, both negative and positive in nature, some of which overlap with the benefits discussed above. Participants generally found collaboration to be worthwhile and interesting, and mentioned achievements of both a tangible and not-so tangible nature.

Regarding the more concrete achievements in the area of biocontrol, it was mentioned that social scientists helped to identify society's performance standards for the technologies. Also achieved was a re-shaping of the research priorities and a clearer definition of the outcomes sought from the work. Communication and risk management strategies were developed through the collaborative biocontrol research, and these have assisted in the engagement with the community over the technologies.

In the area of nanotechnology in the UK, social science has contributed to the wider public debate about its implications. Another achievement has been the ability to advise government on processes that can reduce the chances of controversy about nanotechnology, and how potentially contentious science can be discussed positively through a democratic process aimed at addressing public concerns early on in the development of a technology.

Within the New Zealand setting, the relative lack of collaborative social and physical science research on nanotechnology has meant that outcomes have been insubstantial.

Some participants mentioned negative outcomes of collaboration, such as the difficulty in getting collaborative work involving a social scientist published in mainstream science journals. It was also stated that it was difficult to identify what social science might bring to the 'doing of physical science', and that the collaboration had brought about no real change in the science.

By its nature collaboration facilitates the development of new networks and promotes sharing between the parties involved. Participants noted a number of achievements of this sort, some of which were unexpected. For example, the ability to communicate with other disciplines was found to be an enduring benefit even once the particular collaborative project was complete. In the UK case links were developed and strengthened between different science stakeholders (e.g. science policy makers).

The UK social scientist was afforded the opportunity to not only collaborate, but be 'embedded' with physical scientists, allowing a deeper understanding of the fundamental science and its practitioners. Having established this relationship the UK social scientist was able to facilitate the participation of nano-scientists in a national-level social science discussion on nanotechnology policy.

A number of less tangible achievements around improved attitudes and understandings were also noted by participants. Firstly biological and physical scientists were said to gain an increased awareness of the basis for public concerns about their work, bringing society and its concerns into the laboratory and challenging the assumption of value free science. Biophysical scientists stated that they had gained a new understanding and value of social science and its methods (including qualitative) during collaborative work. Social scientists stated that they gained a greater appreciation of science and its practical limitations and constraints. Lastly, collaborative work has helped provide insights into the relationships between basic research, science policy and social issues around science and technology. This has made scientists thinking about nano-technology, its potential use, and commercial development more reflective and critical.

## **6. How have social science and public engagement informed research directions in nanotechnology and another publicly contentious area of science?**

### 6.1 Social science

Social science work contributed to the NanoJury UK process (a way of involving the public in science policy). Social scientists encouraged public engagement and facilitated the discussion, which could have far reaching implications for the direction of nanotechnology research and policy in the UK.

In New Zealand, projects run by social scientists have been influential in setting directions for research into the use of biotechnology in pest control. The conclusions were used to shape the future priorities for research, and justified discontinuing work into socially unacceptable forms of biocontrol. Currently there is an objective within the possum 'outcome based investment' which is centred on social research.

### 6.2 Public engagement

The NanoJury UK was developed as part of a move towards public involvement in science policy. It was described as an 'experiment' to test how a public dialogue on nanotechnology policy might work.

The idea was to put the UK government's nanotechnology policy on trial. Citizen involvement in discussion and debate was used to find out how government policy could steer the technology and achieve the outcomes that citizens would hope for.

The structure was that of a citizen jury, with various witnesses raising possibilities and problems with the use of nanotechnology. The recommendations that the citizens came up with were described as being very useful, interesting and not necessarily falling in either the pro, or anti camp. Issues that came out through the citizen jury and its findings were said to not provide answers, but to raise more questions.

As mentioned above, through engagement with the public, understandings of priorities for, and concerns around the possible use of various bio-technologies were made explicit. The social science research programme involved members of the public in a series of focus groups and telephone interviews. The findings from this research (Fitzgerald et. al., 1994 & 1996) were used to inform the recommendations by the New Zealand Parliamentary Commissioner for the Environment in his report 'Caught in the Headlights' (2000), and have directly influenced the promotion, or discontinuation of research into various forms of pest biocontrols.

## **7. Lessons and observations about collaboration**

Lessons, observations and advice about collaboration were offered by nearly all informants in the study. This knowledge could be of value to future collaborative researchers, particularly

since many of our informants found collaborative research to be a challenging endeavour that could develop in unexpected ways.

Investing time in conversation about the nature of the science of your collaborator was regarded as important by a New Zealand social scientist. By all accounts collaborative work can take significantly longer than intra-disciplinary work, and it was suggested that investing non-funded time could be necessary. These conversations could cover what they see as the issues related to their work, and the possibilities of how the collaborative research could proceed. Experimenting with practising collaboration was considered necessary in order to develop a capacity to collaborate further.

The UK social scientist noted that social science collaboration, and consideration of social, ethical and cultural issues of technology, should be incorporated into the design of science projects rather than being 'tacked on' or treated as an after-thought. Another participant punctuated this point by stating that scientists and institutions need to design collaborative strategies. A way of doing this could be through a broad scoping of the subject area and international literature, with a particular focus on models for collaboration.

Most informants mentioned the issue of funding which was regarded as playing a key role in the development of collaborative research capacity. Investment in monitoring and studying how collaboration is done was seen as necessary. It was further suggested that the work of collaboration (such as negotiation, translation and learning) should be explicitly recognised in funding, and that cross-disciplinary teams need to be seen by science funders as valuable. One researcher felt that FRST was ambivalent towards funding of social research in the context of biophysical science. This informant believed the foundation gave out mixed messages about collaboration. It was also noted that research funding should have a component dedicated to the social, ethical and cultural dimensions of a technology under development.

The UK social scientist suggested a coordinated approach to collaboration which involves a balance between participation and observation, achieved through the use of a team of social researchers. This way one of the social scientists could be more embedded in the biophysical science work while the others "carry out more traditional social science (based outside the science institution), but in close cooperation with the embedded social scientist". In this way, a level of disciplinary autonomy useful in reflecting on findings can be maintained. A complementary approach suggested by a New Zealand social scientist was to collaborate with many scientists, identifying networks operating in an area and exploring the linkages. This approach could be particularly useful in the field of nanotechnology which was thought of as being genuinely cross-disciplinary in its scope.

An understanding that not all social scientists or biophysical scientists want to collaborate is important in putting together collaborative teams. Some individuals are already working in areas with cross-disciplinary potential because this is where their interests lie. Compatibility on a number of levels should be sought when putting together a collaborative team. Trustworthiness, approach to work, pace of work, feelings about publication, and agreements on standards and quantities of work should all be examined.

Other attitudes considered useful in collaboration include; a basic belief that social science has the same value as biophysical science, an open mind towards various approaches, and being prepared to debate with, and listen to others.

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## Appendix

### Comparison of Collaboration, Cooperation and Coordination

From Pollard, D (2005)

	<b>Coordination</b>	<b>Cooperation</b>	<b>Collaboration</b>
Purpose	Avoid gaps & overlap in individuals' assigned work	Obtain mutual benefit by sharing or partitioning work	Achieve collective results that the participants would be incapable of accomplishing alone
Desired Outcome	Efficiently-achieved results meeting objectives	Same as for Coordination, plus savings in time and cost	Same as for Cooperation, plus innovative, extraordinary, breakthrough results, and collective 'we did that' accomplishment
Optimal Application	Harmonizing tasks, roles and schedules in <i>simple</i> situations	Solving problems in <i>complicated</i> situations	Enabling the emergence of understanding and realization of shared visions in <i>complex</i> situations
Examples	Project to implement off-the-shelf IT application; Traffic flow regulation	Marriage; Operating a local community-owned utility or grain elevator; Coping with an epidemic or catastrophe	Brainstorming to discover a dramatically better way to do something; Jazz or theatrical improvisation; Co-creation
Appropriate Tools	Project management tools, schedules, roles, critical path (CPM), PERT and GANTT charts; "who will do what by when" action lists	Systems thinking; Analytical tools (root cause analysis etc.)	Appreciative inquiry; <u>Open Space</u> meeting protocols; <u>Four Practices</u> ; Conversations; Stories
Degree of interdependence in designing the effort's work-products (and need for physical co-location of participants)	Minimal	Considerable	Substantial
Degree of individual latitude in carrying out the agreed-upon design	Minimal	Considerable	Substantial