Communicating complexity through visualisation: the use of schematics in gaming/simulations

Jac L. Geurts – Tilburg University, PO Box 90153, S 165, 5000 LE Tilburg, The Netherlands
Ivo Wenzler – Institute for Applied Social Science, PO Box 9048, 6500 KJ Nijmegen, The Netherlands
Hans J. J. van Kuppevelt – Institute for Applied Social Science, Nijmegen, The Netherlands

Abstract

This paper discusses visualisation as a key tool in the related fields of gaming/simulation and system dynamics. Using two gaming projects as examples, techniques and proccesses of visualisation from the gaming discipline are explained. Conceptual modelling through the use of schematics is an important element of the system dynamics as well as gaming/simulation methodology. The authors conclude that both schools should invest in doing research and applying existing visualisation theory to their special styles of schematic building. The review of some concepts of a 'visual language' shows that there is a lot that "we-in-gaming" or "we-in-system-dynamics" take for granted when we work with schematics.

Introduction

To a large extent the discipline of gaming/simulation was developed more or less independent of the system dynamics tradition. In the last years we have witnessed a growing interest within the system dynamics community for gaming/simulations. The merging of the system dynamics modelling methodology with concepts and processes from the organisational learning paradigm (De Geus, 1988; Lane, 1989; Senge, 1990), plus the availability of powerful software tools (STELLA, Microworlds, IThink), have without doubt influenced this interest in gaming/simulation.
System dynamics and gaming/simulation have become popular tools in industry and government since the mid sixties, early seventies. From the early period onwards system dynamics and certain traditions of gaming/simulation have shared common values, ideas, concepts and tools. It is the purpose of this paper to describe to the system dynamics community how gaming/simulations use a tool which system dynamicists have more and more identified as a key element in their craft: the visual representation of complex systems in a schematic.

The structure of this paper is as follows. First we describe the background of the gaming/simulation tradition we want to focus on and point out some common elements which it shares with system dynamics. Secondly we introduce and describe two Dutch gaming/simulation projects during which complex policy exercises have been developed. Both of them were designed using a system analytical modellingprocess and a schematic representation of the problem and its environment. Following that we also present the schematics produced. Finally we try to summarize the insights into the role of visualisation in policy-analysis which we have drawn from our experiences and from a literature review. The conclusion is that hardly any theory or empirical evidence exists in policy analysis regarding the contributions of schematics and visualisation in general. We end this article with the suggestion that system dynamicists and gamers should initiate further research on this issue.

Schematics in gaming/simulation

The gaming/simulation tradition which makes extensive use of schematics was stimulated and professionalised by Richard D. Duke (1974, 1980). Duke has contributed much to the further development of gaming/simulation as a form of participative systems analysis. Duke and his followers (a.o. Klabbers, 1980; Greenblat & Duke, 1988; Wenzler, 1990; Geurts & Vennix, 1991; Geurts, 1993) perceive gaming/simulation as a communication process in which a pluriform group of stakeholders engage in a well structured policy-exercise to jointly explore possible futures.
The policy exercises based on gaming/simulation are tailor-made configurations which emerge from a process of participatory model-building. Interestingly enough, the extensive participation of members of the client organisation in the game-design process has increasingly been understood as having more than a technical (internal) project value. The step by step modelling effort has great value as a gradual learning

process for the whole organisation. The game itself is more and more used as the final (very intensive) step in a multi-stage communication process, and less as one, all encompassing, event.
Gaming/simulation methodology shares several ideas, concepts and tools with modern system dynamics. Both schools aim at facilitating organisational learning and communication on complex and "ill-structured" (Dunn, 1981; Mintzberg, a.o., 1976) problems. The processes applied are basically the same: they combine elements from a systems analytical model-building process with group-dynamic tools and techniques. Both schools make extensive use of supporting methods like Delphi's, scenario-writing, conceptual modelling and schematic-building. This latter element is the main focus of this paper.
Before we describe our observations on schematic building we want to stress that we are aware of the fact that there are also differences in theory and practice between the two schools. It seems worthwhile to go back to Donella Meadows' article on 'The unavoidable apriori' (Meadows, 1977) and compare modern system dynamics practice with current gaming/simulation projects. We expect that this exercise would reveal more commonality than it would have done if the two schools would have been compared in, say 1970. That is why we consider it important that the two disciplines exchange ideas and discuss common ground. This article is intended to be one contribution to this exchange.

Two cases of gaming/simulation-based policy exercises

Health care negotiations

The Dutch government is presently working on a fundamental change of the health care system in the Netherlands. The purpose of this change is the creation of a flexible, efficient, and affordable health care system of excellent quality. The new health care system should bring a shift from government imposed rules and regulations to more regulation by market. The strict regulation of the supply side of health care will be replaced by attempts to influence the demand of care. A crucial element of the new system will be direct negotiations between health care providers and insurance companies. Although negotiations as such are not completely new, they are key to the proposed system. This will turn them into a whole new game, with a new arena and a new set of rules.
Unavoidably, many problems will emerge with the advent of the new system. Currently the different parties face uncertainties regarding the operational consequences, opportunities, and degrees of freedom within the new system.
One thing was very clear from the onset: things will not be regulated at the central level anymore. That is why the Dutch Hospital federation (NZf) started to look for ways to support the main participants in their process of finding their own way. The specific policy issue of interest was the need to establish a structured forum through which all interested parties can understand and confront the new regulations in order to clarify and explore alternative models of negotiation and workable methods for interaction in the future. For this purpose the Health Care Negotiations Policy Exercise (Zorg!Markt) was developed. In the environment created by the exercise, participants are able to define and test their own solutions, learn from their experience and develop insights in possible real life options available (Wenzler et al., 1992).

Technology in Vocational Education

In an attempt to develop a coherent policy regarding technology developments and their influence on the vocational educational system, the Dutch government initiated the so-called PRESTO programme. The aim of PRESTO is to stimulate development and implementation of new and sophisticated educational materials on new educational technologies as well as on new technologies in the work place. Also the aim of PRESTO is to increase the effectiveness of the secondary vocational training in general. Effectiveness in this case means the extent to which educational institutions deliver students who meet the needs of the work environment.
The PRESTO-management team is convinced that successful diffusion of technology into the secondary vocational education and training will occur only if different parties in the system develop and implement policies which are complementary to each other. At the moment the policies are too fragmented and lacking interdependence. The idea has emerged that no party alone has the possibility to develop and successfully implement an optimal technology policy. Co-operation between the government, schools, businesses and intermediary organisations is considered a key condition to a long term success.
From this perspective, PRESTO has initiated the development of a large-scale policy exercise in which participants from all parties involved can explore different policy options in a safe environment.
The main purpose of this policy exercise is to create a common view on policy issues regarding technology in vocational education. The exercise will help participants to get insight into different

opinions of all those involved. It will also help to explore possible futures by allowing the group to develop different solutions, implement different options, and experience the effects of decisions made. One product of this policy-exercise will be a white-paper for the Dutch Minister of Education which will summarize the ideas generated by participants. The exercise is currently in the design-stage, and the final runs are planned for the Fall of 1993.

The Schematic Building Process

Both policy exercises are products of a design process which follows the "steps in game design" defined by Duke (1980). This process is not unlike the group-modelling approach which has gradually become popular in system dynamics (Vennix, et al., 1990 and 1992; Richardson, et al., 1992).
The first phases in developing a policy exercise are "problem definition," and "specifications." One begins with a clarification of the problem to be addressed by the policy exercise. It is essential that the problem is defined with precision at the outlet because the whole process following this step will be driven by it. The final product will be also evaluated against this problem statement and the specifications which accompany it.
The next step in this process is a thorough systems analytical procedure aimed at capturing the problem environment in its entirety. During this step designers have to create an overview, gestalt, or perspective of the problem which reflects the views of the various stakeholders. The goal is to use all possible sources of scientific and non-scientific data to develop a "working theory" of the problem at hand and to detail the "decision base" on which the gaming/simulation exercise has to focus. One process-element in the procedure is to create an extensive list of issues relevant to the problem and its environment. Each issue generated is recorded on a separate "issue card" as a brief statement. A major source of issue cards are discussion and brainstorming (brainwriting) sessions involving different groups of actors with a vested interest in the problem. During these sessions the stakeholders review scientific information, opinions and other data relevant for the problem. Each individual writes down all the issues he/she perceives to be important for a better understanding of the problem and its environment. Additional cards are also generated by the project-staff from literature and interviews with key people in the field.

For a successful generation of issues the facilitators of the process have to stimulate creativity and openness. To achieve this, rules and techniques from the creativity literature are applied. The first rule is that judgement and criticism of the issues of others are postponed. Too early criticism may kill future ideas, while the absence of it creates free thinking and reduces tensions. By acquiring the attitude of "anything goes," minority issues are not stifled and dominance by strong personalities is eliminated. Imagination should be turned loose, participants should suggest any issue that comes to mind without fear that they will be immediately evaluated The "wilder" the idea or the issue is, the better it is for the result, because many times a "wild" proposal is the only way to bring out a really innovative and unique idea or solution. "Backcasting" is one such technique to help the imaginative skills of the participants.
Participants are also stimulated to try different approaches to the problem and to think of as many issues as they can. The more ideas and issues there are to choose from, the more chance there is for a valuable conceptualisation to be developed. Another rule is that in addition to continuously contributing ideas of their own, participants should seek improvement and combination of already generated ideas, regardless of whether they are their own or somebody else's. The whole process is organised in such a way that it ensures that all issues and ideas raised are continuously recorded.
The following is a list of kinds of issues (not necessarily mutually exclusive) that are usually generated during this process: components, characteristics, roles, actors, themes, plans, events, decision makers, problems, solutions, alternatives, questions, future considerations, needs, forces, concerns, goals, options, actions, resources, activities, objectives, strategies, decisions, information, aspects, trends.

The next challenge is to organise these different conceptual elements in one working theory and to find a way to document this integrating work. The primary task facing the design team at this stage is to provide a basic system's structure by searching for clusters and categories of these isolated issues. During this sorting and classification process the issue cards are placed under general headings and sub-headings which seem logical at the moment, and all duplicates should be thrown away. This process of sorting and re-sorting continues until a satisfying structure has emerged. Usually the process is an alternation of inductive (idea-sorting) steps and deductive steps in which (partial) theories and conceptual structures from the literature are contrasted with the structure emerging in the inductive steps.

Typically for gaming/simulation the schematics developed are more of a hybrid character if one compare them with the signal-flow diagrams of system dynamics. At least three organising frameworks or principles are often used simultaneously: casual and hierarchical relations, material and information flows and processes or activities.

First of these organising frameworks for building a schematic is to present the relationships among the elements of the problem and its environment, such as: interactions, influences, hierarchy, layout, feedback, etc.

Another organising principle is to present material and information flows between the elements of a problem and its environment, using concepts such as: decisions, activities, time, resources, information, people, regulations, inputs, outputs, etc.

Yet another framework is to present phases in processes or activities taking place, focusing on elements like: project cycles, planning, decision-making, impact assessment, research, life cycle, problem solving, design, development, evaluation, analysis, production process, etc.

All of these frameworks are used separately or combined with one another. Not all of the elements listed above have to be taken into consideration as part of the schematic building process in order for the schematic to be an appropriate presentation of the problem and its environment. However, most schematics we have seen or developed for gaming/simulation projects are usually hybrids of two or more of these organising frameworks.

The outcome of this process is a draft schematic presentation of the conceptual model. This draft schematic is discussed again with the experts on the policy issue being modelled to insure that the system presented is also for them a valid representation. When all concerns and recommendations are incorporated, the final version of the schematic is developed.

Presented in the appendix is a simplified version of the schematic created for the Health Care Negotiations policy exercise. In its full version this model contains several hundred elements connected and related to each other. The connections and relationships are organised around different flows. In the case of Health Care Negotiations exercise the main elements of the model are the flows of money, flows of care, and flows of information. These flows connect main actors (roles) in the model, namely insurers, providers of care, consumers, and government. The four main processes in the model are negotiations between insurers and providers of care, negotiations between insurers and consumers, delivery of medical care , and monitoring of the care delivered.

In the case of PRESTO policy exercise the model (not presented here) is organised around the following flows: students, money, information, representation, communication, regulations, and products/ services. These flows connect all actors represented in the model. The main ones are schools, businesses, technology providers, government, and intermediary organisations. The central point of the model are markets for products/services, labour, and technology. Main activities represented in the model are those related to providing inputs to the market, respective of each actors role.

In both projects, and in quite a few of its predecessors, the schematic building phase is very positively evaluated by the clients. "If you would not do anything else, you have done your money's worth," in a statement once made and often repeated by the clients in one form or another.

The schematic has at least four functions in a gaming/simulation project:

- it shows to client that the project team has a mature understanding of the problem and is an acceptable discussion partner;
- it forces intensive debate between stakeholders with different views;
- it makes individual stakeholders look beyond the limited boundaries of their own positions;
- it provides a solid basis for selecting components the policy exercise should focus on.

Towards an empirical theory of schematics for communicating complexity

There is a striking difference between the intensity of use of graphics and schematics in policy analysis and the amount of empirical and theoretical work devoted to it. If schematics are key success factors in system dynamics and gaming/simulation, then both schools should study this tool in experimental studies and link their theories-of-practice on this subject with the theories on visualisation from o.a. semiology, psychology, educational theory and graphic design research (Arnheim,1970; Bertin, 1967; Bowman, 1968;

Attneaves, 1954; Kaufmann, 1980; Knowlton, 1966). Apart from Lippets work in 1973 we do not know any theoretical or empirical policy-analytical publications on the subject.

In the following text we are looking at some aspects of visualisation that need further study. The primary utility of a schematic is to capture and convey an insight into a complex policy issue. The communication between the conceptual modeller and the observer is achieved by means of visual representation. Visual language stimulates our thoughts about a policy problem in a way which is very different from the spoken and written language. A mature "visual language" for communicating complexity must be able to employ different graphical forms allowing its users to explore a policy issue from many different angles. In our effort to identify some aspects of this visual language, we will address some questions of its syntax, its semantics and its pragmatic aspects (Eco, 1976), as well as some of the "powers" of graphical visualisation (Bertin, 1967).

The syntax of a schematic

The syntax of schematics refers to the grammar of the visual language employed in designing policy-analytical schematics. What we need is a theory on elements of this language as well as the rules of manupulation and combination. A very inspiring, although general theoretical work on sign-syntax, is Bowman's (1968) extensive study on graphic communication. Bowman believes in the possibility of a visual language and we would like to follow him by stating that a well coded, visual policy-analytical language seems possible and desirable. To show the reader what it would take to develop a sign-language specifically for policy-oriented applications, we will describe with some detail Bowman general syntactic structure.

Bowman identifies thirteen functional elements of the "figure as a communicative vehicle." His first goal is to understand what is it that elements of a schematic or graphic are communicating.

For Bowman a graphic is a conceptual logic rather than a technical method; a way of seeing the graphic figure as a visual statement. The visual language, has broad communicational potentional, comparable to the verbal language. This communicational potentional is described from four basic questions: to show what ?, to show how ?, to show how much ?, to show where ?

Using these four basic questions Bowman defines in thirteen categories the total range of instruments of visual communication.

For the first basic question, "To show what ?" he distinguishes three categories:

Appearance	concerns the natural features of a subject as they are seen by the eye under normal circumstances.
Structure	concerns the essential physical constitution of a subject, beyond that which can normally be seen.
Organization	concerns the logical interrelation of elements of a subject in terms of the whole.

The second basic question, "To show how", is explained by the following three categories:

Movement	concerns the physical action or behavior pattern of a subject in motion.
System	concerns the pattern of operation of a subject, in terms of its interdependent elements.
Process	concerns the procedure of independent subject actions, as a succession of related events.

Within the third basic question, "To show how much ?", Bowman finds four sub-categories:

Size	concerns the physical extent of a subject, in terms of the space it occupies.
Quantity	concerns the amount of a subject, in terms of a fixed scale of measure.
Trend	concerns the progressive increase or decrease of a subject, in terms of its amount.
Division	concerns the separation of whole amount in terms of its component quantities.

The last question, "To show where ?", is again explained in three categories:

Area	concerns the space occupied by a subject in relation to its natural surroundings.
Location	concerns the spatial relationship between a subject and its overall environment.
Position	concerns the spatial relation of a subject element to other elements within a area.

The above thirteen categories summarise the functions for which graphical representations can be used. Bowman's next question is how basic graphical symbols can be applied (both in isolation or combination) to perform these functions. The visual elements he discovers represents a visual language grouped in four categories: "Form vocabulary", "Space Grammar", "the Perspective Idiom", "Phrasing the Image".

Form vocabulary
One of Bowman's very strong points is that he is able to show that graphics are really multi-shaped variations of only five elements of form: point, line, shape, value, and texture. For each element he tries to identify not only what they are (their definition) but also what they can do (their function).
For example, a point can act as a center for circular form, as a terminal for converging form, or as a vanishing point within a perspective framework which determines the direction of receding planes.
The value of a grafic element it is a quality of color which refers to its degree of darkness or lightness. In the ansence of hues (red, yellow, blue, etc.), color values become simply shades of gray. In graphics, the impression of gray is created by a concentration of minute dots which at the eye's distance seem to blend with the intervening white spaces. The resultant shade depends on the relative size and density of the dots. As a structural element, color value is a useful means for describing volumetric forms, through light and shadow. This can be done with solid planes of differing value, or with graduated tones.

Space grammar
Schematics are created within the two dimensions of a flat space. Depth, the third dimension, has to be suggested. Using concepts like "plane," "multi-plane" and "continuous space," each divided in many subcategorises, Bowman gives a very fine-grained classification of visual elements as they "use up" or "relate to" the three dimensions. Again he links this with ideas of functionality of different syntactic elements.

The perspective idiom
Bowman devotes a special section of his publication to matters of perspective which we will not discuss in this article.

Phrasing the image
Different shapes in a schematic influence each other. Form interacts in the figure as words do in the sentence. Each is affected by its context. According to Bowman the three primary modes of interaction are: "relation," "differentiation," and "emphasis." Again, for each category he tries to suggest a "thesaurus" or a "dictionary" of a visual language with which a graphic designer can work.

The semantic aspects of a schematic
A semantic analysis of a visual language studies the messages that are conveyed via graphical symbols and structures. It concentrates on iconographical signs. Like some theories on classifications of models, Knowlton (1966) distinguishes three levels of pictures in a abstraction hierarchy: realistic pictures, analogue pictures, and logical pictures, each using basic elements, patterns, and connections in a completely different way.
On 'realistic pictures' Knowlton (1966, p 175) states that when "we need to represent some state of affairs of a sort that is visually perceivable either directly or with technological aid, one quite naturally employs pictures. This category is thus the most obvious one of the three because it includes pictures in the vernacular sence".
Regarding 'analogue pictures' Knowlton states that 'objects are portrayed only in order to show the nature of a structure or process: a process in which the portrayed objects 'participate' in a manner common to the less familiar process in the state of affairs that is of interest. This then, is analogical representation. The sign vehicle in such case will be labeled 'analogical picture'." (op. cit. p 177)
The 'logical picture' is a visual representation "where in the elements are arbitrarily portrayed, while pattern and/or order of connection are isomorphic with the state of affairs represented" (op. cit. p 178).

In policy analysis the schematic presentation of the conceptual model is the means for visualising perspectives and knowledge of different policy experts and participants in the particular policy arena. Very often these experts and policy makers, once confronted with a schematic they themselves contributed to develop, use the same schematic to reflect on their earlier positions and reassess their own perspectives. This provides them with a continuous learning experience and helps them to continually increase their understanding of the policy issue in question.

In relation to different perspectives and knowledge about a policy problem or issue there is a need for developing standards for visualising these problems. Those characteristics or elements of a policy problem that occur frequently, and have more or less a fixed meaning regardless of the policy issue being presented, should be standardised as icons or some other graphical representations. This would be an important contribution to the semantic aspect of the visual language in communicating complexity through schematics.

The pragmatic aspects: schematics as a form of language.

As we described earlier schematic development is a process through which participants continually reassess and develop their understanding of the problem. It is also a process of transfer of knowledge into a visual language. The result of this process is a conceptual model represented as a "big picture" of a particular policy problem.

This schematic representation of the conceptual model is the end point of the system's analytical process and at the same time the starting point of the policy exercise development process. In other words schematic is a static representation of a dynamic reality which is then used to model the same reality through the simulated environment of a policy exercise.

A schematic contains, in one logic picture, all the essential elements of the policy problem, and it is a tool in coming to terms with the complexity of reality it represents. It also represents a reference point to all subsequent discussions on the problem between policy makers and experts who participated in its development.

As a student of cartography, Knapen (1980) has reviewed an immense number of documents which refer to the "power of visualisation." He orders his insights in five categories, using Bertin's (1967) concepts of "five powers."

The power of memorising through compactness

The power of a schematic in memorising through compactness means that in a single glance we are able to overview and get information about a policy problem. The quick transfer of knowledge is emphasised through the use of schematics because only the more relevant elements are represented and the less relevant details are omitted. The schematic is an important contribution in getting an impression about the structure of problems in a certain policy area. Through the spoken and written language the information is communicated sequentially. With the schematic the time factor is greatly reduced and therefore it is more convenient and contributes to compactness of transfer of knowledge.

The instrumental power

With the help of graphical visualisation in the schematic representation of a conceptual model it is possible to reveal the complexity of multi-variable relationships between policy elements of different characteristics.

The power of attraction

The power of attraction of a schematic depends on its recognition aspect. The recognition aspect is large for an expert or policy maker which participated in the schematic development process. Through the development of standards in representing a complex policy issue the power of attraction can become large for non-participants as well.

The power of persuasiveness

It is easy to imagine that ten apples is more then two, but the idea is totally clear when you put these apples near each other. In a similar way the schematic is also a good medium for transferring knowledge and supporting arguments. The problems become much more clear and complete in their presentation through the use of a schematic. If we perceive the information in a better way, we also increase the possibility that we understand the reality it represents in a better way.

The power of many-sidedness

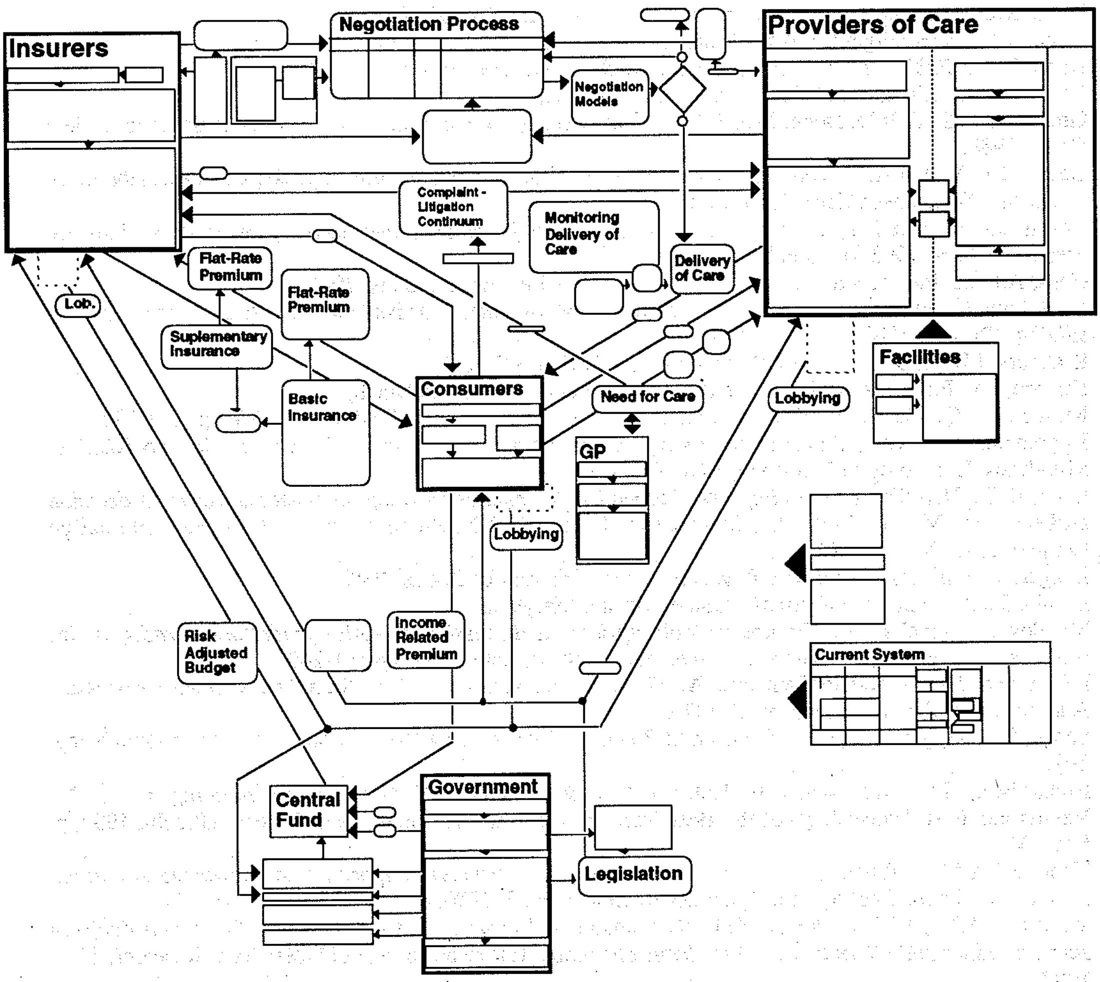
Graphical visualisation in a schematic can be used to successfully represent concrete as well as abstract ideas from many different perspectives or angles. If we compare our efforts in communicating this many-sidednees of a complex policy issue with the achievements of communicating complex information in other fields such as cartography, we realise that we are standing at the very beginning.

Conclusions

Our first conclusion is that many authors have positive things to say when it comes to assessing the role of schematics in policy-oriented studies.
A schematic, being a visual (graphical) representation of a system's analytic approach to a problem, is an aid to clear thinking and it has proven to be an essential communication tool. The laws that govern visual articulation of a complex problem and its environment are very different from the laws of syntax that govern language. The most important difference is that schematics, as a visual form, do not present their elements successively, but simultaneously. The relationships that determine a structure of a problem are grasped in one act of vision.
Presenting a complex problem through a well-designed schematic adds to what can be conveyed through a text. It is said that a "picture is better than a thousand words". The ability of a picture to convey complexity is not limited, as the text and discourse are, by what the mind can retain from the beginning to the end of a successive presentation of a problem and its elements. Problems that contain a large number of closely interrelated elements cannot be successfully projected into a discursive form.
Schematic presentations of complex problems are exploiting the advantages of visual communication. They do so by using simultaneous expression of all the issues significant for increasing the awareness and understanding of the problem and its relationship with the environment. A well-designed schematic is an effective way to engage a group of actors in discussing those issues, to provide them with a "big-picture" overview, and to help them to develop solutions that reflect the inherent levels of interdependency amongst the problem elements.

Conceptual modelling through the use of schematics is an important element of the system dynamics as well as gaming/simulation methodology. Our second conclusion is that both schools should invest in doing research and applying existing theory to their special form of schematic building. If schematics are key to our craft, we have to study them more intensely.
Our review of some aspects of a visual language was only intended to show that there is a lot that "we-in-gaming" or "we-in-system-dynamics" take for granted when we work with schematics. Some of our future research in Nijmegen and Tilburg will be devoted to understanding better what is it that we do with schematics.

Appendix: The Health Care Schematic as an example.



References

Arnheim, R., *Visual thinking*. London, 1970.
Attneave, F., *Some informational aspects of visual perception*. Psychological Review 61: 1954.
Bertin, Jacques., *Sémiologie graphique*. Les diagrammes. Les réseaux, les cartes. Paris, La Haye, 1967.
Bowman, W.J., *Graphic communication*. New York, 1968.
Duke, R.D., Gaming: the future's language. Newbury Park, CA, 1974.
Duke, R.D., A paradigm for game design. Simulation and games, 11-1980 pp 364-377.
Dunn, W.N., *Public policy analysis: an introduction*. Prentice-Hall, 1981.
Eco, U., A theorie od semiotics. Bloomington, London, 1976.
Greenblat, C.S., & R.D. Duke, *Principles and practices of gaming/simulation*. Beverly Hills/London/New Delhi, 1988.
Geurts, J.L.A., & J.A.M. Vennix, *Verkenningen in beleidsanalyse; theorie en praktijk van modelbouw en simulatie*. Kerkebosch Zeist, 1989. (in Dutch)
Geurts, J.L.A., *Omkijken naar de toekomst, lange termijn verkenningen in beleidsexercities*. Samson Tjeenk Wullink, 1993. (in Dutch)
Geus, A.P. de, *Planning as learning*. Harvard Business Review, 2-1988 pp 70-74.
Kaufmann, G., *Imagery, language and cognition. Toward a theory of symbolic activity in human problem-solving*. Bergen, 1980.
Klabbers, J.H.G., De toekomst als spel. Leiden, 1990. (in Dutch)
Knapen, J.W.F.M., *De grafische visualisering*. Nijmegen, 1980. (in Dutch)
Knowlton, J.Q., On the difinition of 'picture'. in: AV communication Review, 14, 1966, p. 157-184.
Kuppevelt, H.J.J. van., *Visualiseren van informatie als hulpmiddel voor advies in beleidsontwikkeling*. MA-thesis, University of Nijmegen, 1990. (in Dutch)
Lane, D.C., *Modeling as learning: creating models to enhance learning amongst management decision makers*. In: Marray-Smith, D., Stephenson, J., Zobel, R.N. Proceedings 3rd European Simulation Congress, Edinburgh, 1989.
Langer, S., *Philosophy in a New Key*. New York, NY: Menfor Books, 1942
Lippitt, L., *A handbook for visual problem solving*. Maryland, 1973.
Meadows, Dounella, H., *The unavoidable apriori., a discussion of major modelling paradigms, in*: Randers, J., L. Ervik (eds) The system dynamics Method, Oslo, 1977, pp 161-240.
Mintzberg, H., D. Raisingham and A. Theoret, The structure of unstructured decision processes. Administrative Science Quarterly, 21-1976.
Senge, P., *The fifth Discipline; The art and Practice of the learning Organization*. New York: Doubleday, 1990.
Richardson, G.P., Andersen, D.F., Rohrbaugh, J. & Steinhurst, W. *Group model building. in*: J.A.M. Vennix a.o. (eds) Proceedings of the 1992 International System Dynamics Conference, Utrecht, 1992, p. 595-604.
Vennix, J.A.M., Gubbels, J.W., Post, D., Poppen, H.J., *A structured approach to knowledge elicitation in conceptual modeling*. System Dynamics Review, 6 no. 2, 1990.
Vennix, J.A.M., D.F. Andersen, G.P. Richardson, J. Rorbaugh., *Model building for group decision support: issues and alternatives in knowledge elicitation*. European Journal of Operational Research. 59.1, 1992.
Wenzler, I., *Project Assessment Game (PAG), A new approuch to development planning*.
Ph D-thesis. University of Michigan, 1990.
Wenzler, I., R.D. Duke, J.L.A. Geurts, & P. van de Lugt, *Health care negotiations policy exercise*. Paper presented at the joint annual ISAGA/NASAGA Conference, Edinburgh, 1992.