

Group model-building: tackling messy problems

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Abstract

Group model-building here refers to a system dynamics model-building process in which a client group is deeply involved in the process of model construction. The problem that is modelled can be reasonably well defined, but it can also take the form of an ill-defined or messy problem, i.e., a situation in which opinions in a management team differ considerably. These messy managerial situations are difficult to handle, primarily because thus far little theoretical work has been conducted to shed more light on the question why these messy situations exist and why it may be difficult for a management team to reach agreement. This article fills this theoretical gap by drawing on literature from sociology, (social) psychology and small-group research. Insights from this literature are discussed and translated into guidelines for conducting Group Model-Building projects for messy problems. The article ends with the conclusion that system dynamicists should include Group Model-Building and facilitation training in their teaching programs. Copyright © 1999 John Wiley & Sons, Ltd.

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The evolution of group model building

Almost since its inception, system dynamicists have involved the client (groups) in the model-building process for at least three reasons. First, to capture the required knowledge in the mental models of the client group (Forrester 1961; 1987). Second, to increase the chances of implementation of model results (cf. Roberts 1978; Weil 1980), and, finally, to enhance the client's learning process (Greenberger *et al.* 1976; de Geus 1988; Lane 1989; Morecroft 1992; Morecroft and Sterman 1992). As a result, the number of projects involving the client has proliferated rapidly over the last decades (Rouwette *et al.* 1999).

Given this development, it is no wonder that a number of system dynamicists started to reflect more deeply on the issue of client involvement. Some concentrated on how system dynamics could be used to support strategic executive dialogue in management teams (Morecroft 1992). Others introduced "modelling as learning" as an alternative consultancy methodology for system dynamicists (Lane 1992). Still others focused on particular issues when working with groups, for example knowledge elicitation from groups, cognitive tasks and small group dynamics (Richardson *et al.* 1989; Vennix *et al.* 1992).

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The literature also produced fine-grained descriptions of methods and techniques to capture the required knowledge from a group on conceptualisation (cf. Vennix *et al.* 1990) and in formalisation and quantification (Ford and Sterman 1998) of a system dynamics model. And, inevitably, some designed standard procedures to build system dynamics models with groups, for instance the Reference Group approach (Randers 1977; Stenberg 1980), and the Strategic Forum (Richmond 1997).

Further detailed and systematic research on quantitative modelling with groups was conducted by system dynamicists at SUNY Albany, who coined the term Group Model-Building.¹ Their efforts led, amongst others, to a more detailed description of the different roles in working with teams (Richardson and Andersen 1995) and the notion of scripts for Group Model-Building, i.e., refined pieces of small group processes, which chained together, direct the stream of group activity in Group Model-Building sessions (Andersen and Richardson 1997; Andersen *et al.* 1997).

Others have employed Group Model-Building interventions to work with management teams on less tangible, ill-defined strategic issues, labelled by some scholars as messy problems (Ackoff 1974; 1979), i.e., situations in which there are large differences of opinion on the problem or even on the question of whether there is a problem.² In these cases the emphasis is necessarily, but not exclusively, on problem structuring and on creating consensus and commitment with a group decision (Lane 1992; 1993; Wolstenholme 1990, 1992, 1999; Vennix 1996; Majone 1984; Zakay 1984), in order for concerted action to result (Drucker 1988). This paper continues this latter line of research by exploring a couple of theoretical questions concerning the origins of messy managerial situations and their implications for system dynamics modelling with groups.

Questions addressed in this paper

Although some have tried to bridge the gap between soft OR and system dynamics (Lane 1994; Lane and Oliva 1998), and attempts have been made to find a social theoretic home for system dynamics (Lane 1998; 1999), there remain large theoretical gaps, particularly when it comes to the application of system dynamics and Group Model-Building to messy managerial situations. Exploring these complex intervention situations may significantly improve our understanding and effectiveness of Group Model-Building (or systems thinking interventions for that matter) in both semi-structured and ill-structured decision situations.

The first step towards more understanding is to ask why these messy managerial situations exist (i.e., why opinions differ so widely) and to identify the most important deficiencies that occur in teams dealing with these type of problems when trying to reach agreement. More specifically, we have to provide answers to two sets of questions. The first set of questions is:

- How do humans process information and construct models of reality?
- What potential deficiencies can be observed in this process of mental model construction?
- How can Group Model-Building be helpful to overcome these deficiencies?

The second set of questions is:

- How do members of management teams interact and communicate their mental models?
- What deficiencies occur in group interaction processes?
- How can Group Model-Building be helpful in this respect?

With regard to the first set of questions, we will make a distinction between the information processing capacity of the human mind, on the one hand, and the way humans interpret and perceive situations, on the other.

Individual sources of messy problems: limited information processing capacity

Research over the last four decades has convincingly demonstrated that our information processing capacity is limited (e.g., Simon 1948; 1985; Miller 1956) and that humans employ biases and heuristics (e.g., anchoring and adjustment, the representativeness heuristic, and the availability heuristic) in order to reduce mental effort (Hogarth 1987; Kahneman *et al.* 1982). Application of biases and heuristics is not limited to individuals. Groups display the same biases and will thus not make better decisions than individuals (Stasson *et al.* 1988).

Research into the area of cognitive maps has also illustrated the restricted character of human information processing. Humans seem to experience difficulty thinking in terms of causal nets (Dörner 1980), and are incapable of entertaining imbalanced paths and feedback loops in their cognitive maps (Axelrod 1976; Sevon 1984). Even extensive training cannot alter this (cf. Vennix 1990; Verburch 1994; Kenis 1995).

In addition, experiments in dynamic decision making have revealed that people tend to ignore feedback processes, which produces detrimental results

(Sterman 1989a; 1989b; 1994; Brehmer 1989; Kleinmuntz 1993), a result that is confirmed by field research (Hall 1984). And again explicit training in understanding the feedback structure of the system has virtually no impact on people's ability to manage such a system effectively (Maxwell *et al.* 1994; Richardson *et al.* 1994).

Implications for Group Model-Building

Conclusions from research in human information processing with regard to system dynamics and Group Model-Building seem straightforward. Forrester has repeatedly pointed out that the human mind is not well equipped to trace the dynamics of complex feedback structures. Hence, the need for system dynamics simulation. In fact, as Sterman (1994) argues, simulation may be the only effective way to learn in and about complex systems. Many Group Model-Building and systems thinking interventions work on this assumption and consider simulation to be the primary contribution to the improvement of a group's information processing capacity.

However, there is another, sometimes underestimated, aspect in which system dynamics can increase a group's information processing capacity. That is through mapping or qualitative modelling. Qualitative modelling has been widely discussed in the system dynamics literature and is a continuing source of controversy.³ Proponents of quantitative modelling point out that it is dangerous to draw conclusions on the dynamics of a system that are solely based on diagrams, a position which can hardly be refuted, given the wide range of evidence (for an overview, see Sterman 1994). Advocates of the use of qualitative modelling have argued that in a number of cases quantification may either decrease the model's relevance for an audience or can even be dangerously misleading (cf. Coyle 1996; 1999; Wolstenholme 1992; 1999). This argument becomes critical when confronted with messy problems. The choice for the interventionist is then to either simply walk away from the management problem or to use the rigour of diagramming to aid the debate and increase the group's information processing capacity. After all, diagrams help to keep track of complex structures (Anderson 1980; Larkin and Simon 1987; Lippitt 1983). More specifically, they (a) add rigor to the analysis and group discussion (Wolstenholme 1982; 1990; 1999; Vennix *et al.* 1993; Lane 1993), (b) help to identify feedback loops and potentially understand behaviour (Coyle 1999), (c) put the problem on one sheet of paper (Coyle 1999), and (d) serve as a so-called group memory in Group Model-Building sessions (Vennix 1996). In short, when one is working with groups on messy problems, increasing the

information processing capacity does not only concern the dynamics of a system, but also its causal feedback structure.

However, the limits on people's cognitive abilities are just one of the problems encountered. Humans do not "simply" process information as if they were computers, they continuously make selections, interpret information and perceive situations in different ways.

Individual sources of messy problems: perceptions and reality construction

Psychologists have, for example, found that differential previous information may lead to quite different interpretations of similar situations. For instance, if two groups of people have to judge the suitability of an applicant for a job on the basis of such information as a resumé, a letter of application and the like, they interpret this written information quite differently if they have previously been provided with an unfavourable (as opposed to a favourable) letter of reference about the application (Tucker and Rowe 1979). In short, people can easily be led to believe things and, even when told in retrospect that they participated in an experiment, this may have no marked influence on these beliefs (cf. Naftulin *et al.* 1973).

As well as the effect of previous information, selection and interpretation are heavily affected by one's professional background or position in an organisation. Different people in an organisation have different interests. It is frequently believed that these differences of interest are the sole cause of differences of interpretation. However, Dearborn and Simon (1958) convincingly demonstrated that these differences of interpretation remain even when there are no real interests at stake. Obviously professional criteria for selecting information are deeply internalised and automatically guide our perceptions and interpretations.

To complicate the matter further, humans are social beings and their interpretations are thus influenced by what others think (see, for example, Asch 1963; Berkowitz 1959). Everyday reality presents itself as an intersubjective world which is shared with others (Berger and Luckmann 1966). And, as phenomenologists have argued, everyday reality is generally taken for granted (Schutz 1962) and serves as a context that guides our interpretations. Similar information will be interpreted differently depending on the context in which we find ourselves. This has, for instance, been convincingly demonstrated in a famous and illustrative experiment conducted by Rosenhan (1984). In this experiment, a number of volunteers were instructed to go to psychiatric

hospitals telling doctors that they heard voices, which in fact was not the case. One goal of the experiment was to find out how soon a person would be released if this person behaved normally after being admitted. This proved not to be too easy. After all, once someone is hospitalised, any kind of behaviour is interpreted in the context of the psychiatric institution and is almost suspect by definition, much to the detriment of the “healthy” persons who took part in this experiment.

Finally, to complete the picture, human memory is also often distorted, a phenomenon known as hindsight bias (Fischhoff 1975; Fischhoff and Beyth 1975). Memory is not a device that stores and retrieves information; rather it continuously reconstructs the past in order to fit it in with current beliefs and opinions. Worse still, it has been demonstrated that memories can be deliberately created of events that actually never occurred (see, for instance, Loftus and Ketcham 1994).

Implications for Group Model-Building

Summarising, we may conclude that the way humans perceive situations and construct their models of reality is a complex phenomenon. We observe that interpretations, perceptions and memory may be distorted as a result of a number of factors.

With respect to Group Model-Building, this implies that we have to be careful when talking about eliciting knowledge from group members. First, we ought to be aware that people can easily be led to believe things and that the opinions they hold may be strongly affected by what others think and the context in which they find themselves. In other words the definition of a problem may be a socially constructed phenomenon that has not been put to the test. As Hogarth points out:

It has been suggested, for instance, that illusory correlation persists in situations where people do not receive good feedback concerning their judgements and where others share the same illusions. Thus instead of feedback concerning actual outcomes, each person both reinforces and is reinforced by the illusions of the others. In many organisations, common beliefs are precisely of this nature. (Hogarth 1987, 114).

Group model building and system dynamics help to uncover these illusions, because the rigour of mapping and modelling forces participants to carefully and consistently make their mental models explicit and put their problem definitions to the test, by surfacing implicit (causal) assumptions.

Second, people's mental models are frequently only partial representations of a complex situation. Managers tend to see parts rather than wholes, particularly when they are not trained in systems thinking (cf. Dearborn and Simon 1957; Hall 1984). The result is departmental bias and potential deadlock situations, which may jeopardise organised action and may even lead to the demise of the organisation (Hall, 1984). Group Model-Building not only offers an opportunity to share and align piecemeal mental models (Huz *et al.* 1997), but also creates the possibility of assimilating and integrating partial mental models into a holistic system description, making participants overcome their local, departmental views (Vennix 1995; 1996).

However, in order to accomplish the latter, more is needed than mapping or modelling. Let us therefore turn to the second set of questions: the way group members interact, create their social reality and frequently get locked into undesirable situations.

Group sources of messy problems

Group sources of messy problems relate to deficiencies in group interaction and to the self-fulfilling nature of reality construction in groups. Each of these will be discussed below.

Deficiencies in group interaction

Groups can show a variety of deficiencies.⁴ Frequently encountered is the mixing up of cognitive tasks, in particular the production and evaluation of information. This is partly caused by our strong tendency to evaluate what is said, which inhibits our potential to listen carefully (Rogers and Roethlisberger 1988). Special group process techniques like brainstorming, Delphi and the Nominal Group Technique can help to bring more structure into the discussion, which will in turn increase the group's performance as well as the commitment to a decision (White *et al.* 1980). In that respect, the type of structure (or decision-making sequence) is of limited importance (Brilhart and Jochem 1964; Hirokawa 1985); just unthinkingly following a sequence of steps does not automatically result in a good decision (Gouran 1982; Hirokawa 1985).

Another problem in groups is the lack of critical investigation, or, in extreme cases, the deliberate suppression of it, leading to groupthink situations (Janis 1972; Janis and Mann 1977). Suppressing critique and avoiding differences of opinion has a negative impact on decision quality (Cosier and Rose 1977; Hall and Watson 1971; Nemiroff and King 1975; Harper and Askling 1980;

Smith *et al.* 1981; Smith *et al.* 1986; Tjosvold 1982; Tjosvold and Field 1985). Special conflict-promoting group process techniques like Devil's Advocate and Dialectical Inquiry can be helpful in this regard (for a concise description of both procedures, see Vennix 1996, Appendix 3).

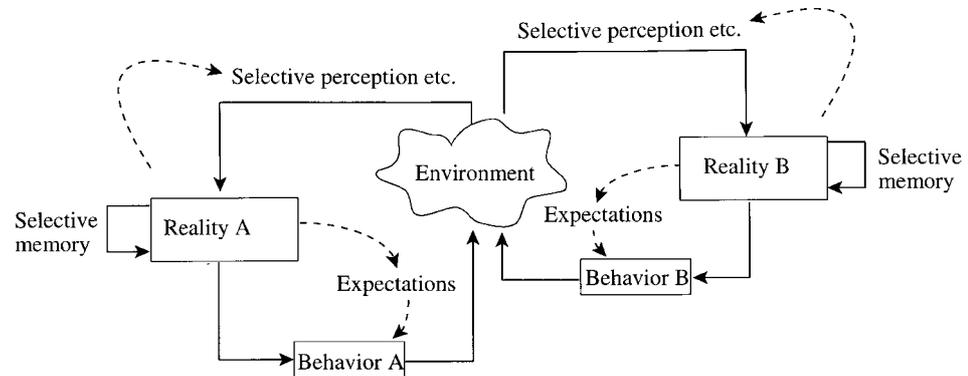
However, in messy managerial situations the biggest problem is the way team members communicate. Apart from our inclination to evaluate and our inability to listen, a third inhibiting factor to effective communication is defensiveness, leading to low-quality communication, which in turn (a) increases decision time (Fouriezos *et al.* 1950), (b) has a negative impact on decision quality (Leathers 1972), and (c) inhibits creativity in groups (Klimoski and Karol 1976). In spite of these disadvantages, defensiveness is ubiquitous. Humans employ defensive routines as a way to protect themselves from losing face when exposing their ideas to others (Schein 1987; Argyris 1990; 1994). And losing face in a group is strongly feared by most people. As a result, defensive routines are difficult to discuss openly. 'Accusing' someone of being defensive will automatically backfire ("Me? I am not being defensive!"). The question might be raised how these ineffective communication patterns should be altered. To answer this question, let us return to the construction of reality in people's mind and take the argument one step further by looking at how people create their social reality in groups.

Reality construction in groups: the reality of multiple realities

We have observed that there are several reasons why people interpret situations differently. As early as the 1920s, Thomas directed our attention to the fact that it is not so much a question whether these individual realities are valid; rather, the interesting question is what this implies. The answer to this question led him to the formulation of what later became known as the famous Thomas theorem: "If men define situations as real, they are real in their consequences" (Thomas and Thomas 1928, p. 572). In other words, if people define situations as real they will behave accordingly. And this behaviour in turn creates a reality that is perceived by others and affects their thinking and behaviour, as can be seen in Figure 1.

A person A acquires information from the environment, subject to a number of mechanisms that have been described previously. Based on his own reality description and this information, this person constructs a "model of reality", which not only affects subsequent perceptions, but also forms the basis for his behaviour. In a dyadic relationship A's behaviour forms part of B's environment, and for B, *mutatis mutandis*, the same holds. B selects and interprets data in the environment, constructs his model and behaves accordingly.⁵

Fig. 1. The creation of social reality in a dyadic relationship



A person's behaviour is to a large degree affected by expectations, which are in turn based on a person's model of reality. Research in the realm of expectations has shown the existence of self-fulfilling prophecies: we anticipate certain expectations and then direct our behaviour in such a way that these expectations actually become reality. Humans not only construct reality in their minds; their behaviour also causes this reality in their minds to become reality in their environment.⁶

Self-fulfilling prophecies are ubiquitous (Merton 1957; Johnson Abercrombie 1960; Jones 1977; Watzlawick 1984) and are extremely difficult to uncover (see, for instance, Farina *et al.* 1968). They occur, for example, in education and teaching (cf. Baker and Crist 1971; Jussim 1986) and in selection recruitment interviews (Dipboye 1982), and, surprisingly, they have also been demonstrated in the training of rats (Rosenthal 1966) and even earthworms (Cordaro and Ison 1963). They also occur in (small group) interaction. Argyris (1990) presents fine examples of people communicating with each other about an organisational problem where each person blames the other for the difficulties. One of the things that both sides often think (but not really say in public) about the other side is: "you do not really understand the issues". The result is that, based on this assumption, combined with the expectation that the other will not listen and will not easily be convinced, each will do the utmost to convince the other by talking as much as possible and limiting their listening. Typically, this kind of behaviour may put the other person "one down" or even irritate, which in turn will make the other person act in the same manner (getting both potentially locked into an escalation archetype). And gradually we become convinced that there is an inevitable social reality, which dictates that people in meetings do not listen to each other, never let each other finish talking, and only try to convince one another. This inevitability (and the taken-for-grantedness of social reality for that matter) is indicated by such statements as: "well, that's the way it works

in organisations". But, basically, it is the reality that we, willingly or unwillingly, create through our own actions. My *expectation* that the other will not listen leads me to behave in a particular way (trying to convince by talking a lot), which in turn makes the other behave the way I expected in the first place.

As the example shows, there may be an undesirable situation and, although we may be aware of its undesirability, it is a different matter to change it. There are at least three requirements to alter situations that are problematic to most people. The first is that we are slow learners. In many situations we are simply not aware of how and why we interpret situations in a particular way. Moreover, humans are inclined to ignore information that is not in accordance with their beliefs and to look for information that is in agreement with their mental models (Einhorn and Hogarth 1978). Rather than learning from outcome feedback, humans are inclined to explain away mistakes and failures (Brehmer 1980, pp.228–229; Sterman 1994), and to manipulate meanings in order to maintain their "definition of the situation" (McHugh, 1968). Finally, being able to learn also presupposes that our memory works well. As we have seen, this is questionable, to say the least.

The second problem with breaking self-fulfilling prophecies is that one has to be well aware of one's own behaviour. However, as several scholars have shown, what people say they do may differ substantially from what they actually do (Argyris and Schön 1978, Deutscher 1973). Research conducted by Argyris (1992) demonstrates that we are very capable of seeing a discrepancy between another person's verbal and non-verbal behaviour, but we are bad at seeing such a discrepancy in ourselves. For instance, when people have to judge their own behaviour after having been involved in a conflict, they are inclined to see themselves as cooperative while the other party is generally seen as competitive (Jones 1977, p.122; Kelly and Stahelski 1970).

Finally, if both previous requirements are met, one should also be able to change one's own behaviour significantly in order to break through a self-fulfilling prophecy and change the "inevitable" social reality. This can be particularly difficult. In the example where two people continuously try to convince each other, the simple rule to break the vicious cycle (and to see that social reality is actually constructed by our own behaviour) is to act in the opposite manner: start listening and think along with the other person. The rule is deceptively simple, but it can prove extremely difficult to apply consistently.

Implications for Group Model-Building: the role of facilitation

Interaction patterns in groups can be particularly poor. It will be clear that the construction of a map or model of a problem is not very helpful in this case.

Here another important ingredient of Group Model-Building comes to the fore: the group facilitator, a role that is of paramount importance in turning Group Model-Building interventions into a success (cf. Phillips and Phillips 1993; Vennix *et al.* 1993).

Frequently, it is tacitly assumed that good model-builders will also be effective group facilitators. However, characteristics that are essential for model-building are often orthogonal to those necessary for effective group facilitation. Given the way we described reality construction in groups, it is obvious that the facilitator's non-verbal behaviour is significant: not what a facilitator says, but rather what this person otherwise does is critical (see also Hackman 1990, xvii). A facilitator is primarily a person who acts as a role model for the group, a person who avoids the common deficiencies in group interaction, which negatively affect the quality of the decision.

Critical characteristics of an effective facilitator

Group facilitation is primarily concerned with procedure (i.e., the way a problem is tackled) and process (i.e., the way group members interact with each other) and only indirectly with content (the subject matter under discussion). In other words, a group facilitator is concerned with how things are done in a meeting. When it comes to the characteristics of an effective facilitator, we have to make a distinction between attitudes and skills.⁷

Facilitation attitudes

The right attitudes are critical, more critical than the required skills. It is sometimes overlooked that the most important characteristic for a facilitator is a helping attitude. In addition, an effective facilitator is neutral with regard to the content of the discussion. As we have seen, the facilitator is primarily responsible for procedure and process. Getting involved in the content of the discussion will cause the facilitator to lose his special role and effectiveness. What a facilitator does need is an enquiring attitude. This means being curious about how people perceive and interpret situations and how and why they define situations as problematic. This implies that the facilitator asks questions rather than providing answers. He or she is *not* supposed to teach, but to foster reflection and learning in a team by discouraging defensive communication. Another attitude that is required is integrity. As a facilitator, it is not wise to rely on tricks, since people will see through them, maybe not the first time, but certainly after several times. Tricks will be counterproductive since people will

either anticipate them or be irritated by them (Gibb 1960, 145–146). Showing integrity and being authentic will prove to be more effective in the long run.

Facilitation skills

Although the right attitudes are critical, skills are of course indispensable. One prerequisite in the context of Group Model-Building is a thorough knowledge of system dynamics and model-building skills in order to be able to ask the right questions during meetings and to be able to translate what participants say into system dynamics terms. Thorough knowledge of system dynamics is also required in order to be in a position to judge whether system dynamics is suitable for a particular problem.

Furthermore, process structuring skills are required. The construction of a system dynamics model involves a wide variety of activities and cognitive tasks. These range from generating variables to be included in the model, to identifying feedback structure, to establishing system boundaries, to evaluating model output, to name only a few. Process structuring skills presuppose an awareness of the existence of various cognitive tasks that a group can face, as well as knowledge of group process techniques that support particular types of cognitive tasks (e.g., brainstorming, Nominal Group Technique, Delphi, Devil's Advocate and Dialectical Inquiry).⁸

Closely related to process structuring are conflict handling skills. Central to messy problems are cognitive conflicts, i.e., differences of viewpoint. As described previously, avoiding conflict and seeking premature consensus negatively affects the quality of the decision. As might be expected, the relationship between the number of conflicts and quality of decision is curvilinear in shape. More conflict induces higher-quality decisions. Beyond a certain point, however, decision quality will deteriorate with a further increase in the number of conflicts (Wall *et al.* 1987). The lesson for the facilitator is that, in situations of low cognitive conflict, he or she should induce conflict (for instance, by employing conflict promoting techniques), while in groups where cognitive conflict abounds he or she should foster consensus.

Finally, communication skills are important. As we have seen, a facilitator's attitude of open communication will help prevent defensive routines. When it comes to skills, an important required skill for a facilitator is active (or reflective) listening to prevent miscommunication: listening and trying to understand what someone means by what he or she says. Again, by modelling in his or her own behaviour what good communication means, the facilitator may expect that others in the group will also start communicating more effectively.

Conclusions and discussion

System dynamicists have repeatedly pointed out the flaws in human mental models and blame many of the problems in policy making to these deficiencies. Much of the literature in system dynamics (tacitly) assumes that better understanding of the structure and behaviour of complex systems by employing system dynamics simulation will solve most of these problems. The latest trend in this respect is the use of management flight simulators to train people to become better “dynamic decision makers”. However useful these simulators may be (and it is the author’s opinion that they are), it is simplistic to suggest that, if we just put our students and policy makers through these simulators, this will significantly improve performance of organisations, much analogous to flight simulators in aviation. One reason is the existence of persistent barriers to learning, not only cognitive but also social, primarily those related to defensive routines and face saving (Schein 1987; Argyris 1990; 1994; Senge 1990). In fact, Sterman (1994) argues that, only if we deal with these barriers competently, will real learning take place and he continues by pointing out that learning will be effective if participants do not just play a game, but actively participate in the construction of the model. Group Model-Building is a way to accomplish that. But when conducting systemic interventions through Group Model-Building, we have to be well aware that cognitive limitations are only one of the problems to be encountered. Two important additional issues are: differences in perceptions, leading to multiple realities, and ineffective communication patterns, which block productive discussion of these multiple realities.

If one really wants to have an impact on these situations and if one is serious about supporting the resolution of messy problems, two issues become crucial and need to be addressed. First, and maybe most difficult of all, one will have to accept that in a number of cases it is not very useful or even impossible to go through the whole model-building cycle. In some cases quantification will either not add to understanding an issue, or will in fact be dangerously misleading, as Coyle (1999) convincingly demonstrates. In fact, as Richardson (1999) points out, the growing trend in qualitative mapping is ‘here to stay’. Rather than getting locked into a trench warfare, it may be more productive to reflect on the wise uses of both qualitative and quantitative modelling and to develop rigorous guidelines for mapping as well as criteria to evaluate the quality of diagrams (see, for instance, Coyle 1996, p. 46). Simply walking away from situations that defy quantification will make management teams run the risk of ignoring feedback in their problem with the detrimental consequences that we have seen. And, although awareness of feedback processes (which might come through qualitative modelling) does not imply that one understands its dynamic

consequences, it is probably still better to be aware of them than to ignore them entirely.

Second, we will have to adapt our teaching programs. Apart from teaching our students “classical system dynamics”, we will also have to make them familiar with processes in groups and instruct them how to become effective facilitators (see, for instance, Haslett *et al.* 1999), not only by teaching facilitation skills, but primarily by creating favourable attitudes. A good starting point may be to show them that scientists are frequently as prone to judgmental errors as laymen (Sterman 1994), an observation which probably also holds for biases in perception and ineffective communication patterns in groups. We should avoid developing teacher characteristics in our students, but instead try to foster an open mind and a reflective attitude. In short, we should help students to become persons who encourage team learning by supportive communication. This is not to say that analytical and system dynamics model-building skills are insignificant; they are very important indeed. The message is that systems thinking interventions will be made much more effective, if system dynamics model building abilities are skilfully combined with adequate facilitation.

Notes

1. In this paper I will use Group Model-Building as a generic label for all approaches that involve the client in the system dynamics model building process, be it in the conceptualisation and/or formalisation and simulation of the model.
2. This type of studies is related to research conducted in problem structuring and soft Operations Research (Rosenhead 1989; Eden and Simpson 1989; Eden and Radford 1990; Checkland 1981; Checkland and Scholes 1990).
3. Qualitative system dynamics was first made an issue in system dynamics by Wolstenholme (1982) and Wolstenholme and Coyle (1983) and has since been the subject of controversy within the system dynamics community. We will return to this issue in a later section. Although related, the issue of qualitative versus quantitative modelling should be distinguished from the inherent problems in the use of causal loop diagrams as described by Richardson (1985; 1997).
4. A number of well-known handbooks on small group research, discussing these deficiencies (and their potential resolution) are: Hare (1962); Collins and Guetzkow (1964); Hare *et al.* (1965); Steiner (1972); Fisher (1974); McGrath (1984); Hirokawa and Poole (1986); Hackman (1990); Jensen and Chilberg (1991); and Worchel *et al.* (1992).

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5. For reasons of simplicity, the figure has been restricted to a dyadic relationship, but it could easily be adapted to a group situation and the arrow indicating the effect of person A's opinions on those of B and vice versa, i.e., the social nature of reality construction as discussed above, has been omitted. In addition, we have to point out that when talking about a person's model of reality, we in fact refer to the so-called theory in use rather than the espoused theory (Argyris and Schön 1978).
 6. For an alternative view on the construction of social reality, in relation to the use of system dynamics and modelling with groups, see Lane (1998).
 7. Space does not permit a detailed treatment of the topic of group facilitation. For a more detailed discussion in the context of Group Model-Building, the reader is referred to Vennix (1996, chapter 5). Other relevant sources include; Bostrom *et al.* (1993), Doyle and Straus (1976), Krueger (1988), Jensen and Chilberg (1991), Hart (1992), Heron (1993), Phillips and Phillips (1993), Rees (1991), Schwarz (1994), Westley and Waters (1988).
 8. For a summary of these techniques and examples of their application in the context of Group Model-Building see Vennix (1996). For more detailed information on the effectiveness of brainstorming see Lamm and Trommsdorf (1973), Stroebe and Diehl (1994), Diehl and Stroebe (1987, 1991), Cooper *et al.* (1990) and Graham (1977). With regard to Delphi, see Dalkey (1969) and Linstone and Turoff (1975). A thorough critique of Delphi is given in Sackman (1975). More information on Nominal Group Technique can be found in Delbecq *et al.* (1975). For comparisons of the relative effectiveness of NGT versus Delphi see Gustafson *et al.* (1973), van der Ven and Delbecq (1974), Rohrbaugh (1979; 1981), Reagan-Cirincione (1991, 1994), Fischer (1981), Stewart (1987), and Sniezek (1990). For a comparison of the effectiveness of Devil's Advocate and Dialectical Inquiry see Schweiger *et al.* (1986; 1989) and Schweiger and Sandbert (1989).

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References

- Ackoff RA. 1974. *Redesigning the Future: a Systems Approach to Societal Problems*. Wiley: New York.
- . 1979. The future of Operational Research is past. *Journal of the Operational Research Society* **30**(2): 93–104.

- Andersen DF, Richardson GP. 1997. Scripts for group model-building. *System Dynamics Review* **13**(2): 107–129.
- Andersen DF, Richardson GP, Vennix JAM. 1997. Group Model-Building: adding more science to the craft. *System Dynamics Review* **13**(2): 187–201.
- Anderson JR. 1980. *Cognitive Psychology and its Implications* (3rd edn). W.H. Freeman & Co.: New York.
- Argyris C. 1990. *Overcoming Organizational Defenses, Facilitating Organizational Learning*. Allyn and Bacon: Boston.
- . 1992. *On Organizational Learning*. Blackwell: Cambridge, MA.
- . 1994. Good communication that blocks learning. *Harvard Business Review* (July-August): 77–85.
- Argyris C, Schön DA. 1978. *Organizational Learning: A Theory of Action Perspective*. Addison-Wesley: Reading, MA.
- Asch SE. 1963. Effects of group pressure upon the modification and distortion of judgments. In *Groups, Leadership and Men: Research in Human Relations*, Guetzkow H (ed.). Russel & Russel: New York.
- Axelrod R. 1976. *Structure of Decision: The Cognitive Maps of Political Elites*. Princeton University Press: Princeton, NJ.
- Baker JP, Crist JL. 1971. Teacher expectancies: a review of the literature. In *Pygmalion Reconsidered*, Elashoff JD, Snow RE (eds). Charles A. Jones: Worthington, OH.
- Berger P, Luckmann T. 1966. *The Social Construction of Reality: A Treatise in the sociology of Knowledge*. Doubleday: New York.
- Berkowitz LR. 1959. Reactions to opinion deviates. *Sociometry* **22**: 81–91.
- Bostrom RP, Anson R, Clawson VK. 1993. Group facilitation and group support systems. In *Group Support Systems: New perspectives*, Jessup L, Valacich J (eds), Macmillan: New York; 146–168.
- Brehmer B. 1980. In one word: not from experience. *Acta Psychologica* **45**: 223–241.
- . 1989. Feedback delays and control in complex dynamic systems. In *Computer-based Management of Complex systems. Proceedings of the 1989 International Conference of the System Dynamics Society*, Milling PM, Zahn EOK (eds). 189–196. Springer Verlag: Berlin.
- Brilhart JK, Jochem LM. 1964. Effects of different patterns on outcomes of problem-solving discussions. *Journal of Applied Psychology* **48**(3): 175–179.
- Checkland P. 1981. *Systems Thinking, Systems Practice*. Wiley: Chichester.
- Checkland P, Scholes J. 1990. *Soft Systems Methodology in Action*. Wiley: Chichester.
- Collins BE, Guetzkow H. 1964. *A Social Psychology of Group Processes for Decision-making*. Wiley: New York.
- Cooper WH, Gallupe RB, Bastianutti LM. 1990. Electronic versus non-electronic brainstorming. *Proceedings of the 50th Annual meeting of the Academy of Management* 237–241.
- Cordaro L, Ison JR. 1963. Observer bias in classical conditioning of the planaria. *Psychological Reports* **13**: 787–789.
- Cosier RA, Rose GL. 1977. Cognitive conflict and goal conflict effects on task performance. *Organizational Behavior and Human Performance* **19**: 378–391.
- Coyle G. 1996. *System Dynamics Modelling: A Practical Approach*. Chapman & Hall: London.

-
- . 1999. Qualitative modelling in system dynamics or what are the wise limits of quantification? *Keynote address to the conference of the System Dynamics Society*. Wellington, New Zealand.
- Dalkey N. 1969. An experimental study of group opinion: the Delphi method. *Futures* **1**: 408–426.
- Dearborn C, DeWitt, Simon HA. 1958. Selective perception: a note on the departmental identifications of executives. *Sociometry* **21**: 140–144.
- Delbecq AL, van der Ven AH, Gustafson DH. 1975. *Group techniques for Program Planning: A Guide to Nominal Group and Delphi Processes*. Scott, Foresman: Glenview, IL.
- Deutscher I. 1973. *What We Say/What We Do, Sentiments and Acts*. Scott, Foresman: Glenview, IL.
- Diehl M, Stroebe W. 1987. Productivity loss in brainstorming groups: toward the solution of a riddle. *Journal of Personality and Social Psychology* **53**(3): 497–509.
- , ———. 1991. Productivity loss in idea-generating groups: tracking down the blocking effect. *Journal of Personality and Social Psychology* **61**(3): 392–403.
- Dipboye RL. 1982. Self-fulfilling prophecies in the selection-recruitment interview. *Academy of Management Review* **7**: 579–586.
- Dörner D. 1980. On the difficulties people have in dealing with complexity. *Simulation and Games* **11**(1): 87–106.
- Doyle M, Straus D. 1976. *How to Make Meetings Work*. Jove Books: New York.
- Drucker P. 1988. The coming of the new organization. *Harvard Business Review* **66**(1): 45–53.
- Eden C, Radford J. 1990. *Tackling Strategic Problems: The Role of Group Decision Support*. Sage: London.
- Eden C, Simpson P. 1989. SODA and cognitive mapping in practice. In *Rational Analysis for a Problematic World*, Rosenhead J (ed.). Wiley: Chichester.
- Einhorn HJ, Hogarth RM. 1978. Confidence in judgment: Persistence of the illusion of validity. *Psychological Review* **85**: 395–416.
- Farina A, Allen JG, Sal BB. 1968. The role of the stigmatized person in affecting social relationships. *Journal of Personality* **36**: 169–182.
- Fischer GW. 1981. When oracles fail: a comparison of four procedures for aggregating subjective probability forecasts. *Organizational Behavior and Human Performance* **28**: 96–110.
- Fischhoff B. 1975. Hindsight does not equal foresight: the effect of outcome knowledge on judgment under uncertainty. *Journal of Experimental Psychology: Human Perception and Performance* **1**: 288–299.
- Fischhoff B, Beyth R. 1975. I knew it would happen. *Organizational Behavior and Human Performance* **13**: 1–16.
- Fisher BA. 1974. *Small group Decision-making*. McGraw Hill: New York.
- Ford DN, Sterman JD. 1998. Expert knowledge elicitation to improve formal and mental models. *System Dynamics Review* **14**(4): 309–340.
- Forrester JW. 1961. *Industrial Dynamics*. MIT Press: Cambridge, MA.
- . 1987. Lessons from system dynamics modelling. *System Dynamics Review* **3**(2): 136–149.
- Fouriez NT, Hutt ML, Guetzkow H. 1950. Measurement of self-oriented needs in discussion groups. *The Journal of Abnormal and Society Psychology* **45**: 682–690.

- de Geus AP. 1988. Planning as learning. *Harvard Business Review* (March/April): 70–74.
- Gibb JR. 1960. Defensive communication. *The Journal of Communication* **10**: 141–148.
- Gouran DS. 1982. *Making Decisions. Choices and Concepts*. Scott Foresman: Glenview, IL.
- Graham WK. 1977. Acceptance of ideas generated through individual and group brainstorming. *The Journal of Social Psychology* **101**: 231–234.
- Greenberger M, Crenson MA, Crissey BL. 1976. *Models in the Policy Process: Public Decision Making in the Computer Era*. Russell Sage Foundation: New York.
- Gustafson DH, Shukla RK, Delbecq A, Walster GW. 1973. A comparative study of differences in subjective likelihood estimates made by individuals, interacting groups, Delphi groups and nominal groups. *Organizational Behavior and Human Performance* **9**: 280–291.
- Hackman JR. 1990. *Groups that Work (and Those That Don't)*. Jossey-Bass: San Francisco.
- Hall EJ, Watson WH. 1971. The effects of a normative intervention on group decision-making performance. *Human Relations* **23**(4): 299–317.
- Hall RI. 1984. The natural logic of management policy making: its implications for the survival of an organization. *Management Science* **30**(8): 905–927.
- Hare AP. 1962. *Handbook of Small Group Research*. The Free Press of Glencoe: New York.
- Hare AP, Borgatta EF, Bales RF. 1965. *Small Groups: Studies in Social Interaction*. Alfred A. Knopf: New York.
- Harper NL, Asklings LR. 1980. Group communication and quality of task solution in a media production organization. *Communication Monographs* **47**: 77–100.
- Hart LB. 1992. *Faultless Facilitation*. Kogan Page: London.
- Haslett T, Barton J, Sarah R. 1999. The use of group modelling techniques as a teaching tool. In *Proceedings of the 1999 International conference of the System Dynamics Society*. Wellington, New Zealand.
- Heron J. 1993. *Group Facilitation: Theories and Models for Practice*. Kogan Page: London.
- Hirokawa RY. 1985. Discussion procedures and decision-making performance, a test of a functional perspective. *Human Communication Research* **12**(2): 203–224.
- Hirokawa RY, Poole MS. 1986. *Communication and Group Decision Making*. Sage: Beverly Hills, CA.
- Hogarth R. 1987. *Judgment and Choice*, (2nd edn). Wiley: Chichester.
- Huz S, Andersen DF, Richardson GP, Boothroyd R. 1997. A framework for evaluating systems thinking interventions: an experimental approach to mental health system change. *System Dynamics Review* **13**(2): 149–169.
- Janis IL. 1972. *Victims of Groupthink, A Psychological Study of Foreign-Policy Decisions and Fiascoes*. Houghton Mifflin: Boston.
- Janis IL, Mann L. 1977. *Decision Making: A Psychological Analysis of Conflict, Choice and Commitment*. The Free Press: New York.
- Jensen AD, Chilberg JC. 1991. *Small Group Communication. Theory and Application*. Wadsworth: Belmont, CA.
- Jones RA. 1977. *Self-fulfilling Prophecies: Social, Psychological and Physiological Effects of Expectancies*. Wiley: New York.

-
- Johnson Abercrombie ML. 1960. *The Anatomy of Judgment*. Penguin Books: Harmondsworth.
- Jussim L. 1986. Self-fulfilling prophecies: A theoretical and integrative review. *Psychological Review* **93**(4): 429–445.
- Kahneman D, Slovic P, Tversky A. 1982. *Judgment under Uncertainty: Heuristics and Biases*. Cambridge University Press: Cambridge.
- Kelley HH, Stahelski AJ. 1970. Social interaction basis of cooperators' and competitors' beliefs about others. *Journal of Personality and Social Psychology* **16**: 66–91.
- Kenis D. 1995. Improving group decisions: designing and testing techniques for group decision support systems applying Delphi principles. Ph.D. dissertation, Utrecht University.
- Kleinmuntz DN. 1993. Information processing and misperceptions of the implications of feedback in dynamic decision making. *System Dynamics Review* **9**(3): 223–237.
- Klimoski RJ, Karol BL. 1976. The impact of trust on creative problem solving groups. *Journal of Applied Psychology* **61**(5): 72–74.
- Krueger RA. 1988. *Focus Groups; A Practical Guide for Applied Research*. Sage: Newbury Park, CA.
- Lamm H, Trommsdorf G. 1973. Group versus individual performance on tasks requiring ideational proficiency (brainstorming): a review. *European Journal of Social Psychology* **3**(4): 361–388.
- Lane DC. 1989. Modelling as learning: creating models to enhance learning amongst management decision makers. Paper presented at the European Simulation Conference, Edinburgh.
- . 1992. Modelling as learning: A consultancy methodology for enhancing learning in management teams. In *Modelling for learning, special issue of European Journal of Operational Research* (Morecroft TDW, Sterman JD (eds)) **59**(1): 64–84.
- . 1993. The road not taken: observing a process of issue selection and model conceptualization. *System Dynamics Review* **9**(3): 239–264.
- . 1994. With a little help from our friends: how system dynamics and soft OR can learn from each other. *System Dynamics Review* **10**(2/3): 101–134.
- . 1998. Rerum cognoscere causas; Social theory, determinism and the agency/structure debate. *LSEOR working paper: OR.98.26*, London School of Economics.
- . 1999. Social theory and system dynamics practice. *European Journal of Operational Research* **113**(3): 501–527.
- Lane DC, Oliva R. 1998. The greater whole: towards a synthesis of system dynamics and soft systems methodology. *European Journal of Operational Research* **107**(1): 214–235.
- Larkin JH, Simon HA. 1987. Why a diagram is (sometimes) worth ten thousand words. *Cognitive Science* **11**: 65–99.
- Leathers DG. 1972. Quality of group communication as a determinant of group product. *Speech Monographs* **39**(1): 166–173.
- Linstone HA, Turoff M. 1975. *The Delphi Method: Techniques and Applications*. Wiley: New York.
- Lippitt GL. 1983. *A Handbook for Visual Problem Solving: A Resource Guide for Creating Change Models*, (new edition). Development Publications: Bethesda, MD.
- Loftus E, Ketcham K. 1994. *The Myth of Repressed Memory: False Memories and Allegations of Sexual Abuse*. St. Martin's Press: New York.

- Majone G. 1984. A good decision is more than a right decision. *Acta Psychologica* **56**: 15–18.
- Maxwell T, Andersen DF, Richardson GP, Stewart TR. 1994. Mental models and dynamic decision making in a simulation of welfare reform. *Proceedings of the 1994 International System Dynamics Conference*. July 1994, Stirling, Scotland, Vol: Social and Public Policy, pp. 11–28. System Dynamics Society: Lincoln, MA.
- McGrath JE. 1984. *Groups: Interaction and Performance*. Prentice Hall: Englewood Cliffs, NJ.
- McHugh P. 1968. *Defining the Situation: The Organization of Meaning in Social Interaction*. Bobbs-Merill: Indianapolis/New York.
- Merton RK. 1957. *Social Theory and Social Structure*. The Free Press: New York.
- Miller GA. 1956. The magical number seven, plus or minus two: some limits on our capacity for processing information. *The Psychological Review* **63**(2): 81–97.
- Morecroft JDW. 1992. Executive knowledge, models and learning. In *Modelling for Learning, special issue of the European Journal of Operational Research* (Morecroft JDW, Sterman JD (eds)) **59**(1): 9–27.
- Morecroft JDW, Sterman JD (eds). 1992/1994. *Modelling for Learning*. Special issue of the *European Journal of Operational Research* (Also published as: Morecroft JDW, Sterman JD (eds) 1994. *Modelling for Learning Organizations*. Productivity Press: Portland, OR.).
- Naftulin DH, Ware JE, Donnely FA. 1973. The Doctor Fox Lecture: a paradigm of educational seduction. *Journal of Medical Education* **48**: 630–635.
- Nemiroff PM, King DC. 1975. Group decision making performance as influenced by consensus and self-orientation. *Human Relations* **28**(1): 1–21.
- Phillips LD, Phillips MC. 1993. Facilitated work groups: theory and practice. *Journal of the Operational Research Society* **44**(6): 533–549.
- Randers J. 1977. *The Potential in Simulation of Macro-social Processes, or How to be a Useful Builder of Simulation Models*. Gruppen for Ressursstudier: Oslo, Norway.
- Raegan-Cirincione P. 1991. Improving the accuracy of forecasts: A process intervention combining Social Judgment Analysis and Group Facilitation. Ph.D. dissertation, Rockefeller College of Public Affairs and Policy, State University of New York at Albany.
- Raegan-Cirincione P. 1994. Improving the accuracy of group judgment—A process intervention combining group facilitation, social judgment analysis, and information technology. *Organizational Behavior and Human Decision Processes* **58**(2): 246–270.
- Rees F. 1991. *How to Lead Work Teams: Facilitation Skills*. Pfeiffer & Co: San Diego.
- Richardson GP. 1986. Problems with causal-loop diagrams. *System Dynamics Review* **2**: 158–170.
- Richardson GP. 1997. Problems in causal loop diagrams revisited. *System Dynamics Review* **13**(3): 247–252.
- Richardson GP, Andersen DF. 1995. Teamwork in group model-building. *System Dynamics Review* **11**(2): 113–137.
- Richardson GP, Anderson DF, Maxwell TA, Stewart TR. 1994. Foundations of Mental Model Research. *Proceedings of the 1994 International System Dynamics Conference, Stirling, Scotland*. System Dynamics Society: Lincoln, MA.
- Richardson GP, Vennix JAM, Andersen DF, Rohrbaugh J, Wallace WA. 1989. Eliciting group knowledge for model-building. In *Computer-based Management of Complex*

-
- Systems, Milling PM, Zahn EOK (eds). Proceedings of the 1989 International Conference of the System Dynamics Society: Berlin/Heidelberg; 343–357.
- Richmond B. 1997. The Strategic Forum: aligning objectives, strategy and process. *System Dynamics Review* **13**(2): 131–148. (Previously published as a working paper: Richmond B. 1987. *The Strategic Forum: from vision to strategy to operating policies and back again*). Lyme, NH. High Performance Systems.
- Roberts EB. 1978. Strategies for effective implementation of complex corporate models. In *Managerial applications of System Dynamics*, Roberts EB (ed). MIT Press: Cambridge; 77–85.
- Rogers CR, Roethlisberger FJ. 1988. Barriers and gateways to communication. In: John J. Gabarro, People: Managing your most important asset. *Harvard Business Review*, Special edition of articles, 19–25.
- Rohrbaugh J. 1979. Improving the quality of group judgment: Social Judgment Analysis and the Delphi technique. *Organizational Behavior and Human Performance* **24**: 73–92.
- . 1981. Improving the quality of group Judgement: Social judgment Analysis and the Nominal Group Technique. *Organizational Behavior and Human Performance* **28**: 272–288.
- Rosenhan DL. 1984. On being sane in insane places. In *The invented reality: how do we know what we believe we know?*, Watzlawick P (ed). W. W. Norton: New York; 117–144.
- Rosenhead J (ed.) 1989. *Rational Analysis for a Problematic World: Problem Structuring Methods for Complexity, Uncertainty and Conflict*. Wiley: Chichester.
- Rosenthal R. 1966. *Experimenter Effects in Behavioral Research*. Appleton-Century-Crofts: New York.
- Rouwette EAJA, Vennix JAM, van Mullekom T. 1999. Group model building: a review of assessment studies. *Proceedings of the 1999 International conference of the System Dynamics Society*. Wellington, New Zealand.
- Sackman H. 1975. *Delphi Critique: Expert Opinion, Forecasting and Group Process*. D.C. Heath: Lexington, MA.
- Schein EH. 1987. *Process Consultation*, Vol. II. Addison-Wesley: Reading, MA.
- Schutz A. 1962. *Collected Papers I: The Problem of Social Reality*. Martinus Nijhoff: The Hague.
- Schwarz RM. 1994. *The Skilled Facilitator: Practical Wisdom for Developing Effective Groups*. Jossey-Bass: San Francisco.
- Schweiger DM, Sandberg WR. 1989. The utilization of individual capabilities in group approaches to strategic decision-making. *Strategic Management Journal* **10**: 31–43.
- Schweiger DM, Sandberg WR, Ragan JW. 1986. Group approaches for improving strategic decision making: a comparative analysis of dialectical inquiry, devil's advocacy, and consensus. *Academy of Management Journal* **29**(1): 51–71.
- Schweiger DM, Sandberg WR, Rechner PL. 1989. Experimental effects of dialectical inquiry, devil's advocacy, and consensus approaches to strategic decision-making. *Academy of Management Journal* **32**(4): 745–772.
- Senge P. 1990. *The Fifth Discipline: The Art and Practice of the Learning Organization*. Doubleday: New York.
- Sevon G. 1984. Cognitive maps of past and future economic events. *Acta Psychologica* **56**: 71–79.

- Simon HA. 1948. *Administrative Behavior: A Study of Decision-Making Processes in Administrative Organizations*. Macmillan: New York.
- . 1985. Human nature in politics: The dialogue of psychology with political science. *The American Political Science Review* **79**: 293–304.
- Smith KA, Johnson DW, Johnson RT. 1981. Can conflict be constructive? Controversy versus concurrence seeking in learning groups. *Journal of Educational Psychology* **73**(5): 651–663.
- Smith KA, Petersen RP, Johnson DW, Johnson RT. 1986. The effects of controversy and concurrence seeking on effective decision making. *The Journal of Social Psychology* **126**(2): 237–248.
- Sniezek JA. 1990. A comparison of techniques for judgmental forecasting by groups with common information. *Group and Organization Studies* **15**: 5–19.
- Stasson MF, Kaoru Ono, Zimmerman SK, Davis JH. 1988. Group consensus processes on cognitive bias tasks: a social decision scheme approach. *Japanese Psychological Research* **30**(2): 68–77.
- Steiner ID. 1972. *Group Process and Productivity*. Academic Press: New York.
- Stenberg L. 1980. A modelling procedure for public policy. In *Elements of the System Dynamics Method*, Randers J (ed). MIT Press: Cambridge, MA; 292–312..
- Sterman JD. 1989a. Misperceptions of feedback in dynamic decision making. *Organizational Behavior and Human Decision Processes* **43**: 301–335.
- . 1989b. Modelling managerial behavior: misperceptions of feedback in a dynamic decision-making experiment. *Management Science* **35**(3): 321–339.
- . 1994. Learning in and about complex systems. *System Dynamics Review* **10**(2–3): 291–330.
- Stewart TR. 1987. The Delphi technique and judgmental forecasting. *Climatic Change* **11**: 97–113.
- Stroebe W, Diehl M. 1994. Why groups are less effective than their members: on productivity losses in idea-generating groups. In *European Review of Social Psychology Volume 5*, Stroebe W, Hewstone M (eds). Wiley: Chichester; 271–303.
- Thomas WI, Thomas DS. 1928. *The Child in America: Behavior Problems and Programs*. Alfred Knopf: New York.
- Tjosvold D. 1982. Effects of approach to controversy on superiors' incorporation of subordinates' information in decision making. *Journal of Applied Psychology* **67**(2): 189–193.
- Tjosvold D, Field RHG. 1985. Effect of concurrence, controversy, and consensus on group decision-making. *The Journal of Social Psychology* **125**(3): 355–363.
- Tucker DH, Rowe PM. 1979. Relationship between expectancy, causal attributions, and final hiring decisions in the employment interview. *Journal of Applied Psychology* **64**(1): 27–34.
- van der Ven AH, Delbecq AL. 1974. The effectiveness of nominal, Delphi and interacting group decision making processes. *Academy of Management Journal* **17**: 605–621.
- Vennix JAM. 1990. Mental models and computer models: design and evaluation of a computer-based learning environment for policy making. Ph.D. dissertation, University of Nijmegen, Netherlands.
- . 1995. Building consensus in strategic decision making: system dynamics as a group support system. *Group Decision and Negotiation* **4**(4): 335–355.

-
- . 1996. *Group Model-Building: Facilitating Team Learning using System Dynamics*. Wiley: Chichester.
- Vennix JAM, Andersen DF, Richardson GP, Rohrbaugh J. 1992. Model-building for group decision support: issues and alternatives in knowledge elicitation. In *Modelling for Learning*, special issue of the *European Journal of Operational Research* (Morecroft JDW, Steman JD (eds)) **59**(1): 28–41.
- Vennix JAM, Gubbels JW, Post D, Poppen HJ. 1990. A structured approach to knowledge elicitation in conceptual model-building. *System Dynamics Review* **6**: 194–208.
- Vennix JAM, Scheper W, Willems R. 1993. Group model-building: what does the client think of it? In *The Role of Strategic Modelling in International Competitiveness, Proceedings of the 1993 International System Dynamics Conference*, Sepeda E, Machuca J (eds). Cancun: Mexico; 534–543.
- Verburgh LD. 1994. Participative policy modelling: applied to the health care insurance industry. Ph.D. dissertation, Nijmegen University, Netherlands.
- Wall VD Jr., Gallanes GJ, Love SB. 1987. Small, task-oriented groups: conflict, conflict management, satisfaction and decision quality. *Small Group Behavior* **18**(1): 31–55.
- Watzlawick P (ed.) 1984. *The Invented Reality, How do We Know What We Believe We Know?* W. W. Norton: New York/London.
- Weil HB. 1980. The evolution of an approach for achieving implemented results from system dynamic projects. In *Elements of the system dynamics method*, Randers J (ed). MIT Press: Cambridge, MA; 271–291.
- Westley F, Waters JA. 1988. Group facilitation skills for managers. *Management Education and Development* **19**(2): 134–143.
- White SE, Dittrich JE, Lang JR. 1980. The effects of group decision-making process and problem situation complexity on implementation attempts. *Administrative Science Quarterly* 428–440.
- Wolstenholme EF. 1982. System dynamics in perspective. *Journal of the Operational Research Society* **33**: 547–556.
- . 1990. *System Enquiry, A System Dynamics Approach*. Wiley: Chichester.
- . 1992. The definition and application of a stepwise approach to model conceptualisation and analysis. *European Journal of Operational Research* **59**: 123–136.
- . 1999. Qualitative vs quantitative modelling: the evolving balance. *Journal of the Operational Research Society* **50**: 422–428.
- Wolstenholme EF, Coyle RG. 1983. The development of system dynamics as a methodology for system description and qualitative analysis. *Journal of the Operational Research Society* **34**: 569–581.
- Worchel S, Wood W, Simpson JA. 1992. *Group Process and Productivity*. Sage: Newbury Park, CA.
- Zakay D. 1984. The evaluation of managerial decisions' quality by managers. *Acta Psychologica* **56**: 49–57.