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ABSTRACT

This report presents basic theoretical and methodological assumptions for investigating the relationship between competence and qualifications by means of simulation tasks. An analysis of the types of tasks that have been used in the study of problem solving psychology serves as a background for an exposition of the relationship between competence and qualifications. The vehicle for investigating competence and qualifications is the INTOPIA computer program, which simulates a virtual international reality of global enterprises from construction of plants to the sale and financing of products. Findings are reported from a pilot experiment involving two teams of two adults each, the aim of which was to examine the feasibility of using the program in research. Findings indicate that the number of sessions needs to be reduced from the amount used in the teaching situation for which it was developed originally. The issues for investigation in a forthcoming experiment and the tool to be used for modeling the behavior of subjects are outlined. (Contains 35 references.) (Author/SLD)

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Abstract

This report includes a presentation of basic theoretical and methodological assumptions for investigating the relationship between competence and qualifications by means of simulation tasks. An analysis of the types of tasks that have been used in the study of problem solving psychology serves as a background for an exposition of the relationship between competence and qualifications. The vehicle for investigating competence and qualifications is the INTOPIA program, which involves a task that simulates entrepreneurial enterprise. Findings are reported from a pilot experiment, the aim of which was to examine the feasibility of adapting the program for use in research. In particular, the findings indicate that the number of sessions needs to be reduced considerably from the amount used in the teaching situation for which it was originally developed. Finally, the issues for investigation in a forthcoming experiment and the tool to be used for modelling the behaviour of the subjects are outlined.

Contents

1. Overall Aim of the Project

The aim of the project *Simulation studies of competence and qualifications* (SimCom) is to investigate the relationship between competence and qualifications, and to elucidate the development of leadership. A number of theoretical considerations and preliminary observations form the basis for developing the experimental set-up (described below) that will enable us to achieve our goal. A model for the description and analysis of human characteristics has been developed (Jensen & Nissen, 1997), certain strategies for analysing dynamic tasks have been established (Jensen & Bredo, 1978; Jensen, 1990; Jensen & Bertelsen, 1991), and preliminary observations have been made of dynamic modelling as an educational tool (Jensen, 1992).

Further, the data collection will be guided by a theory of competence and qualifications development and a theory of leadership/administration (Elstrup Rasmussen, 1997, 1998). The simulation task that will be used in this series of experiments will be generated by the computer program INTOPIA (Thorelli, Graves & Lopez, 1995). The standard version of this type of task includes management of production-, sales-, and marketing systems. The version adapted to fit the current study is described below. The task requires participants to perform reiterative searches and process information in order to make decisions, observe the consequences of their own actions, and make new decisions.

The study of the complex psychological processes involved in leadership and the unfolding of competence requires types of tasks that are sufficiently complicated for such processes to occur. Simulation tasks/dynamic tasks, as argued below, meet this requirement. The overall aim of our endeavour is to contribute to the research literature concerning the generalisation of knowledge. How can competence, qualifications, and leadership/administration capacities, which are developed in a specific experimental context, be generalised to larger, more comprehensive, 'natural' contexts? An essential issue in this general formulation is the problem of *domain-bound qualifications* and *domain-independent competence* (Sternberg & Frensch, 1991; Frensch & Funke, 1995).

1.1 The Content of this Report

The current report presents the findings from our exploration of the strengths and weaknesses of INTOPIA, the task selected for further experiments (Thorelli et al., 1995). This task has been developed over the last few decades as a means for teaching and learning economics. INTOPIA is a simulation program, which simulates a virtual international reality of global enterprises concerning construction of plants, manufacturing, sale and financing of products. A prominent feature is that the simulation "...forces participants into a stream of truly entrepreneurial (top management) decisions of business philosophy and objectives..." (Thorelli et al., 1995, p. 1)

INTOPIA has many attractive features for our purpose, including access to the underlying model, with options for simplifying the task. It offers an assorted selection of information for the participants, as well as a wide range of response possibilities. However, it was considered an empirical question whether it could be sensibly adapted for experimental purposes, with constraints such as relatively few sessions, the enlistment of experimental subjects, and the need for no particular demand on knowledge of economics.

A pilot study designed to address the use of INTOPIA in this context is presented below. The results indicate that it is indeed feasible to adapt the program for experimental purposes.

Our first experiments explore the relationship between competence and qualifications; an examination of 'leadership' is postponed until later experiments. This report also presents a brief account of the background for selecting simulation tasks, as well as an exposition of our conception of competence and qualifications.

Finally, this report outlines the theoretical basis and methodological constraints for conducting experiments on competence and qualifications.

1.2 The Concepts of Task and Problem

The concept of *task* denotes an experimental setting that exists as an *environment*. The description of a task encompasses an – ideally – exhaustive listing of possible states and the legal transformations within the task. This description is, obviously, independent of potential participants in the study. Any task order can be described by two parameters, the type of component relations and the type of organisation.

The term 'problem' denotes how the subject construes the situation, what (s)he perceives, where to go, and how to reach the end. Figure 1 attempts to integrate a characterisation of the task with a subject-dependent setting of 'problem'.

Figure 1.

The Relation between the Concepts of Task and Problem

Task order		Type of component relations	
		Static	Dynamic
Type of organisation	Transparent	Goal attainment	Target attainment
	Intransparent	Serial goal attainment	Stability attainment

Problem

The following list of statements explicates the figure, which can serve as the basis for characterising the selected examples of problem-solving studies that are presented in the following sub-sections.

- A task has a finite set of states; this applies in principle, but some 'dynamic tasks' have such a huge number of states that in practice the set of states may be considered infinite. One of the states is the initial state.

- A task always encompasses at least one input and one output component, i.e. a task has an I/O-interface. A task may encompass one or more internal components.
- A component or a set of components can change randomly, linearly or non-linearly. In practice, randomly changing components are of no major significance in tasks utilised in problem-solving experiments. Tasks constructed by means of non-solvable systems of non-linear equations are yet to be seen within the field of problem solving.
- Components are organised either as a series of causal relations or as a network of causal relations. In the latter case, the task may encompass direct feedback, which means that in a one-component system, a component changes as a function of its own output. The task may also encompass indirect feedback, which means that a component changes as a function of one or more components that are functionally dependent on the first component.
- A task organised as a series of relations is considered static, whereas a task organised as a network of relations is dynamic.
- A dynamic task is either moving towards a state of equilibrium because of a predominance of negative feedback, or moving away from equilibrium because of a predominance of positive feedback. In practice, dynamic tasks are not constructed to move away from equilibrium because they are extremely difficult to manage.
- If a task encompasses one or more components or sets of components that cannot be manipulated directly or indirectly through input components, the task is said to be *intransparent*, otherwise the task is said to be *transparent*.
- Given a *specific input or a specific and finite series of inputs* – subsequently called a specific input – a transparent, static task reaches an endstate. When receiving the final input, a state is reached that makes further inputs impossible; thus, the subject has solved the problem by attaining the goal.
- Given a specific input, a transparent, dynamic task reaches a state of equilibrium. A repetition of the last input preserves the state of equilibrium; thus, the subject has solved a problem by attaining the target.
- Given a specific input, an intransparent, static task reaches an end-state. However, the task may at any point change in such a way that a different end-state is reached when applying another specific input; thus, the subject has solved the problem by attaining a series of goals.
- Given a specific input, an intransparent, dynamic task reaches a state of equilibrium. However, repeating the last input does not necessarily preserve the state of equilibrium. In order to preserve the state of equilibrium, a new specific input must be applied; thus, the subject has solved the problem by attaining stability.

The parameters of task order combined with the concept of problem seem to be capable of clarifying a good deal of empirical observations. In an intransparent, dynamic task, the problem appears as stability attainment; in a transparent, dynamic task, the problem appears as target attainment; in an intransparent, static task, the problem appears as serial goal attainment; and finally in a transparent, static task, the problem appears as goal attainment.

In the following sections, prominent instances of each type of task will be briefly reviewed, providing support for the relevance and validity of the experimental design for the proposed experiments.

1.2.1 Goal attainment task

The Tower of Hanoi is a well-worn task in cognitive research. It has been thoroughly investigated by Klix (1971), and it was the vehicle for proposing "*The* theory of learning by doing" [our italics] (Anzai & Simon, 1979). Recently, researchers have used the task as a neuropsychological tool, attempting to identify frontal lobe dysfunction (Krikorian et al., 1994). The task has been conceived of, somewhat intuitively, as requiring 'planning ability', but a proper task analysis has not substantiated the claim.

Three pegs on a board are labelled A, B, and C. A number of seriated discs are positioned on peg A, the largest one at the bottom and the smallest one at the top. The problem consists of getting this series of discs transferred to peg C, using peg B as a relay station, in as few moves as possible. The moves must adhere to two constraints: only one disc at a time can be moved and a larger disc cannot be placed above a smaller disc. The challenge of the problem is to make the moves in the proper sequence. Inter-subject variation consists of the number of redundant moves, redundant with respect to necessary and sufficient moves, which is given by the expression

$$2^n - 1,$$

n denoting the number of discs.

If performance in the task is to be used to reveal cognitive processes, a task analysis must be conducted. Thus, aspects of performance that are specifically contingent on the concrete task must be distinguished from aspects that are of psychological interest beyond the concrete situation.

When such a task analysis is performed (see e.g., Bredo & Jensen, 1983, p. 74), it becomes apparent that the necessary and sufficient moves can be divided into blocks of five different operations in a particular sequence. For instance, for a five-disc version of the task, the number of states is 31. Each block of states comprises the operations of 'partitioning', 'relaying', 'assembling', 'sub-goal solution', and 'new sub goal'. Each of these terms refers to the series of discs. At first glance, one might think that since there are 31 states, there are also 31 situations in which to choose the next move. However, when the rules of the game are considered, the only real options are in the partitioning operation and the assembling operation, reducing the number of situations in which a choice can be made to eight. The basis for deriving subjects' strategies, from the *pattern of choices during the solution*, is correspondingly reduced. This type of task is obviously transparent and static in the sense specified above.

1.2.2 Serial goal attainment task

The well-known Wisconsin Card Sorting Test can serve as an example of this type of task. Four cards containing geometric figures varying with respect to number, form and colour are presented to the subject. Each card from a separate pile of cards has to be matched with one of the four cards, and the subject has to discern the sorting principle. The subject is informed whether his/her categorisations are correct or not. When the subject has attained a stipulated number of correct responses, the experimenter changes the criteria for the category, without notifying the subject. The subject then has to adapt his/her choices to a new situation. The number of presentations of cards is considered a measure of the subject's flexibility (see e.g., Posner & Raichle, 1994).

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When the card sorting task and the experimenter are viewed as one 'system', the system is considered intransparent. Thus, the subject, in fact, has to attain a series of goals of the same kind.

1.2.3 Target attainment task

In Berry and Broadbent (1995, p. 132), the subjects of the experiment

> ...took on the role of manager of a simple SUGAR PRODUCTION FACTORY and were required to reach and maintain specified levels of sugar output by varying the number of workers employed.

The equation relating sugar output to workforce "was such that there was no unique output associated with any one input" since "the resulting sugar output depended on the previous sugar output as well as the new workforce figure." (ibid., p. 133) According to Buchner (1995, p. 49),

> ...the system operates according to a simple equation, which states that the sugar output at time t+1, S_{t+1}, is determined by the most recent output S_t and the present input I_t, the number of workers employed by the subject:
>
> $$S_{t+1} = 2 * I_t - S_t$$
>
> where 1 = I = 12 and 1= S = 12. The values of I are multiplied by 100 and the values of S are multiplied by 1,000 to represent the number of workers and the sugar output in tons, respectively, at time t.

In the equation, the term 'S_t' may be interpreted as if the workers at time t+1 are tired, due to the hard work performed at time t. One possible implication is that at any time, except at time t_0, only part of the workforce is active. An alternative interpretation of the equation is that a portion of the working hours has to be used for production dependent maintenance. If the target value is an even number, 8(000) for example, it is possible to attain the target value and maintain the production at that level by using 8(00) workers (8=2*8-8). When the target value is an uneven number, for example 7(000), it can only be approximated. In order to maintain an average production of 7(000), that is, 8(000) at time t and 6(000) at time t+1, the subject has to use 7(00) workers (8=2*7-6 and 6=2*7-8).

In the Berry and Broadbent experiment, the equation was not given to the subjects. However, in several similar experiments, the subject was told that the output was determined by his/her input, and that he/she should "try to crack the pattern" (Berry & Broadbent, 1995, p. 144). The experimenters made the relationship between input and output variables more or less salient by changing the instructions. When the salience was high, the subjects performed better. When the subjects knew that the problem was governed by some sort of regularity, they were not only able to control the system better, they were also better at explaining why they performed as they did.

Thus, the type of component relations is dynamic, because a *network* of causal feedback relations among the variables of the task exists. In the 'factory', the amount of workers influences the production, which in turn influences the amount of workers necessary for attaining a specific level of production. The type of organisation is transparent, because the task does not encompass unreachable components.

1.2.4 Stability attainment task

The paradigmatic case of this type of task is represented by the pioneering work of Dörner and co-workers (Dörner et al., 1983). "Lohhausen" is a problem-generating environment, in which the subjects must establish a sense or an interpretation of what is required to maintain a 'state of well-being' for the citizens of Lohhausen.

The subjects are instructed to imagine themselves as mayor of a small, rural town. They are provided with a map of the town, and a description that includes the number of inhabitants, the geographical relation to other towns, infrastructure, and types of industry, commerce, schools and sports facilities. Health services, pensions, unemployment support, as well as all housing sites are publicly owned. The mayor reportedly has full executive power. The subjects are further instructed to manage the town and its citizens for a period of ten years.

The course of the task is organised in eight sessions of two hours, two sessions per week, each session terminated by the subjects' decisions about what to do.

The model of "Lohhausen" consists of a network of 44 variables, 17 of which can be manipulated by the subject, singly or in any combination. There are some, but not many, positive and negative feedback relations. The model was constructed to include a certain sluggishness in its behaviour, thus encouraging the subjects to use an experimental approach in their search for information about the system, as well as effects of interventions. "Lohhausen" obviously is an intransparent and dynamic task, according to Figure 1.

1.3 Summary

To summarise, a task can be characterised by the types of relations among its components and by the type of organisation that components of the system can occupy. In the following section, it is argued that competence can only be investigated by tasks that are intransparent and dynamic, given the basic assumptions and definitions underlying competence (also to be introduced in the next section).
However, these tasks must be presented in such a way that goals and sub-goals are developed by the subjects, and the registration of the subjects' behaviour must comprise a juxtaposition of subjects' goals and actions. How the subjects construe the situation is an essential feature of the observation, not only in the beginning of the problem solving session but continually through to the end.

2. A Conception of the Relationship between Competence and Qualifications

The following brief exposition presents the basic assumptions concerning competence and qualifications, and – since the terms are a part of everyday language – an interrelated set of definitions of these terms and related concepts.

2.1 Basic Assumptions

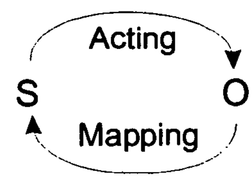
In general, the SimCom project is regarded as a continuation of the 'European perspective of complex problem solving' (Frensch & Funke, 1995); specifically, the project is regarded as an expansion of the tradition developed by Dörner. In order to understand how the basic assumptions of the SimCom project differ from those of Dörner, his position is outlined in the following section.

2.1.1 Dörner's position

Dörner (Dörner et al., 1983) suggests that a subject acts towards an object that emits information, which then allows the subject to create a mental picture of the object (as illustrated in Figure 2).

Figure 2.

The Fundamental Relation between Subject and Object, According to Dörner et al., 1983



The subject, called the actor ('Acteur'), and the object, called the reality-segment ('Realitätsausschnitt'), are *eigen-dynamic* systems that are intransparent and dynamic. They can be described by means of system theoretical concepts: active and passive elements (variables), relations, relations among relations (networks), feedback mechanisms, and states. Both the actor and the reality-segment are changeable; as systems, they can take up different states because of internal or external causes. Any reality-segment has, vis-à-vis the actor, a set of internal unreachable variables, a set of variables that constitutes an output-edge ('Ausgangsrand') and a set of variables that constitutes an input-edge ('Eingangsrand'). The actor is able to perceive the output-edge and to manipulate the input-edge. Having perceived the output-edge, the actor creates a mental picture of the reality-segment in which elements and relations are mapped to elements and relations of the reality-segment. The actor is also able to reflect on his/her own internal system, which means that he/she has some sort of autonomy in administering skills to deal with the reality-segment. Of course, the mental picture can be partly incorrect because the input-output state does not reveal all the internal states of the reality-segment. If a reality-segment encompasses too many aspects for the actor to comprehend, the reality-segment is complex, implying that 'complexity' is defined by means of quantity. Thus, a reality-segment is not complex in itself, but complex because the actor is unable to fully comprehend its structure.

In general, the actor and the reality-segment are considered deterministic systems, they transform from one state into another in a causal way because of internal or external influence. In other words, the actor and the system can be described as a more or less advanced calculus, which moves from one state to another.

Using these fundamental assumptions, Dörner has studied how people behave in complicated, eigen-dynamic reality-segments.

2.1.2 The ontology of SimCom

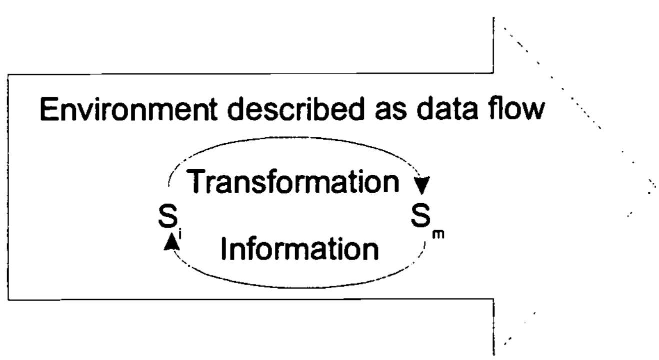
The ontology of SimCom asserts that it is impossible to describe the performance of a living organism without concurrently describing the object that is subjected to the performance of the organism.

The *intentional subject* (S_i) and the *subject matter* (S_m), constitutes an *ecological unity* and has to be analysed as such. Thus, the ontology is based on the assumption that a specific natural stratum exists within the objective world, which can be described as a contralateral unity encompassing a transformation process and an information flow. The contralateral unity is denoted as ($S_i \Xi S_m$), where the symbol (Ξ) (the majuscule form of the Greek chi) designates the transformation/information relationship. The transformation/information process is a relationship and not a simple relation. Transformation/information is the process that keeps the inseparable parts of the unity together. This unity, contrary to other objective phenomena, can be described as meaning, that is, the ($S_i \Xi S_m$) unity encompasses or rather *is* the unit of meaning.

The environment of the ($S_i \Xi S_m$) unity can be described in different ways. However, in order to understand the relation between the ($S_i \Xi S_m$) unity and the environment in which this unity is embedded, the environment can be viewed as a data flow, which the subject transforms into information. Thus, subject matter is a material subjective construction, but a construction that is causally generated by the objective environmental data flow (Kugler & Turvey, 1987; Elstrup Rasmussen, 1997). The subject does not map the object, but generates forms of subject matter, according to circumstances that are specified by the flow of data. Thus, subject matter is not a mental image; it is, so to speak, a material phenomenon loaded with ideas.

Figure 3.

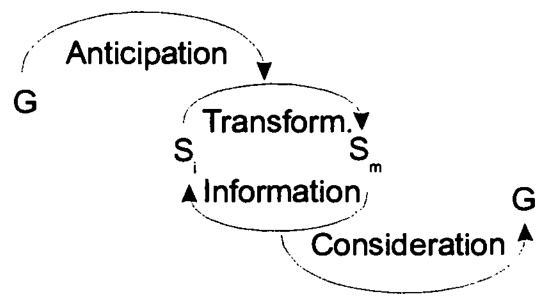
The Fundamental Relationship between the Intentional Subject and Subject Matter Embedded in an Environmental Data Flow.



The contralateral unity may encompass incongruities between type of information andways of transformation. If there is no incongruity between the transformation processand the information flow, the unity is stable. However, if an incongruity exists, the unity is unstable and the subject has to negotiate the incongruity. Thus, any unstable transformation-information dynamism has to be negotiated, which means that the incongruity must be transformed into order. In other words, the unit of meaning must change in order to survive. At least for human beings, the creation of order is partly a reflexive activity. The activity of the ($S_i \Xi S_m$) unity is constrained by yet another process, which is illustrated in Figure 4.

Figure 4.

Embedding the ($S_i \Xi S_m$) Unity in the Reflexive Person



The subject/subject-matter relationship is embedded in the anticipation/consideration relationship, thereby meeting the fundamental assumption of the person being reflexive (see Figure 4). That is, the concept of person includes the ($S_i \Xi S_m$) unity and a generating function (G). Through this constraint, stability may be achieved. The person makes sense of the situation, which is equivalent to the unfolding of competence and enactment of qualifications in a reflexive way. If the person is unable to make sense of the situation encompassing the ($S_i \Xi S_m$) unity and by that transform incongruities into order, he or she must flee or succumb.

Consider a person entertaining the concepts of 'horse' and 'bird' as separate entities. For this particular person at a particular time, 'horse' and 'bird' may be viewed as two stable states, representing a stable state of subject matter comprised of the idea of horse and the idea of bird.

However, if incongruity exists between transformation and information, subject matter has to be restructured. If, for example, it is necessary for the subject to merge 'horse' and 'bird' into 'animal' in order to establish stability at a higher level of abstraction, a new dimension has to be added. This addition of a new dimension can be described topologically (see Figure 5).

The stable states of 'horse' and 'bird' are synthesised into a new stable state 'animal', which encompasses 'horse' as well as 'bird'. The described structure is of course a very simple one. The more advanced the subject matter is, the more dimensions the structure has. A well-elaborated structure of subject matter has an infinite number of dimensions, which means that it is impossible to transform the structure into a veridical drawing. However, it is possible to map an n-dimensional structure onto a two-dimensional space as shown in Figure 6. The two-dimensional representation of the n-dimensional structure is called a holophor. Holophor means the bearer (phor) of an entirety (holo). (Elstrup Rasmussen, 1996, p. 15)

Further, it is possible to map the merging of substructures into superstructures (Figure 7). The structure 'horse'-'bird'-'animals'-'me'-'my animals' merges with the structure 'market-place'-'buyer'-'sales potential' into the final state of 'selling animals', or more precisely, 'I am selling animals.'

Figure 5.

The Merging of Forms of Subject Matter into a Higher Form of Abstraction

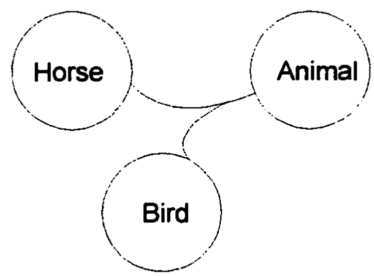
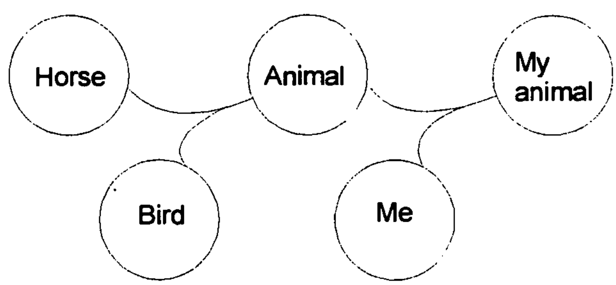


Figure 6.

An n-dimensional Structure Mapped onto a Two-dimensional Drawing



2.2 Definitions

The following definitions of essential concepts are proposed in order to clarify the brief description of the relationship between competence and qualifications.

2.2.1. Competence

This basic concept is defined as follows:

Competence: A person's aptitude for handling complex subject matter and by that establishing and changing the unit of meaning.

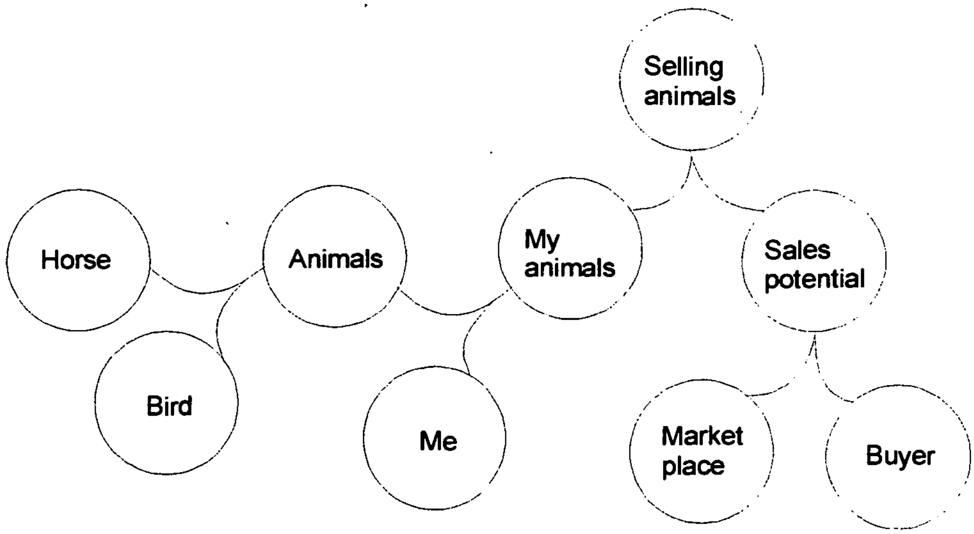
When a certain disorder arises in subject matter, the person attempts to establish a new order, which is expressed by decisions about what to do – in a very general sense. To comprehend the process, one must realise that the new order that the person creates – via competence – is not identical with objective reality, but nonetheless fundamentally dependent upon this reality. Thus, the term *subject matter* denotes a subjective reality that is fundamentally dependent on an objective reality, as presented in the following definition:

Subject matter is the form in which an objective reality is subjectively cast

In other words, an objective material reality emits a stream of data that becomes a stream of information when the person acts within the

Figure 7.

The Merging of Substructures into a Superstructure



objective reality. The totality of data transformed by the person into information constitutes subject matter.

The unfolding of competence is constrained by the anticipation/consideration process (see Figure 4), which generates *problem setting* and *decision*. Problem setting entails the notion that something might be different, and decision indicates the establishment of a state that includes a number of options regarding where and how efforts may be made to change the state.

Subject matter can be complex, which is defined as follows:

> **Subject matter is complex when it is necessary to generate new categories and a new order to make action possible.**

A person who experiences subject matter as complex will try to establish new categories and a new order to be able to make decisions as a generator. To be able to act, the person, as a subject, must create new categories and a new order of the field. However, although subject matter may be complex, it is not entirely disordered. There must always be known or recognisable elements present that function as a kind of bootstrap for the unfolding of competence.

2.2.2 Qualifications

If the person 'survives', in the sense that he or she is able to reproduce his or her actions in a similar situation, he or she is considered to be qualified. A prerequisite for the enactment of qualifications is that they are developed through the unfolding of competence. Thus, it is possible to enact qualifications only when subject matter is no longer complex. When subject matter has been supplied with the necessary categories and a new order has been established, the person can – via the generating function – set goal-defined questions and choose among options. In other words, complex subject matter is transformed – by competence – into a complicated subject matter. The meaning of this term is as follows:

> **Subject matter is complicated when it is necessary to abstract and organise available categories to make action possible.**

The meaning of qualifications is as follows:

> **The ability to handle complicated subject matter, and by that, adjusting the unit of meaning.**

Qualifications are enacted by problem solving. Problem solving comprises problem, which is a goal-defined question situated in complicated subject matter, and one or more choices, which is a selection among available options as to when and how to achieve a solution.

Although a subject creates a new order in a complex field, thereby transforming it into a complicated one, immediate action is not possible. Abstracting and organising categories of subject matter are necessary in order to create goals and select among options. This process is realised by a set of tools, which includes ideas and procedures that constitute the basic material in a continual unfolding of competence. The main point is that the unfolding of competence develops qualifications, and the qualifications are embedded in the competence as ready-to-use components.

2.2.3 Learning

Given this conception, learning is now defined as,

> **The transformation of competence and qualifications, which takes place by problem setting and problem solving.**

Competence and, thereby, qualifications may develop throughout life. The amount and kind of qualifications can be viewed as a measure of competence.

2.3 The Structure of the Concepts

Considered from a structural point of view, the set of concepts can be organised as shown in Figure 8.

Figure 8.

A Structural View of the Relationship of Competence, Qualifications, Subject, and Subject Matter

Person			
Subject / generating function		Subject matter	
		Complex	Complicated
Competence	Problem setting	Decision	
Qualifications	Problem solving		Choice

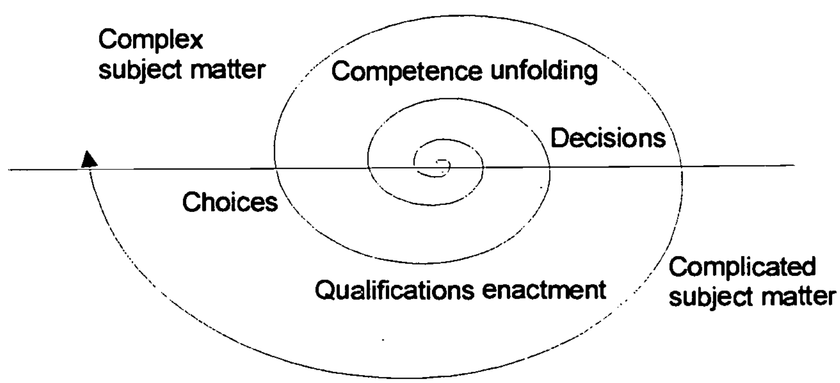
2.4 The Process View of the Conception

As depicted in Figure 9, the relationship between competence and qualifications and subject and subject matter can be considered a process. *Complex* subject matter is located above the horizontal line in the figure, and is also where the unfolding of competence takes place. Below the horizontal line, the enactment of qualifications takes place in *complicated* subject matter.

The unfolding of competence comprises problem setting that will be terminated by a decision – at a particular time. The decision marks the transformation of complex subject matter into a complicated one, in which a problem is formulated and the sub-goals for achieving a solution, as well as the ways and means for achieving the solution, are determined.

Figure 9.

A Process View of the Relationship between Competence and Qualifications



Competence varies among people. The variability of competence is manifested by the degree of complexity people are able to handle, manifesting itself in a set of decisions. Qualifications likewise vary, and the variability is manifested by the degree and nature of knowledge and skills about tools, techniques, communication skills, and analytical procedures that can be employed.

The relationship between competence and qualifications may express itself in various ways, and sometimes a 'disparity' occurs. There are cases in which competence may be 'greater' than qualifications, or qualifications 'greater' than competence.

Enlightened citizens may handle quite complex subject matter, e.g. 'immigrant policy in a Nordic welfare-state', with fairly clear notions about 'a different state of affairs', and with premonitions about 'options', but without commanding the qualifications necessary to achieve 'established goals'.

Correspondingly, qualifications may be quite advanced, without the competence, the meaning of the results of the enactment of qualifications, measuring up. The field of 'information technology' conceived in a wide sense can serve as an example of this. There seems to be quite a gap between the technical achievements in this field and an understanding of their implications, their use and their ensuing societal consequences. In other words, qualifications have been developed, via competence, but existing competence cannot encompass the totality of the components of the subject matter; there is no meaningful pattern in the components of qualifications.

3. A Pilot Experiment

A pilot experiment was conducted during three sessions (July 12 - 14, 1999) that lasted from about 9:00 a.m. until 4:00 p.m. Two two-person teams participated. The first team comprised two women. One woman knew nothing about this type of task and task situation, but the other woman was familiar with essential parts of the psychological literature on 'complex problem solving'. The second team comprised two men, with a similar pattern of knowledge about the situation, and additionally, one of the men was well versed in economics.

The pilot study had three goals. The first one was to test the feasibility of the experimental set-up. The INTOPIA program was developed as a teaching and learning instrument for students of economics. In the SimCom project, it has been somewhat simplified (the entire sub-domain of financial management has been dropped), but all essential types of relations among variables have been preserved. Second, an evaluation was made of a number of technical aids for calculations that had to be provided due to the constraints of the set-up. Finally, an evaluation was made of the use of systemic networks for systematising the oral and written output from the subjects and a tool for analysing 'mental structure'.

3.1 The Course of Task Engagement

3.1.1 Subjects' preparation

About a week before the experiment, the subjects were given the 'manuals' that were to be used in the task. They comprised four texts, the first of which was an introduction to the task; the others were proper manuals about how to handle the task. The introduction was required reading beforehand, and at the time of data collection, all subjects reported that they had read it.

3.1.2 Duration and distribution of activities

The experiment was conducted on three consecutive days, with a one-hour lunch break, and coffee and soft drinks available throughout the day.

The morning of the first day was occupied by an introduction of the task manuals. The subjects studied, and sometimes ruminated over, the material in order to reach the first set of choices. After lunch, the manual about the concern reports was examined again. It was exemplified by the terms and concepts of the system output that describes the consequences of decisions. For the rest of the afternoon, the first period of the task was worked out, terminating in the choices. The second morning started with the subjects' analysis of the previous days' output, and three more sessions were handled. On the third day, another two sessions were dealt with in the morning, and the last two in the afternoon. However, the last two sessions could not be handled properly within the allotted time.

Both teams took a lot of time to consider their course of action. On the third day, both teams felt pressed for time, and somehow reduced their deliberations, because they simply wanted to see how they fared.

At the end of the third day, the subjects were debriefed. Two months after the experiment, the course of events was discussed extensively with the two teams. During this discussion, the team members made substantial contributions concerning the feasibility and rationale of the set-up.

3.1.3 Handling the task-materials

There were four types of task materials, manuals, various concern materials, data from 'external consultants', templates for registering concern policy, a logbook, and 'tools' for calculation and communication procedures between teams and between teams and administrators.

The collection of manuals comprised four texts (Elstrup Rasmussen, Jensen, & Pedersen, 1999a-d). The first text, *INTOPIA I, A virtual world*, is a context-setting description of the content of the game. It was to be read beforehand as a preparation for participation. At the beginning of the pilot experiment, the participants were asked whether they had studied the text. All participants confirmed that they had read the material, and that the text had provided substantial orientation about the game. This text was not consulted further during the experiment.

The second manual, *INTOPIA II, Rules of the game*, sets the rules of the game. The rules cover concern policy, construction of factories and production, sales, type of products, market data, freight, financing, and licences. As the title indicates, this manual is to be consulted during the entire course of events. The consultation is enhanced by a detailed list of contents and a register with all keywords of the game. Our informal observations, as well as reports from the participants, indicated that the manual served its purpose satisfactorily.

The third text, *INTOPIA III, Quarterly report to the management*, consists of five parts: a balance sheet displaying assets, liabilities and equity; an income statement displaying value of forms of sales and income, as well as gains; a management information system displaying amount of sales, as well as various analyses of sales and purchases; and finally an inventory. The last part of this manual includes an overview of the market research reports that had been available for the team during the preceding session.

The manual describes these types of data. It was presented in the general introduction the first day of the experiment, and it was explicated when a team received its first quarterly report after the first session.

The amount of data provided for the participants was quite comprehensive, and the pattern of data of the quarterly report quite complicated. Neither of the teams succeeded in exploiting fully the amount and pattern of data. Instead, they more or less clung to selected, 'conspicuous' variables, such as gains, total revenue, amount of debt, etc.

There may be a number of reasons for this. One reason is the generally high level of 'difficulty' of a task such as INTOPIA in combination with the relatively short duration of the experiment. Another reason might be that the introduction and analysis of the quarterly reports was not thorough enough. A more specific reason might be that the built-in time lag between the construction of the factory in period x, production by the factory in period x+1, and sale of product from the factory in period x+2 was a constraint that seemed difficult to handle. Not that it was difficult in itself to 'understand', but it tended to be 'forgotten', given the host of decisions to be made. These considerations led to a substantial revision of the set-up, to be described below.

The Gazette is a quarterly-issued newsletter from the 'Computer Industries Association'. The first issue was given to each team at the beginning of period one. Hence, it was to be specifically ordered at a price. It contains various kinds of data ranging from messages about changes of currency rates to forecasts about rising inflation.

Probably due to - again - time pressure, neither team exploited this data systematically; bits of data in *the Gazette* issues were attended to seemingly contingently. Further, the purchase of the issues did not seem to happen very deliberately; it was done more as a routine. This observation led to considerations about how to provide 'tools' that could free the subjects to ponder the problems of interest to the researchers. A number of templates were provided for the subjects in which to register their observations and deliberations. The templates were included in the fourth manual, INTOPIA IV, *Registration forms*.

Concern policy is a topic that is given considerable weight in the introduction to the task. The teams were asked to write down what they would consider their long-term goals, intermediate goals, and their reasons for setting these goals. It was stressed that the concern policy was not to be formulated as if it were a final version, it might well undergo revisions during the problem-solving course, and such revisions were to be registered. A template for registering this was provided. As a template, it served its purpose well. However, some of its distinctions turned out to be too elaborate, and some of its categories seemed unclear. Again, a need for revisions was indicated.

The logbook is intended to be a medium for the teams' continual descriptions of their activities. It can be seen as an attempt to externalise the subjects' deliberations, as a supplement to their verbal exchange during the task, an essence, so to speak, of each period's work.

Again, time pressure in combination with all the other required writing led to insufficiently prepared and non-specified use of this template. One team tried to use it according to instructions, with moderate success. The other team forgot the requirement, and had to be reminded of it at the end of the fourth period. They then produced the logbook entries in retrospect. Therefore, the items of concern policy and logbook will be revised as described below.

Nine types of *choice forms* for registering the choices that drive the simulation are normally included. The forms are grouped according to 'local area' (USA, EU, Brazil), headquarter decisions, inter-concern sales, and various types of long-term contracts and loans. After making the entries on the sheets, the subjects have the INTOPIA program copy the entries from the sheets into the program. The diskette is then given to the administrator, who runs the simulation (after having performed a number of checks, comparing the sheets and disk entries). After the first introduction, this part of the set-up seemed to function well.

A number of tools were offered to the participants. The elementary calculator from Microsoft's Office package was given a conspicuous icon on the desktop so that it was readily available. Both teams made good use of it.

Another tool provided was a cross-table for rates of currencies: U.S. dollar, Sterling, Cruzeiros, and Swiss francs. The table makes it possible to view, at a glance, what an arbitrary amount in one currency is worth in the other currencies. The tool was a small Excel-document. There were noticeable differences between the teams' use of this tool, but when actually used, it served its purpose well.

Finally, a 'communication tool' was established, an e-mail routine, to be used by the teams to communicate with each other, and for communication between a team and the administrator.

During the course of events over the three days of the experiment, it became obvious that the set of tools was insufficient. The computations required for reaching sensible decisions were simple enough, but they had to be made in a somewhat complicated pattern. Tools for making such patterns visible were needed: e.g., the continual reminder of the time lag (construction, production, and sale) and realistic price setting. New tools are described below.

3.1.4 Concluding remarks about handling task-materials

In conclusion, it should be noted that the task materials were sufficiently constructed to show their limitations. Further, it was apparent that the set of materials needed to be supplemented, in particular the group of tools.

3.2 Preliminary Examination of Instruments of Analysis

The third aim of the pilot experiment was to examine two instruments of analysis: 'systemic networks' and 'PERTEX'. Systemic networks is an instrument that systematises so-called qualitative data, interview data, verbal exchanges, peoples' thinking aloud, etc. PERTEX is an instrument that purports to map the mental structure of an agent, an intentionally acting person, at a particular time.

3.2.1 Systemic networks

The data of the SimCom project comprise transcripts of verbal interactions between team members, texts of concern policy and the teams' written logbooks. Conventionally, this type of data is regarded as qualitative. Such data offers a subtlety and detail that is well suited to our exploratory purposes, but the sheer bulk of data necessitates the imposition of order. This order cannot be provided by simple category schemes for counting frequencies, or by extensive quotes of data.

The use of 'systemic networks' (Bliss, Monk & Ogborn, 1983) can provide this order. For the current study, two networks were established: one for the verbal exchange of the team members and one for the transformations possible within the task. The systemic network idea is inspired by systemic linguistics, and the basic assertion is that language has essentially to do with 'choice in a context'.

A 'systemic network' is a system of categories (i.e., named distinctions). It may comprise nested categories of exclusive data items, and data items viewed from more than one point of view (i.e., simultaneous categorisation with respect to different aspects, and combinations thereof, to any desired level of intricacy). A network defines a system of well-defined descriptive structures, to be coded in a language whose meaning is given by the network. Thus, a network can be regarded as a formal specification of a data-description language.

Analysis of data ordered by such a network can be done by observing the types of events, their frequency and the succession of events. Such distributions may then be related to selected person- and task properties. Further, the network analysis can be used to select parts of the verbal exchange to be analysed by the PERTEX instrument (see below).

When confronted with the transcript of the verbal exchange of a team, a major problem is how to segment it. What is the meaningful unit to employ to order the exchange? The idea as well as the context of INTOPIA suggests 'decisions' and 'choices' as markers to segment the stream of verbal exchanges into a stream of events. In Appendix A, an example of such a network is presented, solely for illustrating the technique. The example is based on one of the teams from the pilot experiment, and is confined to the verbal exchange of the first session. For proper analysis, the network must comprise the entire verbal exchange of all eight periods of the experiment.

The events of the verbal exchange have been distinguished by a 'unit of sense-making'. Such a unit consists of a 'determination' and a 'discourse'. The former comprises either a 'decision' or a 'choice'. A choice signifies a determination that is *directly executable* via one or more choices; a decision signifies a determination that

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requires *implementation* by one or more choices. Distinct expressions of determination were used to separate the units of sense-making.

The second part of the unit consists of what has been termed 'discourse'. The term refers to the expressions that precede the determination. These expressions have been divided into seven types, as seen in Appendix A (e.g., problem-setting, focussing, clarification).

Each unit can be coded as a realisation of the network. For instance, a unit may be a 'focussing, single choice', or a 'clarifying chain of decisions'. These are simple examples. However, the 'distinct expression of determination' that separated the units of sense-making sometimes comprised a decision as well as one or more choices; and a discourse comprised, for example, clarification and problem-setting. Therefore, the network must allow for recursive runs through the network, yielding examples of coding such as a unit of 'orienting/scanning/recapitulating single decision', or 'ends-means, single choice/chain of decisions'. Each coding is referred to as a *paradigm*.

The entire coding should be viewed as still another data transformation. Patterns of codes will be the substance of model-determined control parameters and forms of problem-solving performance.

A second systemic network was established covering what is termed the transformation space of the task.

The states of the INTOPIA system are determined by a large number of variables. The variables may take a large number of different values, in fact – as stated above – making a heuristic approach to the handling of the system the only feasible one.

In our adaptation of the system, there are 64 possible interventions for each state. (The network is displayed in Appendix B.) The network read from left to right states that the transformation space can be divided into a number of paradigms, each of which is unequivocally denoted by the far right column. The intervening columns show the variables that must be given a value to reach the specific transformation.

The results of applying this network to the protocols of the teams can be analysed with respect to frequency over time, and – again – be related to person- and task parameters. Further, such results can be analysed in combination with selected results from the operations analysis and the PERTEX-analysis.

3.2.2 PERTEX: an instrument for mapping mental structure

Bierschenk (1991) argues that Kant's synthetic proposition can be transformed into a psychological model for the study of consciousness: (int(A) a (ort(O)). This model asserts that an acting organism expresses an intentional (int) and an orientated (ort) schematisation. This means:

> ...that psychological phenomena must be conceived as meaningful actions carried out by an agent. Acting purposely presupposes not only that structure can be detected but also that intentionality and orientation can be observed. (ibid., p. 7)

Thus, it is argued that the (AaO) formula expresses the mechanism of the establishment of consciousness. It is further hypothesised that this mechanism picks up environmental invariants or information by direct perception (Gibson, 1979). Finally, it is argued that the establishment of 'consciousness' is "closely tied to a linguistic mechanism". The essential concepts for establishing conceptual invariance are 'perspective' and 'viewpoint" (Bierschenk, 1991, p.17). Thus:

> It is assumed that a pictorial and symbolic expression of the organism-environment interaction entwines perspective and viewpoint in the same way as intention and orientation have entwined organism and environment. (ibid. p. 17)

In other words, natural language production is governed by a language mechanism that expresses and builds up consciousness:

> Inherent in the process of text building is the process of cognitive integration of experience. The ability to give expression to integrated experience co-varies with the text building behaviour of the agent as reflected in natural language expression. (Bierschenk, 1993 p. 4)

Thus, if it is possible to uncover the inherent structure of a text, it is also possible to uncover the structure of consciousness.

Bierschenk (1991, 1993) proposes that it is possible to uncover the internal structure of a text, and also that the text-structure can be divided further into four components: Figure, Ground, Means and Goal. Thus, a text analysis is assumed to reveal four aspects of the text: a) the 'viewpoints' of the text, which is equivalent to the focus of the text; b) the 'standpoint' of the text, which is equivalent to the foundation of focus; c) 'aid-points' of the text, which is equivalent to everything that aids the achievement of goals; and finally d) 'set-points' of the text, which refers to what is constituted as goals.

Finally, Bierschenk (1991, 1993) has argued that any text-structure has a specific 'perspective', which means that a specific subset of a specific text-structure is of major importance for the agent producing the text.

Perspective Text Analysis is based on the assumption that consciousness is schematised in a two-, or maybe a three-dimensional space. It is conceivable that immediate consciousness is built up as assumed by Bierschenk.

However, the basic idea of the ($S_i \Xi S_m$) unity is based on the assumption that subject matter is an n-dimensional space ($n \geq 3$). Therefore, the concepts of 'consciousness' and 'meaning' cannot denote the same phenomenon. The development of meaning by means of competence and 'being conscious' are not the same phenomenon, although 'being conscious' as a personal characteristic must be considered necessary in the unfolding of human competence, and through that, decision making. This means that the text structure revealed by PTA must be regarded as a specific language-carried, concept-bound mapping of the underlying structure of subject matter. Thus, PTA points to the specific way in which subject matter is consciously expressed.

The fundamental principles of Perspective Text Analysis (PTA) have been implemented in the PC-system PERTEX (Helmersson, 1992), which is based on the work of Bierschenk and Bierschenk (1986a, 1986b):

> PERTEX is built to realize the following main steps of PTA:
>
> (1) *Coding of function words for verbs, prepositions, sentence openers, clause openers.* PERTEX has a specially developed dictionary and language dependent routines for identification of function words in the text.
>
> (2) *Design and coding of blocks according to the AaO-paradigm.* A block is based on a verb, the a-component in AaO. The block also

consists of an agent, the A-component, and an Objective, the O-component. The O-component is differentiated by prepositions used in the text. The limits of a block are in the general case set by sentence- or clause-openers, e.g. full stop or comma.

(3) *Supplementation of A- and 0-dummies.* In normal text, variables for the A- and O-components are sometimes omitted. All the implicit references to and from A- and O-components are made explicit in this step. Even different forms of self references are handled by PERTEX.

(4) *Generation of A/O-matrixes.* The block oriented connection between A and O is a corner stone in PTA. All such connections between the unique A- and O-components in the text are organized in different binary A/O-matrixes.

(5) *Cluster analysis based on A/O-matrixes.* Ward's method for clustering is used in PERTEX. By clustering the O-rows in an A/O-matrix, with the A's as variables, we extract the structural relations of the Objective in the text. When, in the transposed matrix, the A-rows are clustered, with the O's as variables, we extract the structural relations of the text producer's perspective on the Objective.

(6) *Topological presentations of outcomes.* The user of PERTEX has to select the significant number of clusters in every cluster analysis. Here PERTEX offers not only Ward's ESS-values but also different t-tests. The number of selected clusters and the text content of every cluster are presented for the user's naming of the clusters. The clusters are then organized according to the cluster tree and the user can fulfil the investigation of the text by following the synthesis from the clusters to the root of the cluster tree. (Helmersson, 1992, p. 3)

3.3 Changes to the Experimental Set-up Following the Pilot Experiment

As indicated above, the pilot experiment uncovered various aspects of the experimental set-up that require revision.

3.3.1 Selection of subjects

Although the pilot study showed that participation does not require specific knowledge of economics, students of economics will be selected as participants for Experiment One. This will be done mainly to reduce the time needed for 'technical' instruction. Three teams of two persons will be selected.

3.3.2. Duration of task engagement

Because of the time pressure experienced by the participants in the pilot study, the Experiment One will be conducted over a period of four days. However, the experiment will be split into 2x2 days, because the pilot study showed that the participants were quite worn out by the end of the second day. Depending on the participants' availability, the break will be a minimum of one day and a maximum of three days. The participants will be instructed not to engage in mutual discussions during the break.

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3.3.3 Changes in directions for use of templates

The concern policy template has been simplified. Now, the team will only describe the overall goals and the reasons for setting these goals. The team will also describe the production, marketing and R&D strategy.

The major change is with the use of the logbook. The layout will not be changed, but the teams are to mail the logbook to the administrator as they deliver the set of decisions. The next period does not start until a team has delivered its logbook.

3.3.4 Construction of new tools for subjects

Difficulties handling time lag of construction, production and sale, and difficulties managing different types of grades of products has led to the construction of a new tool. With this tool, it will be possible to manage and plan the development of production.

Further, the teams in the pilot experiment used most of their time on price calculation and on keeping track of all the variables that are important for pricing. Therefore, a new spreadsheet tool was developed. By filling in the spreadsheet, the participants can get an estimate of the costs. The tool can be used as a calculation aid as well as a planning device.

3.4 Summarising the Results of the Pilot Experiment

The main finding of the pilot experiment was that the experimental set-up was indeed feasible. A number of modifications, however, seem to be necessary. The modifications include 1) an increase in the number of sessions to four, 2) the provision of more technical aids, and 3) a requirement of a more tightly scheduled use of the scheme of concern policy and the scheme of logbook.

The main instruments for analyses were tried and proved to be of interest. One example of each analysis is provided in appendices A-C.

4. Discussion and Perspectives

In this section, we will briefly outline the issues to be investigated in a forthcoming experiment and describe the modelling tool that will be used.

The main goal is *to describe and model the development of competence through the enactment of qualifications*. This goal implies a number of requirements. First, a directional change of competence must be observable over time. As stated above, competence may vary with subject matter complexity, subject matter being that part of the environment that the person consciously perceives as 'material' for establishing the problem.

It must be shown concretely that the subject – over time – has dealt with a wider environment (determined by the number of interdependence relations), and that the subject displays an increased 'sensitivity' towards the dynamic of the task.

Secondly, beyond the specification of development, the quality of solution must be measurable at least on an ordinal scale (i.e., by ranking the solutions). This implies an analysis of the relation between 'concern policy' and the degree of achievement of a team's goals.

The second goal is *to describe and model different enactments of qualifications that would seem to 'lead to' different degrees of competence*. Therefore, the enactment of qualifications must be characterised, and subsequently analysed in its relation to competence.

As expounded above, these themes will be investigated by studying problem-solving performance in the INTOPIA environment.

A variety of forms of performance was empirically derived by Dörner (Dörner et al., 1983), and some of these forms as well as additional ones will be studied. Clearly, it is possible to observe such forms of performance as expressions of a structure generated by non-linear interactions of conflicting control parameters. The tool to be used is catastrophe theory developed by René Thom (1975).

According to Zeeman,

> Catastrophe theory is a new method for describing the evolution of forms in nature (...) It is particularly applicable where gradually changing forces produce sudden effects (...) The theory depends upon some new and deep theorems in the geometry of many dimensions, which classify the way that discontinuities can occur in terms of a few archetypal forms (...) The remarkable thing about the results is that although the proofs are sophisticated, the elementary catastrophes themselves are both surprising and relatively easy to understand, and can be profitably used by scientists who are not expert mathematicians. (Zeeman, 1977, p.1)

As mentioned above, meaning is multi-dimensional, therefore a personal set of ideas constitutes an immense amount of mental degrees of freedom. In order to structure an adequate set of ideas, expressed in the sense-making process, the sense-making process is hypothesised to be constrained by the 'anticipation/consideration process' manifesting itself as two control processes: *tracking-control* and *goal-control*. It is further hypothesised that tracking-control and goal-control can be split into conflicting parameters. Tracking-control is split into two conflicting control parameters: *efficacy and ruggedness*. Efficacy is a measure of being the master of one's own action, while ruggedness is a measure of the obstacles in the environment. Thus, tracking-control is the degree of manifestation of the person's handling the route towards the goal. Finally, it is hypothesised that goal-control is constituted by two conflicting control parameters: *achievement* and *availability*. Achievement is measured by the degree of manifestation of progress, while availability, posited by the flow of information, is measured by the degree of manifestation of handling environmental abundance. Thus, goal-control is the degree to which the person is closing in on a solution. (Bang & Elstrup Rasmussen, 2000)

If the control parameters, achievement/availability and efficacy/ruggedness, do interact in a conflicting and non-linear way, and if the interacting control parameters give rise to relatively stable forms of performance, between which sudden discontinuities can occur, it is possible to model the connection between control parameters and performance by means of a catastrophe.

This assertion is based on a conjecture about the relation between various patterns of values of control parameters and forms of problem-solving performance. As long as the degree of ruggedness is low, and the feeling of efficacy is of medium strength, the most likely problem-solving performance will be *ensuring*. The term ensuring refers to an activity the person uses to solve problems systematically, because there is a kind of balance between experienced difficulty and mastery. If the degree of efficacy grows, the person will display a certain boldness as long as ruggedness is not too high, that is, the person will behave in an *exploring* way. The person will seek out obstacles regarding solutions, and not give in to the difficulties concerning these obstacles because of efficacy. However, if the degree of ruggedness increases to a point where it cannot be balanced by efficacy, the person will start *roaming*, that is, shooting off the entire arsenal of more or less suitable solutions. At the other end of this range of forms of problem-solving performance, the person will *linger* if the increase in ruggedness coincides with the decrease in efficacy. The person encounters obstacles, but shrinks from further attempts to reach a solution. At the extreme, the person who is very low on the efficacy dimension and who is in a high-rugged situation will *dig in*, i.e., the person will repeatedly offer the same solution to a changing situation. Thus, it is assumed that a range of forms of problem-solving performance exists: digging in, lingering, ensuring, exploring and roaming. It is also assumed that the likelihood distribution of the forms of performance is two-tailed. If, for instance, the degree of ruggedness is sufficiently high, a slight change in efficacy may result in a jump from digging in to roaming and vice versa.

If the likelihood distribution of problem-solving performance is as described, a graph would look like the cusp-catastrophe surface (M) shown in Figure 10 (Zeeman, 1977). If ruggedness and efficacy vary over the horizontal plane C, the problem-solving performance will follow suit over the surface M above, except for the middle sheet. The middle sheet is an inaccessible area that indicates that the performance cannot take two forms at the same time. Each point of the surface M represents an attractor of the dynamical system of sense-making, and the jumps occur when the stability of an attractor breaks down.

The M surface shows that a continuous change in the relationship between the control parameters ruggedness and efficacy can result in a continuous change in problem-solving performance, from digging in, lingering, ensuring and exploring to roaming. As illustrated by the dotted lines, the graph also shows that a very small difference in efficacy via an increase in ruggedness may result in quite different forms of performance (the *divergence* feature of a catastrophe).

Further, the model shows that at a high level of ruggedness, with the person either digging in or roaming, a change of efficacy may result in an abrupt change of problem-solving performance. This change may happen as a jump either from digging in to roaming or from roaming to digging in (the *hysteresis* feature of a catastrophe), or less dramatically from lingering to exploring and vice versa.

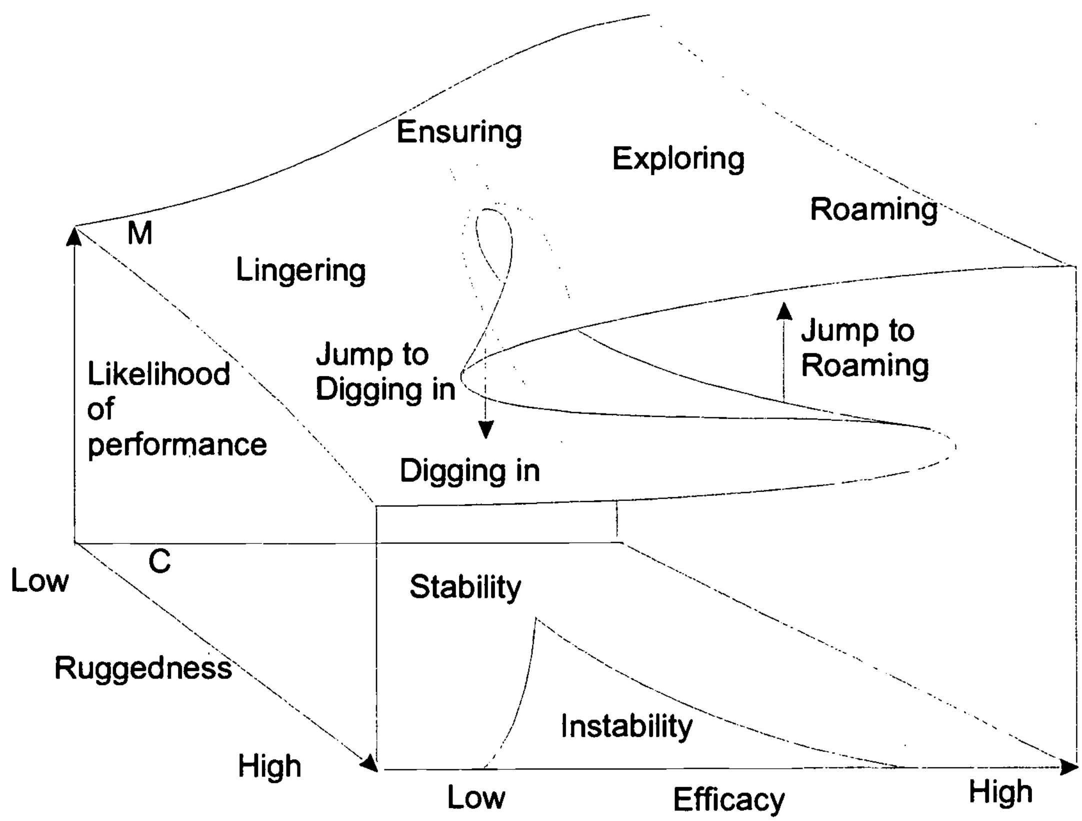
The model shows that the same fundamental control parameters with small quantitative variations are able to generate quite different forms of performance.

The cusp-catastrophe model depicts bimodality, illustrated by the divergence when moving from ensuring to digging in or roaming. However, yet another form of performance has been observed (Dörner et al. 1983), viz. 'muddling through', which modelled by a catastrophe would appear as a kind of compromise between extremes. The presence of this form of performance implies trimodality, the modelling of which would require the next elementary catastrophe, the butterfly-catastrophe.

> Trimodal behaviour determines the unique and much richer five-dimensional geometry of the butterfly-catastrophe. Since trimodality often emerges out of bimodality, the natural way to analyse the butterfly is to regard it as an extension of the cusp. (Zeeman, 1977, p. 29)

Figure 10.

The Relationship between Ruggedness, Efficacy and Problem-solving Performance Modelled as a Cusp-catastrophe.



By means of the second pair of control parameters, *achievement/availability,* it is possible to transform the bimodal behaviour model into a trimodal one, and thus model the range of forms of problem-solving performance described by Dörner and Waring (Dörner & Waring 1995; Bang & Elstrup Rasmussen, 2000). If successful, the model of problem-solving performance will demonstrate that by means of catastrophe theory, and the concept of sense-making, it is possible to move from categorising performance to modelling performance.

5. Final Remark

The purpose of this report was to lay the foundation for future studies that will examine the relationship between competence and qualifications. Towards that end, a series of experiments will be conducted, the first of which will be modelling development of competence through enactment of qualifications. According to the argument stated in the introduction, this study requires a context of observation in which unfolding of competence as well as enactment of qualifications are needed. A simulation task has been judged appropriate in this case.

A wide range of types of data will be collected:

- Continual verbal exchange between participants of a problem-solving team,
- Written statements of the team's goal(s),
- Written statements of sub-goals,
- Sub-problems and arguments concerning these,
- Objective measures of achievement, continual recording of the use of problem-solving tools.

The analysis of data will be performed with the aim of operationalising the control parameters and the behaviour forms outlined in the preceding section. Firstly, performance features indicating the different forms of performance must be distinguished. Secondly, features that may indicate the conflicting control parameters efficacy and ruggedness must be distinguished. Finally, the relation between these groups of performance features must be plotted.

Competence is expressed in the establishment of the unit of meaning, and potential development of competence in the change of the unit of meaning. Competence will be reflected in the problem setting, manifesting itself in the decisions made (see Figure 8, and pp. 15-16). The basis for analysis will be relevant sections of the concern policy and the logbook (see p. 20), and records of the verbal exchange. This material will be analysed by juxtaposing results from PERTEX analyses of significant portions of the concern policy and the verbal exchange, and results from applying systemic network analysis.

Enactment of qualifications will be reflected in the problem solving, manifesting itself in the choices made (see Figure 8, and p. 16-17). Significant portions of the logbook and the verbal exchange will be subjected to analysis by PERTEX and systemic networks. The results will be juxtaposed with the set of choices made, revealed by analysis of the systemic network of transformations (see p. 20-21, and Appendix B). Further, qualifications may be revealed in the subjects' use of the tools available (see p. 20 and p. 24).

Detailed analyses of the 'unfolding of competence through enactment of qualifications' will be guided by the model of cusp- and butterfly-catastrophes. Referring to Figure 10, and looking at the behaviour plane, roaming could be seen as a fairly direct expression of the relationship. A potentially interesting path of behaviour would be from digging in to lingering to ensuring: what change of competence could make such a path possible? Another possibility would be a comparison of two different paths. For example, the path from roaming to exploring would imply changes in both of the control parameters. The other example would be the catastrophic jump from roaming to digging in, implying a constant ruggedness, but a large change of efficacy. Again, the question of what competence changes might be associated with one or the other paths will be examined.

In summary, if successful, the operationalisation will form the basis for examining the hypothesis expressed by the cusp-catastrophe model as stated in the preceding section. If the hypothesis is supported, an explanation of problem solving behaviour in complicated, dynamic tasks will be provided. That is the goal of our first experiment.

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Appendix

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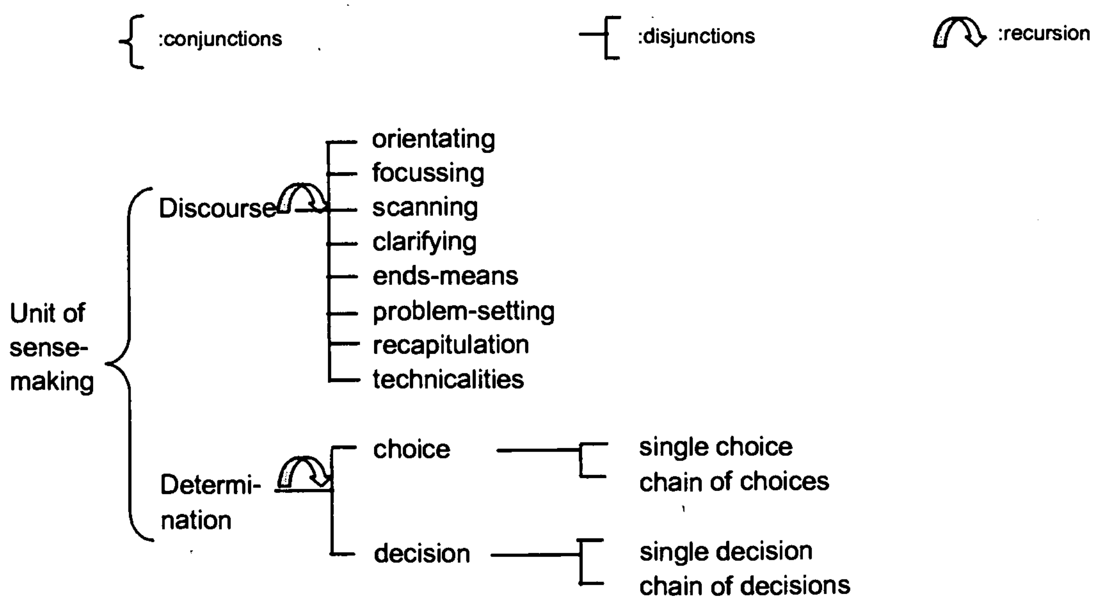
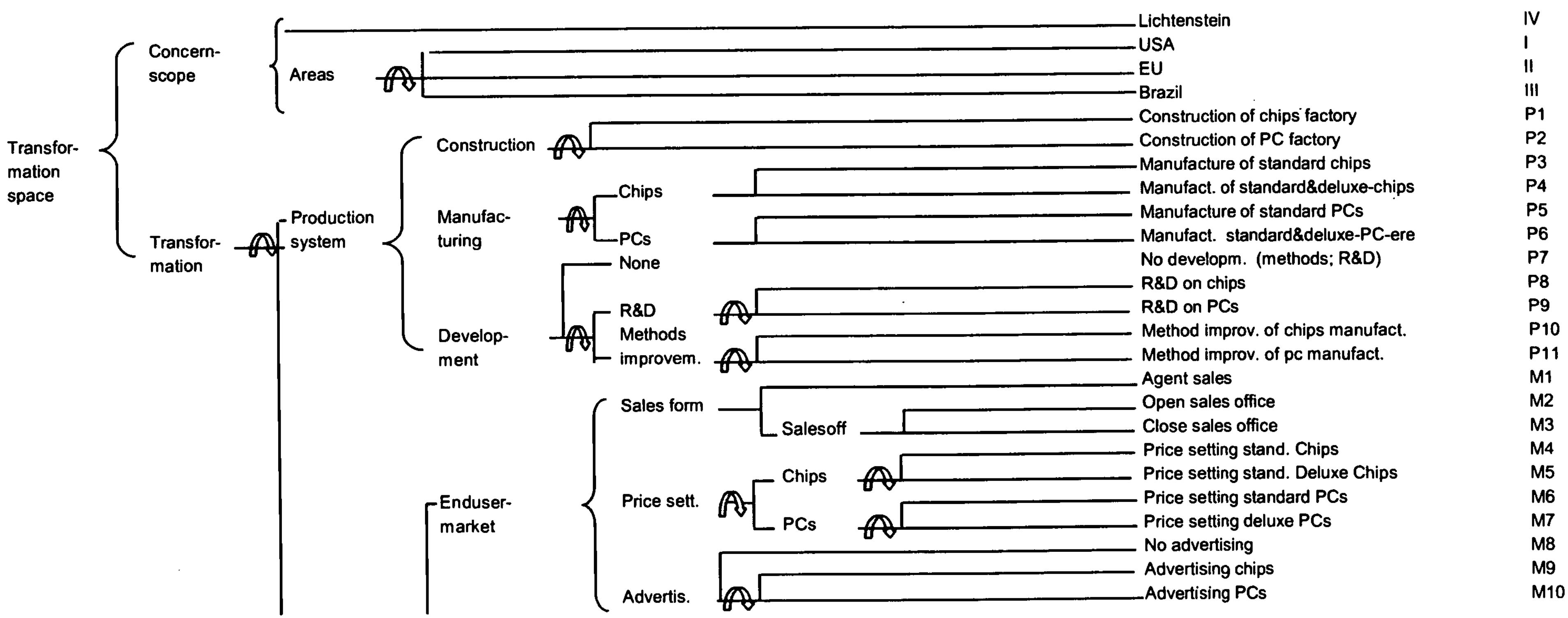
Appendix A. *A Network for Categorising the Verbal Exchange*



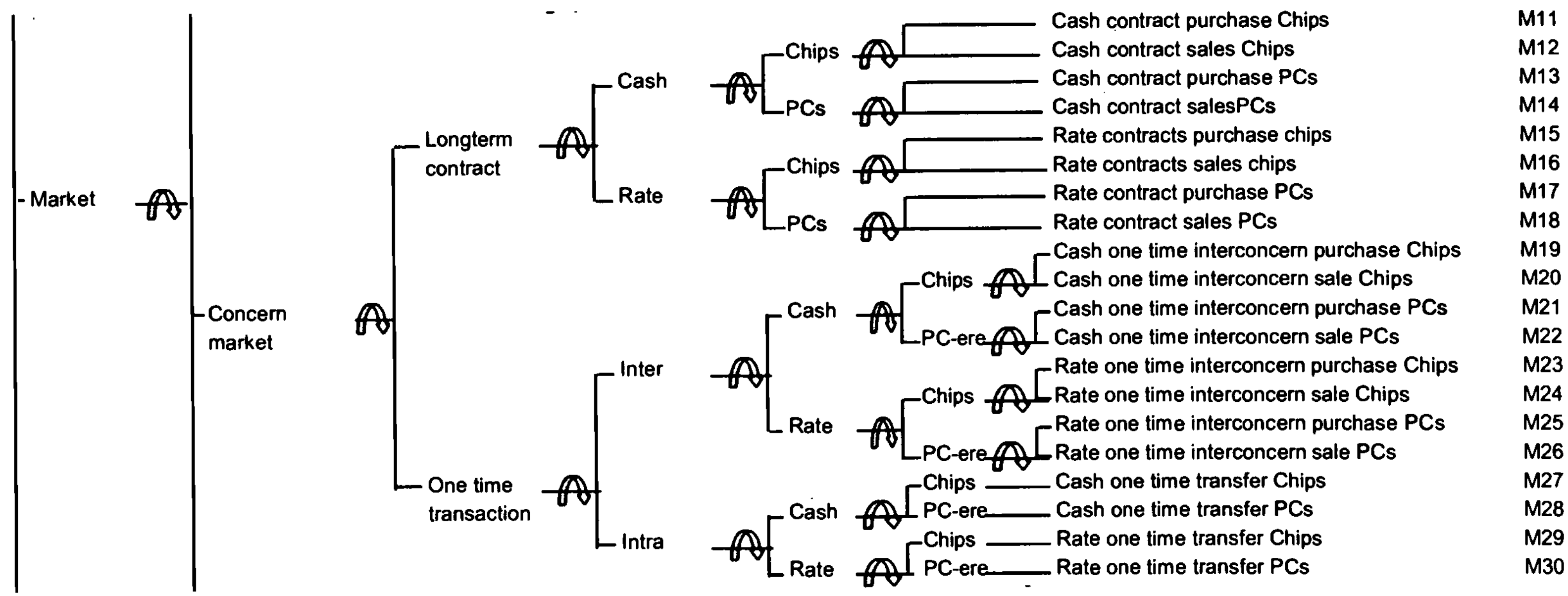
Unit of sence-making' is the unit for partitioning the flow of verbal exchange
Choice' signifies a determination that is directly executable via one or more choices
Decision' signifies a determination that requires implementation by one or more choices

ERIC Full Text Provided by ERIC

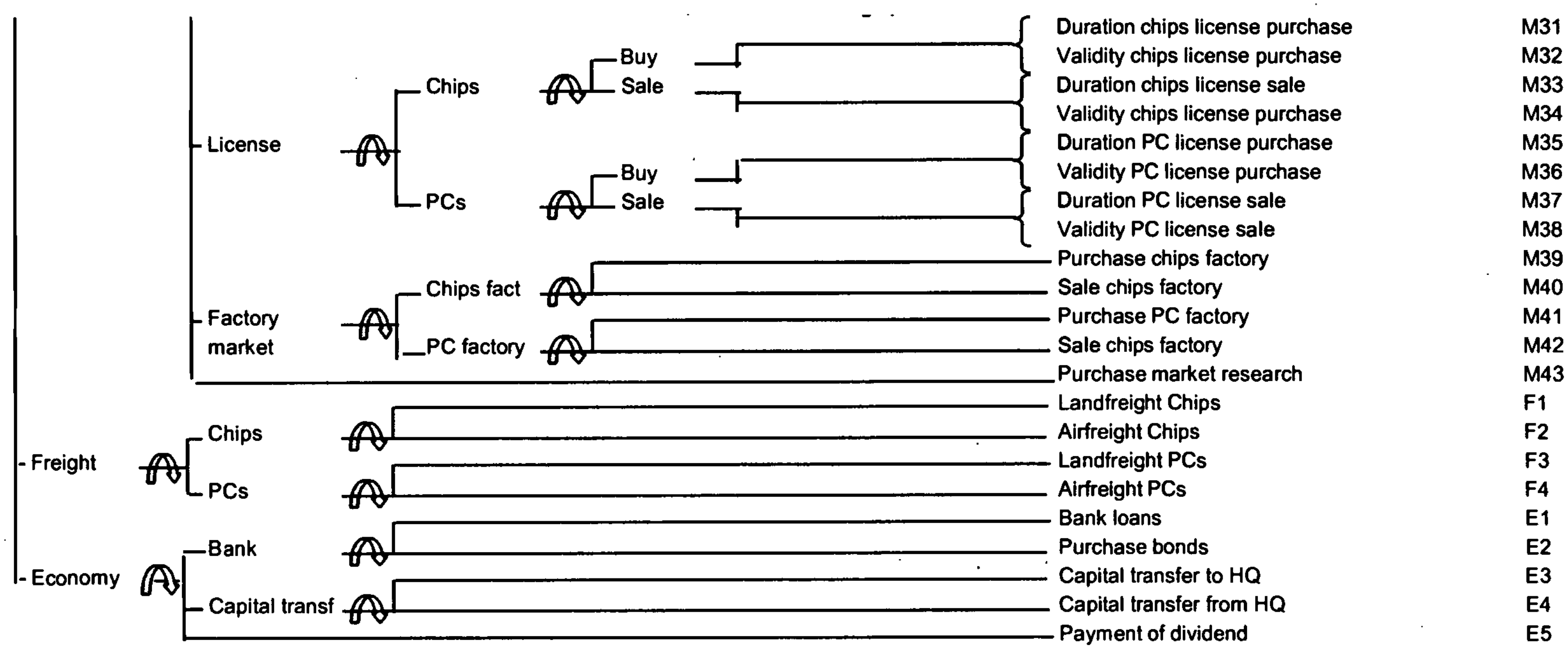
Appendix B. *A Network of Transformation Space*



Transformation Space. Continued



Transformation Space. End



Appendix C. *A PERTEX-analysis*

The analysis is based upon the initial four minutes of the dialogue of team one from the pilot experiment.

A PERTEX analysis starts by naming the clusters. In the figure holophor shown in Figure 1, 19 clusters are connected by means of a string of synthesis. Each cluster encompasses a set of text strings. These text strings are described by the analyser. For example: cluster no. 8 encompasses the following text strings: '1. so many things', '2. inflation', '3. consequently this wrong'. In the analyser's mind, these three strings can be described by the idea: '8. at risk because of inflation', because the three strings point to the idea that so many things can go wrong because of inflation, which means that something is at risk because of inflation. In cluster 9., are '1. many things badly', '2. badly'. The idea '9. mischief' picks up the sense of the strings.

It can be discussed whether the analyser is able to coin the proper idea of such descriptions. However, when several, independent analysers reach the same result, the reliability can be estimated.

After the different clusters are named, synthesis is created. The cluster of the end-states 8. and 9. is synthesised into '*inflation means failure*'. The argument runs as follows: on the one hand we know that something is at risk because of inflation, things may go wrong; but the other idea 'mischief' indicates with certainty that things go wrong. Therefore, 'inflation means failure' seems to be the adequate description.

Figure 1 displays the holophor of the 'figure'.

Figure 1.

The Holophor of 'Figure': Team One

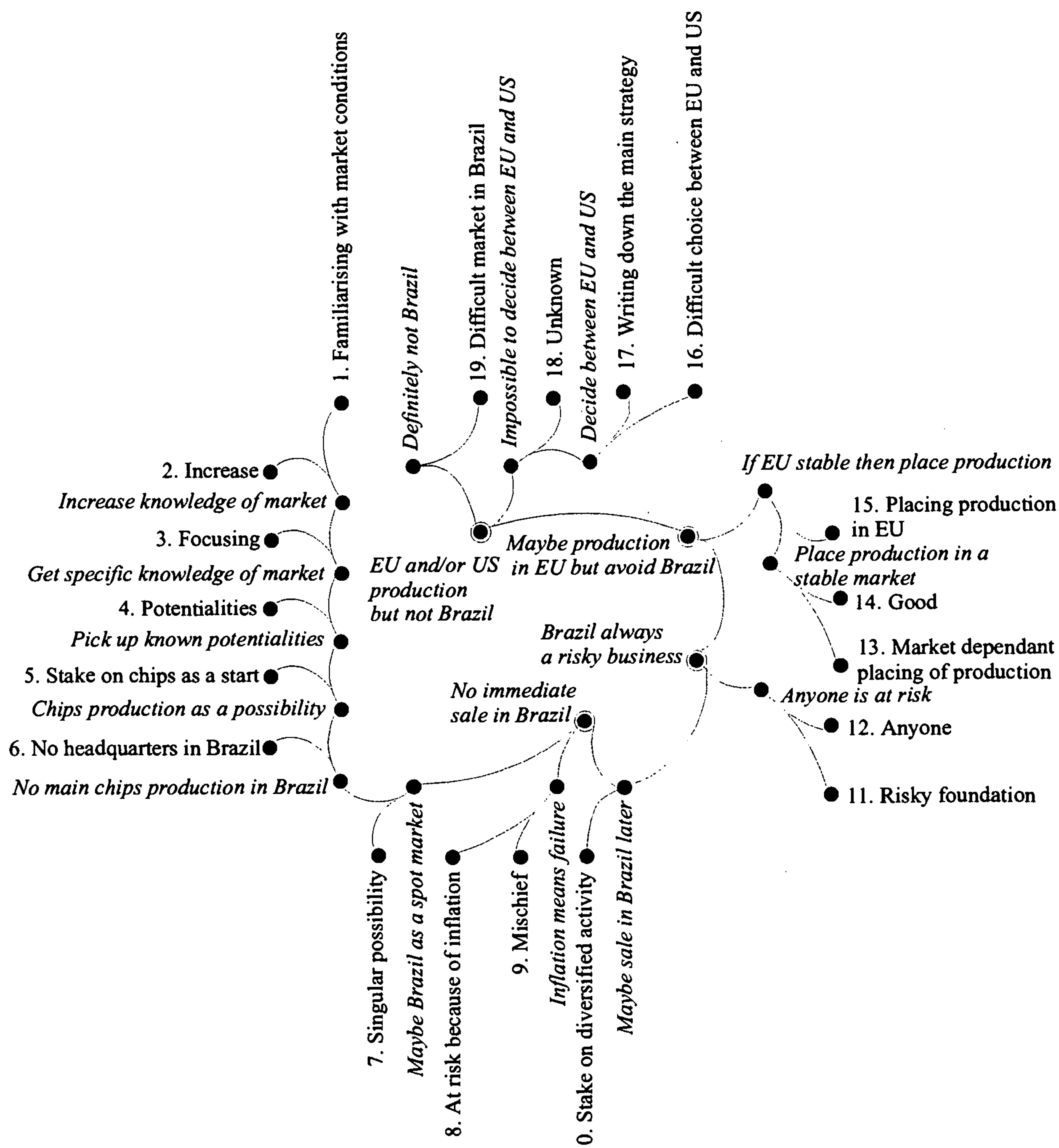
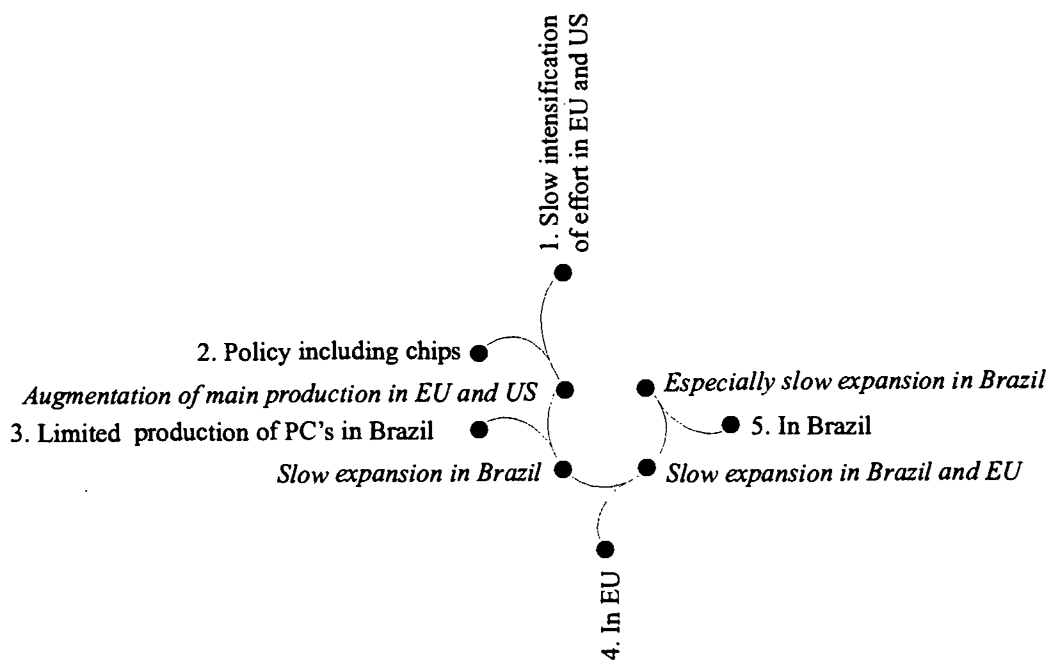


Figure 2.

The Holophor of 'Ground': Team One



The final 'figure'-state *'definitely not Brazil'* and the final 'ground'-state *'Especially slow expansion in Brazil'*, reveal that Brazil is perceived as a difficult market. This perception cannot come as a surprise, because in the manual Brazil is explicitly described as an unstable and risky market. However, the close relationship between data described by the transformation space and the notion of holophors suggests an interpretation of the holophors as the subjects' conscious expression of the environment defined by transformation-field, manuals etc., that is, the experimental set-up.

The team reaches the final 'figure'-state through a string of synthesis starting with the state '1. familiarising with market conditions'. This concept expresses a broad range of information dispersed along the entire four minutes. The concept merges with '2. Increase' and '3. focusing' into the synthesis *'increase knowledge of market'* and *'get specific knowledge of market'*. The argument for the synthesis is that 'increase' and 'focusing' change the more vague expression 'familiarising' into a more specific one. During the next two steps, the team turns towards the transformation *'chips production as a possibility'*. However, the possibility of chips production in general is changed by an assessment '6. no headquarters in Brazil' into *'no main chips production in Brazil'*, but by means of '7. singular possibility' the team states *'maybe Brazil as a spot market'*. Here the chain of synthesis stops for a while, and a new line of thought is introduced. The concepts of '8. at risk because of inflation' and '9. mischief' merge into the general thought *'inflation means failure'*. This is interesting, because within the set-up, inflation

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does not imply automatic failure. By means of existing ideas, the stream of data has been transformed into concepts that do not reflect the objective reality. Incidentally, the members of the team have only an every day conception of economics, and for a good many years, inflation has been on the political agenda as an expression of sheer evil. The above mentioned two lines of thought merges into *'no immediate sale in Brazil'*, however, the state ' 10. stake on diversified activity' gives the structure a twist in the direction of *'maybe sale in Brazil later'*. At this state of the course, the team has not entirely abandoned the idea of doing something in Brazil, but a new line of thought puts yet another question mark regarding Brazil: '10. risky foundation' and '12. anyone' merges into *'anyone at risk'*, which in turn changes the possibility of Brazil into *'Brazil always a risky business'*.

Again, a new line of thought emerges. This time it is a kind of implication: the placing of production must be market dependent (13.), and the market has to be good (14.), therefore *'place production in a stable market'*. There is the possibility of '15. placing production in EU', so *'if EU stable then place production'*. As a consequence, the state *'maybe production in EU but avoid Brazil"* emerges.

Now the team turns to the problem of deciding where the production must be placed. The two end-states '16. difficult choice between EU and US' and '17. writing down the main strategy' point to the self imposed requirement to *'decide between EU and US'*; but because there is no criterion by which a decision can be made, denoted by '18. unknown', the state *'impossible to decide between EU and US'* emerges. EU and US are distinct possibilities, but no decision is made. However, the team is sure that Brazil is no good: 'EU and/or US production, but not Brazil'. This decision is further supported by '19. difficult market in Brazil' which means that the team draws the final decision *'definitely not Brazil'*, that is, the team has made a negative choice.

The reasons for this negative decision are revealed in the 'ground' holophor, although it seems that the ideas in this holophor are more positive concerning Brazil than those of the figure holophor. The final state of the ground holophor says *'Slow expansion in Brazil'*, although this is not entirely in accordance with *'definitely not Brazil'*, a pointer in the same direction. This could indicate that Brazil is out for now, but not entirely devoid of interest. Actually, the team never initiated production in Brazil, but they used Brazil as a spot market for out-dated PCs. Thus, they stuck to the decisions made within the first 4 minutes of the simulation. It is also puzzling that the team seems to agree on 'cautiousness in Brazil and EU'. If it makes sense that they think they have to be cautious concerning EU, why, then, is it difficult to decide between EU and US, as shown in the figure holophor? The reason could be that the ground does not point to whether or not EU and US have to be chosen, but to the order in which production should be initiated. In the end, the team started production in EU and US. In order to make out why, it is necessary to analyse the steps taken after this first decision.

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