

# Expert views on sustainability and technology implementation

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The first expert view on sustainability of the Saxonian  
Oberberghauptmann Hans Carl von Carlowitz (1645 - 1714)



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# Expert Views on Sustainability and Technology Implementation<sup>1</sup>

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## Abstract

Twenty-one senior faculty members and researchers were interviewed about their conception of sustainability and their understanding of implementation in projects linked to the Alliance of Global Sustainability, a joint project of MIT (Boston), ETH (Zurich and Lausanne), UT (Tokyo), and Chalmers (Gothenburg).

We identified five complementary views on sustainability, i.e. i) *science is sustainable per se*, ii) *sustainability is an ethical relationship with the past and future*, iii) *sustainability is the maintenance of a system within functional limits*, iv) *eco-efficiency*, v) *sustainability is a form of ongoing inquiry*. In total, the conception of *ethical relationship* was the most dominant conception whereas *science per se* and *eco-efficiency* were less used. Researchers with a natural science background raised more aspects of sustainability and more emphasized *limit management*. *Eco-efficiency* is important for professors with a social science but not for those with a natural science background.

Most of the researchers regarded *implementation* as the process whereby their work comes into contact with social groups and processes and where concerns about taking action and social technology change became prominent. The interviewed researchers considered successful implementation to be linked to value change, efficient information policy, institutional action but not regulations and supposed technology implementation to create new allocations, i.e. winners and losers.

The relationship between knowledge and action is considered central in views on implementation. Three different conceptions and habits could be identified with respect to this relationship, i.e. a) *action: I act to change the world*; b) *interaction, I exchange information with my environment through my actions*, c) *transaction or mutual learning. I change as a result of my effort to bring about change in the world*.

The concept of sustainability has a surprisingly long tradition and is a child of the 17<sup>th</sup> century crises in forest overuse due to shipping construction and mining. The concept goes back to the Saxonian Oberberghauptmann von Carlowitz, a “principal captain” in the Saxonian silver mining business. In his volume *Sylvicolum Oeconomica. Die Naturmäßige Anweisung zur Wilden Baum-Zucht* (Leipzig 1713, [engl. *Nature based guidelines for breeding of the wild tree*.]), he was concerned about “*wie eine sothane Conservation und Anbau des Holtzes anzustellen, daß es eine kontinuierliche, beständige und nachhaltige Nutzung gebe.*” [engl., “*how to accomplish conservation and growing of wood that a continuous, steady, and sustainable can become possible.*”] In this quote the technical term [engl. *sustainable*] was firstly defined (DIE ZEIT, Nov. 25<sup>th</sup>, 1999, No. 48, p. 98).

## Goals and Motives

Sustainability has always been an elusive term. As we begin to look at how to sustainability should be implemented in action, it become even more so. The variety of theoretical and practical backgrounds that the groups and individuals who work on sustainability bring to bear on the problem come directly into play and affect our ability to understand each other. These differences can be a source of richness, but they also mean it is difficult to keep track of what we mean when we ask whether an action or technology is sustainable. As our use of the term shifts and we interact with others who use sustainability in different ways, understanding becomes a persistent problem. This is especially true in a program like the *Alliance for Global Sustainability (AGS)*, which frames our common project and interaction. AGS is an enterprise based on the premise that exchange across the diverse backgrounds of engineers, natural scientists, and social scientists is not only possible, but can contribute to a richer and more practical understanding of how the problem of sustainability should be understood and how sustainable technology development should be organized.

Our goal in this study was to create a snapshot of how we, as a group of experts who come together under the banner of AGS *understand the meaning of sustainability and good implementation in sustainable technology development*. We asked a group of researchers at the annual AGS meeting in Lausanne in January, 2001 to participate in an interview study that might shed some light on the theory of practice that is developing within AGS. We asked participants to articulate their insights based on their experience in a project that reflects the boundaries, potential, and difficulties of work on sustainable technology development.

The experts who participated in this study are researchers, coordinators, or sponsors at one of the three AGS universities, or an affiliated university. All were involved in a project or study related to technology that involved or raised questions about implementation.

The concept of an "*expert*" is itself a difficult one that has been defined differently when it has become the focus of explicit study in fields like sociology and psychology. In sociology, the focus has been placed on the social role of the expert and the professionalization of domains of activity (Abbott, 1988). On the psychological side, the focus on has been on ways of thinking and knowing, cognition, and the way knowledge is organized (Dreyfus & Dreyfus, 1986; Chi, Glaser, & Farr, 1988). There is no common definition besides an expert is an *individual* who has expertise and can report on it. In our understanding expertise must involve experiential and context-bound knowledge that differentiates it both from sophistication and from a specialist (Scholz, 1987). An expert functions in an interaction or a discourse and combines competence in this interaction with experience and insight into what, why, and how-to do something (Mieg, 2001). In this study we emphasize the experiential roots of expertise and experts' intuitive understanding of a problem field.

We engaged experts as "theorists-of-practice" and asked the participants to talk about a project (i.e. a particular interaction or discourse) in which they used sustainability to try to get access to their intuitive understanding. From a sociological perspective, one of the functions of an expert is to bind uncertainty. This study can be understood in these terms, as a step to a clearer and more robust understanding of the state of the art in our common project.

## Design and Procedure for the Interviews

### Sample

Our study is based on interviews with 21 senior faculty and researchers who had substantial experience with an AGS project. This sample was not stratified, but was designed in order to achieve distribution with respect to academic affiliation (ETH, UT, MIT), professional background, and type of project and technology. It included several project coordinators and two representatives of Chalmers Technical University of Gothenborg.

### Procedure

The interviews were performed by teams of graduate students from ETH, MIT, and UT. In a few instances, interviews were performed by a single student. Each interview ran between a half an hour and one hour. After each interview, the team discussed the session and wrote a summary together. The interviewers described the study to participants as a pilot study on implementation strategies for sustainable technology development. Our analysis summarizes across the interviews. No statements can (or should) be personally attributable to individual experts. The authors instructed the interviewers in the protocols and procedures and held a pilot session in which each interviewer conducted a trial interview and reviewed the experience with one of the authors (who all are members of the AGS research team).

### Questionnaire

The first cluster of questions we analyze addresses views on sustainability. We compiled an initial list of five distinct interpretations of sustainability. The concept of sustainability as eco-efficiency was identified in the study and added to the list for the analysis of the interviews<sup>2</sup>.

- Science is sustainable per se. This perspective holds that the best contribution scientists can make to a sustainable future is to conduct good research. Generating knowledge and upholding standards of open exchange and critical examination of experience provide the insight and model the kind of social interaction that will move us in the direction of sustainability.
- Sustainability is an ethical relationship with the past and future. This refers to perspectives that evaluate actions from the perspective of their significance for and impacts on other persons. The primary example is intergenerational equity as expressed in the Brundtland Commission's definition of sustainable development as that which serves the needs of the present generation without compromising the ability of future generations to meet their needs. The same sort of consideration of ethical relationships can function intra-generationally. Participants in the debate over the responsibilities of the North and the South with respect to issues like reducing green house gas emissions

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<sup>2</sup> A sixth conception labeled as conservation (sustainable development means that everything remains as it is was not further presented to some ambiguities in the rating and confounding with other notions, e.g. "maintenance of a system in its limits."

commonly draw on this kind perspective to evaluate proposals. In the U.S., environmental justice has drawn on a similar kind of perspective-taking to evaluate the distribution of the historical burdens of environmental contamination.

- Sustainability is the maintenance of a system within functional limits. This perspective draws on systems dynamics and treats sustainability as the ability to master the potential for change in a system by identifying functional limits and taking steps to maintain the system within those limits. Development is managed by keeping action within a “funnel” of possibility in which the inner domain provides a flexible set of options that can be treated as sustainable as long as they don’t violate the boundaries of the funnel.
- Eco-efficiency. The most common interpretation of this perspective considers sustainability in terms of the relationship between economic and environmental benefits. Whereas this relationship is often treated as a strict tradeoff, eco-efficiency posits that environmental benefits can be enhanced at the same time as economic performance.
- Sustainability is a form of ongoing inquiry. This perspective treats sustainability as a provisional goal. Action is important not just for furthering the goal, but also for informing the (re)interpretation of the goal. Sustainable development is a process of learning in which action is shaped by goals and goals are revised in light of experience. The commitment to sustainability is understood as a commitment to this process, rather than to a fixed conception of the goal. Transdisciplinarity (see Gibbons et al., 1994; Häberli et al., 2001) and consensus building (Susskind, McKernan, & Thomas-Larmer, 1999) are developed forms of inquiry along these lines that provide methods for organizing interaction and integrating knowledge and values.

We consider these views to be complementary (rather than disjunctive) facets of the concept field of sustainability. Any person can hold more than one of these perspectives without engaging in a contradiction. In this study, we were interested in discerning which conceptions of sustainability were reflected in experts’ thinking about current AGS projects.

The second cluster of questions analyzed concern perspectives on implementation. We asked the interviewers to look for statements that provide insight into the experts' views on what implementation means in the context of sustainability. We did not provide the interviewers with a template of a priori perspectives for this cluster.

Like expertise and sustainability, implementation is used in different ways with different meanings. The classical notion of implementation draws on a model of applied science. Knowledge derived from theory and disciplinary research is applied to improve or perfect problem-solving in the world. Implementation refers to the process of applying the insights derived from research and theory. Policy often serves as a middle-man in this process, translating insights into programs. Thus implementation has attracted substantial attention in public policy and also in organizational development. The main effect of this attention has been to turn the classical relationship between knowledge and action "on its head." (Argyris & Schön, 1996; Pressman & Wildavsky, 1984; Rein & Rabinovitz, 1980; Rein, 1983). Implementation research has em-



phasized how efforts to take action reveal the contradictory imperatives that underpin commitments, surface the complexity and dynamic conservatism of social and physical systems, and engage the intuitive, domain specific knowledge of the "street-level" practitioners who work to produce change on a daily basis (see Lipsky, 1980). Our approach to getting access to experts' views on implementation parallels our approach to capturing views on sustainability. We try to get access to the experts' intuitive understanding of implementation in the specific domain of sustainable technology development.

For each interview, we asked the interviewees to identify core statements that represented the respondent's view on each of the three clusters. Core statements are salient comments that highlight certain facets of the experts' perspective and relate to our framework.

### **Data analysis**

We based our data analysis on the written protocols. Core statements were explicitly documented in the summaries of the interviews. Though the number of interviewees is too small for statistical analysis, we present some tables and frequencies that we believe convey the gist of the qualitative data from the interviews. Due to the exploratory character of the pilot study, we did not formulate any explicit hypotheses. We expected that the dominant characterizations would be closely associated with compatible themes in the technical backgrounds of the experts. Thus we will also present some frequency statistics that address these expectations.

A post hoc analysis suggests that some of the variation may be attributable to differences in the approaches that the five interview teams took. Because we could not detect any systematic effect of the variation in the backgrounds of the interviewees we do not report any analysis of these issues.

## **Results**

### **Where do the experts come from?**

Most of the experts who were asked agreed to participate in the study. This meant finding time within the busy schedule of the conference. Only one expert who was invited declined to participate--because he considered himself a basic researcher. To him this meant that others have the responsibility for thinking about implementation and sustainability. Twenty-one experts were interviewed. Table 1 presents the frequency distribution with respect to national affiliation (i.e. schools) and professional background. As there is no crisp differentiation between natural science and engineering, we differentiated with respect to graduate diploma, as this provides the primary 'career socialization.' The category 'others' encompasses participants whose primary professional identification is in the social sciences, urban planning, or architecture.

**Table 1.** Frequencies of nationality and professional background for the 21 experts

<b>Observed Frequency Table</b>					
	Switzerland	USA	Japan	Sweden	Totals
Natural Sciences	3	1	1	0	5
Engineering Sciences	4	2	4	2	12
Others	2	1	1	0	4
Totals	9	4	6	2	21

The experts were asked to describe their role in the AGS project they had chosen to focus on for the interview: 12 described themselves as primary investigators or coordinators, 5 said that they were researchers, 3 primarily supervised students or had another supervisory role.

### What is the reference project?

Each interview began with the selection of a reference project. This was a project that was underway or recently completed, in which sustainability played a substantial role in setting the research focus. Preference was given to projects that were organized as part of AGS. We have classified these projects according to their origins, geographic reach, and focus. The origins are grouped into five categories. Each project had a primary reason for organizing; some had secondary reasons.

**Table 2.** Project origins according to experts' accounts.

Origin	Experts citing this as primary impetus	Experts citing this as a secondary impetus
Idea arose in discussion with other researchers or another researcher invited the expert to join	6	1
Independent academic interest in the problem (often as a case study)	5	3
Personal interest in the problem or contact in a specific country	4	2
Social / ethical concerns	3	4
Researcher was approached by client	3	0

We grouped projects into four geographic categories, which are mutually exclusive:

- 2 domestic projects focused only within the expert's country
- 2 international projects focused on other developed countries
- 11 international projects focused on developing countries
- 6 projects that apply equally to domestic and international contexts (for example, global climate modeling).

Finally, we grouped projects according to the substantive focus of the research. The research foci are not categorized by subject areas (e.g. hydrology) or by professional affiliation (e.g. mechanical engineering; chemistry) because these categories did not capture the subtle distinctions that the researchers who participated in the study used to describe their projects, relate them to sustainability, and situate them in their career paths. Instead, we relied on distinctions that reflect the terms that experts used. Sustainable information technology implementation can be understood as: a) a physical process of data acquisition and transmission or the social process of using the technology in a cultural context; b) the type of knowledge or information that can be stored and presented; c) in terms of the relationship between the development of knowledge, organizations, and institutions; d) as a physical product with a specific history and design horizon; e) in terms of the infrastructure demands it creates; and, f) in terms of the dynamic relationship between materials and product design.

*Table 3. Primary and secondary focus of the reference project.*

Focus	Experts citing this as primary focus	Experts citing this as secondary focus
Processes [physical and social]	16	4
Information / knowledge	10	3
Institutions / organizations	6	4
Physical product / machines	6	2
Infrastructure	4	4
Materials	1	4
Other	2	0

The forty-five primary and twenty-one foci that are reported reflect the complex terms in which researchers described their projects. The interviews suggest that sustainable technology implementation demands new types of distinctions that go beyond the traditional categories of academic disciplines.

**Views on sustainability**

We first report on the frequency with which the five conceptions of sustainability were used in the personal interviews. We rated each interview on a scale of 0 to 3 with respect to each of the five views on sustainability. Each rating was done by two authors. A rating of ‘0’ designates that this facet of sustainability was not observable in the context of the interview. A rating of ‘1’ is given for minor indications of the facet, a ‘2’ for medium, and a ‘3’ for strong. ‘1,’ ‘2,’ and ‘3’ were all considered observable. Table 4 summarizes the ratings.

The most prominent findings are highlighted in the shaded cells. The following interpretations are suggested by the data for the comparison between the aspects

- Ethical relationship was the most prominent view across the groups. 15 out of 21 participants conveyed that they linked their project to this aspect of sustainability.
- Science per se was observed less frequently than any of the other aspects.
- Eco-efficiency also received a low score.

Some interesting observations emerge from a comparison between the groups, natural scientists (N), engineers (E), and other (O).

- The interviews with the engineers raised more aspects of sustainability across the board.
- In particular, engineers emphasized conservation and limit management.
- Eco-efficiency is not important to the natural scientists. It seems to be more prominent from a social science perspective.
- Ongoing inquiry got a medium score in all groups.

**Table 4.** Number of “observable” and “non-observable” aspects and mean scores for the groups [natural scientists (N), engineers (E), and other (O)] on the sustainability aspects.

Sustainability aspect	“observable”				“Non-observable”				Mean score			
	N	E	O	All	N	E	O	All	N	E	O	All
Science per se	1	2	0	3	4	10	4	18	0.2	0.3	0.0	0.2
Ethical relationship	2	10	3	15	3	2	1	6	1.2	1.8	1.0	1.5
Ecoefficiency	0	4	2	6	5	8	2	15	0.0	0.6	1.0	0.5
Limit management	1	8	0	9	4	4	4	12	0.4	1.3	0.0	0.8
Ongoing inquiry	2	6	2	10	3	6	2	11	0.6	0.8	1.0	0.8
All aspects	6	30	7	41	19	30	13	62	0.42	0.94	0.57	

For exploratory purposes we also conducted contingency, correlation, and factor analyses. The sustainability aspects do not seem to be highly correlated, however there seems to be some contingency between science per se and limit management. The other is that ethical relationship and ongoing inquiry are rarely found together.

### Core statements

The core statements below give an idea of what is behind the classifications and frequencies reported in Table 4.

#### *Ethical relationship*

"... Sustainability ... is a stakeholder approach to the future generation ..."

"... We have to have future generations to have freedom ..."

"... Sustainability is to provide transportation services efficiently and equally ..."

"... We need to awaken other values ... hate, love, passion ..."

#### *Eco-efficiency*

"... sustainability is a balancing of costs ..."

#### *Limit management*

"... using with .. don't impact the whole water cycle ..."

"... preventing positive feedback loops..."

#### *Ongoing inquiry*

"...finesse in ... information and other means ... .. human needs identification"

## **Views on implementation**

### A consensus on the importance of impacts

A prominent characteristic of the survey is the concern the interviewees shared about the nature of the impacts their research will have. This led, in turn, to a concern with implementation. All the researchers had thought about implementation and how it related to their project. They saw themselves as working on problems that had implications for action and hoped their efforts would modify impacts or affect the behavior or impacts of some group or class. They could all identify, for instance, who might or should be affected by their research. This concern is evident in core statements like:

"... Our final goal is really to have an impact. ..."

"... The worst thing that could happen is that we don't have an impact. ..."

"...Part of our task is to develop feasible strategic options. . . we have to keep in mind what it is that can be implemented...."

"... We share the view that in thirty years the entire infrastructure could change. ..."

An interesting question was raised, but not answered, by the interviews. Does the substantive focus on sustainability generate the observed tie between research and implementation? In other words, 'Does research on sustainability inherently raise concerns about implementation?' Only a few of the researchers in the sample had not acted on their concerns with impacts by taking at least some steps to address implementation.

## Understanding implementation

This consensus carried over to the broad terms in which the researchers described implementation. They saw implementation as the process whereby their work as researchers comes into contact with social groups and processes and where concerns about taking action and social and technological change become prominent. This tie extended the relationship between research and values, and institutions that we observed in the terms the participants used to define sustainability. The participants also gave a great deal of attention to barriers to change. The most prominent categories in which the researchers discussed the relationship between their work and social change are reviewed below.

### *Value change is tied to implementation*

Concern with implementation introduces values and “life attitudes.” Some members of the sample included scientific commitments in this class of concerns. The central idea is that change – in technologies, in patterns of use, or in policies – implies or requires change in values. Some discussed this relationship in terms of consumer preferences that shape the marketability of “green” products. Others treated values in broader terms as concerns that provide the foundation for moral commitment and political action, such as a concern about social equity. The former were generally treated as barriers or brakes on implementation – change is difficult because the values that guide individual choice are uninformed or inconsistent. These preferences can make it difficult to sell a higher mileage car, for instance. Those who adopted the latter approach tended to see values as a source of commitment that contributes to change, rather than as a barrier. They cited the “need to awaken other values relating to sustainability” for example.

### *Information influences technology implementation*

The mismatch between the demands of sustainability and social values was often discussed in terms of a need for education. The shortage of accurate and accepted information on environmental problems was viewed by many as a brake that inhibits the development of values that are consistent with sustainability. As some members pointed out, however, clearer and more comprehensive information can also trigger controversy. This did not dampen their enthusiasm for more information and broader public understanding, but did underscore the irony that can attend the development and dissemination of new information.

### *Institutions shape sustainable action*

Institutions were commonly referenced in discussions of implementation (see Table 2). The dominant accounts discussed the barriers that institutions raise and the way they distort efforts to take action and promote change. Subsidies, for instance, were described as an institutional device that distorts information and incentives. Regulations, in turn, were characterized as rigid requirements that often fail to take account of, or leave room for, local contextual knowledge. Even where the need for regulation was acknowledged, some interviewees were quick to point out the importance of paving the way for new regulatory initiatives with a round

of deregulation. The rigidity of bureaucracies and rules, and their inherent resistance to change, were raised frequently in the interviews.

Elections (and the electoral politics that accompany them) were described as a problematic institution because of the way they foreshorten time horizons, distort the framing of problems, and dilute attention.

*The distribution of costs and benefits shapes sustainable action*

New technologies and biophysical changes like climate change create winners as well as losers. The impacts these changing distributions can have on implementation were a prominent theme in the researchers' accounts. This awareness did not lead to clear cut guidelines for action. Interventions on either side can distort or slow change. Winners may promote a favored option or block intervention when the change is beneficial to them. Losers seeking to protect their interests often see the only avenue open is opposition to change.

*Sustainable action is transdisciplinary and cross-cultural*

Finally, researchers regarded the character of the problems they work on as important. They saw the problems they are working on as transdisciplinary and often cross-cultural. Both characteristics put distinctive demands on practice, particularly on the need for communication, that affected implementation.

Knowledge and action in technology implementation

The relationship between knowledge and action is central in views on implementation. It shapes the terms in which knowledge generation is understood and organized and the researchers' professional understanding. In this section, we extend the report in the preceding sections by tracing and constructing patterns in the comments of interviewees that have pragmatic significance for interpreting the relationship between knowledge and action. Unlike the preceding sections, this interpretation is not meant solely as an attempt to classify the interviews. Instead we try to render from the comments an interpretation that may provide insight into the increasing social complexity that attends technology implementation around problems like sustainable development and the emerging character of sustainability as a problem field. Such an interpretation can help us understand the theory-practice interaction that is central to implementation and reflect on the relationship between knowledge and action in sustainability projects. We summarize our interpretation in three stylized "theories of action" and present for each core statements from the interviews that are consistent with these interpretations. These theories suggest the complexity that characterizes thinking about implementation within the AGS and may also offer some more general insights into the development of professional understanding as fields of engineering and science become more tightly coupled to social problems like sustainability.

In naming these patterns we maintain consistency with terminology for consistency while extending these terms in light of the insights provided in the interviews. (See Dewey & Bentley, 1960)

*Action. I act to change the world.*

In this view, the researcher is a problem solver who looks at the larger context and asks, “How can I make a difference?” New knowledge and new technologies are important because they can trigger change. One role of research is to inform people of the urgency of problems and possible actions. Publishing is a prominent and effective way to accomplish this because it disseminates results widely and is durable over time. Education may also help to overcome the lack of public understanding, awareness, and commitment that are the key barriers to implementing the results of research projects. New technologies are important because they change structures and open new pathways of action.

It may also be important to find actors with “leverage” to get things across and push necessary changes. Implementation follows the development of new understanding or new technologies and is a problem of instigating people to adopt new forms of behavior.

*Illustrative core statements.*

- “I’m confident, if there is a need and, more importantly, a market, the technology will be developed.”
- “Society is either disinterested or uninformed about environmental issues. Media can teach people on a worldwide and local basis – both are important.”
- “Law and policy should be changed to provide appropriate incentives to change the behavior of users of transportation.”
- “In order to improve [the] situation, the level of education is important – parents are not teaching children how to behave.”
- “If implementation means dissemination of the results, all results were implemented.”
- “A challenge is “having enough confidence in the science part of the equation to say to the politicians who don’t like to pass regulation . . . that the necessity is there.”
- “People’s value systems are strongly related to sustainability. People have to change their lifestyles.”
- “Changes have to be “institutionalized” to have long-lasting influence. This requires “outreach and education” of the public. Government must have the resources to educate the public.”

*Interaction. I exchange information with my environment through my actions.*

Here the researcher who seeks change tries to gather information from other people and, subsequently, to promote change by providing the public with new information about impacts and options. A prominent characteristic of this view is the importance of preserving a liberal sphere of autonomy. Consumers, for example, should retain the right to make choices. The role of research is to ensure that these choices are informed and that new options are available at a reasonable cost. Outreach is important to understand consumer and political preferences so that options can respond to what people want. Marketing is important to highlight new op-



tions. Education supports marketing by providing information to inform preferences. Implementation should be anticipated in the early stages of development by gathering information on preferences and practices.

*Illustrative core statements*

- “... Any new measures that are taken, we have to explain them, so that [the] public accepts them. ...”
- “... We should form alliance with manufacturers, city government, and suppliers. Suppliers need to put fuel in place. Manufacturers need to advertise [their] product. ...”
- “... We are working a lot with stakeholders. You have think about consumer access. A good technical product does not guarantee customer acceptance of diffusion. ...”
- “... Will the values of society be such that environmentally friendly products will be accepted?...”
- “... Information has to be available so that “people don’t feel left out. ...”

*Transaction or mutual learning. I change as a result of my effort to bring about change in the world.*

The effort to take action changes the actor who seeks to promote change. Boundaries between the actor and her environment are difficult to sustain in implementation. Stakeholder involvement, for instance, becomes a process in which the researcher’s understanding of the problem and of options for action develops. The importance of local knowledge (as opposed to, say, local preferences) is acknowledged. Education becomes learning. Researchers describe their surprise at new insights and options that develop through working together on a problem. Relationships among research partners (in interdisciplinary projects) and between researchers and users are discussed in terms of trust and understanding. The development of these relationships is essential for effective implementation and must start from the beginning of a program. Implementation cannot be separated from the development of the project.

*Illustrative core statements*

- “...Developing a relationship is very important for success. It takes a long time. ...”
- “... They (the local partner) are a good partner and help us a lot. Without them we couldn’t develop these processes. ...”
- “... Good quality management will be a management that cares for consumers and eco-efficiency. ...”
- “... The best way to implement this project is to build an atmosphere of mutual respect with partners. This can take years. ...”
- “... If you integrate quality as you conceive a product then quality will in fact reduce the cost. ...”

## Conclusions

The interviews in this study reveal that status of sustainability is a complex problem field. Researchers who work in this field see sustainability in complex terms that combine a conventional understanding of research with a concern for ethical relationships and the need to take action in the world. The evidence we have presented is consistent with the interpretation that the field is in a process of historical development, though it is not sufficient to conclude that this process is going on or provide clear indication of the direction of the developmental process.

The evidence from the interviews suggests a number of findings that may provide grist for further reflection.

- The ethical standard of sustainability is the most common and most frequently presented.
- Ongoing inquiry is more visible than expected. Experience in sustainability projects appears to highlight the importance of the process.
- Engineers are close to the process and operations. This orients to concerns with management and correction or repair.
- The negative correlation between ethical interpretation and ongoing inquiry suggests that researchers may start with normative commitment and move on to process, but this is clearly beyond the data.
- Experience with sustainability projects promotes and reinforces concerns about implementation.
- Concern with implementation appears to promote consideration of the relationship between knowledge and action, though no core consensus has developed on this relationship.

In our interviews with researchers we found committed transdisciplinary. Many think about the relationship between different domains of knowledge in their work and draw on both ethical and epistemological considerations to explain their efforts. They know implementation is important and had given it thoughtful consideration prior to the interviews. These concerns provide substantial common ground, even if disagreements persist about the meaning and implications of these terms. We conclude the study hopeful about the potential these “meaningful disagreements” provide for further research, collaboration, and efforts to take action in the world.

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