11

Process Design, Workflow Development, and Knowledge and Information Transfer

F.M. Lillehagen, J. Høyte, D. Karlsen and R. Hysom
NCR ED&D Solutions
NCR Norge AS, Postbox 1085 Bekkajordet, 3194 Horten, Norway
Phone: +47 3304 6900, fax: +47 3304 2297, email: fli@metis.no

Abstract

This paper describes a new scientific and industrially proven approach to process design, workflow development and deployment and knowledge, information and IT solutions transfer. The new approach is made possible by process oriented methods and thinking, the development of Active Knowledge Models, the rapidly growing availability of workflow methods and tools on the world-wide web(www) and recent advances in collaborative networking.

The paper introduces and defines the four structural flows of process, a classification of process hierarchies with characteristic properties, their common Flow Logic, how the Flow Logic is the multi-dimensional net (neural net) for Active Knowledge Models, how processes are mutually descriptive (reflective knowledge) and finally how process design, workflow development and enactment can be achieved and implemented using a holistic approach.

Keywords

Process design, instrumentation, re-engineering, simulation, workflow capture, development, enactment, information management, Active Knowledge Models, knowledge representation, communication, holistic enterprise modeling.

1 INTRODUCTION

The authors advocate a number of important scientific discoveries[1] that is having great impact on existing enterprise challenges[2] and the prevailing approaches in trying to tackle them. The discoveries and the methods and rules developed are summarized in a technology we call Active Knowledge Models (AKM)[3].

The natural and man-made world is both process and object oriented. Object orientation is well understood and many disciplines are exploiting the manifested methods and rules. The IT and systems industry is in a transition and is still struggling with concepts like complex inheritance, alternatives or variants and the handling of multiple valuesets. Complex inheritance is powerful, but it often contradicts and even prohibits the capture of evolution and change

Process orientation has only recently attracted attention. Process knowledge and descriptions must cover many technical, human and social disciplines and is an infinitely huge area of practise and research. Process descriptions define temporal and other relationships that support capture and management of evolution and change, and if integrated with object oriented structures in an Active Knowledge Model process descriptions can give support to complete solutions to many of

G. Doumeingts et al. (eds.), *Modelling Techniques for Business Process Re-engineering and Benchmarking*

the present challenges.

Process orientation is characterized by freedom in variation of flow descriptions and the mutual dependencies and descriptiveness of process flows, workflows and context. Processes are reflective in that they provide mutually descriptive and operational data. One process may have many workflows depending on instrumentation, competencies and the context of enactment. A process is driven by subjective values.

The world can be described in interdependent decomposition, specialization, concretization and concept/view hierarchies[4]. These interdependent process hierarchies are the basis for most of our structured enterprise knowledge of product, workflow, organization and system, and support the development of methods and views of how most enterprise aspects are object-oriented and interdependent. Knowledge, information and solutions transfer is a matter of somehow replicating or repeating parts of or whole process hierarchies with supporting aspects.

2 A HOLISTIC APPROACH

Process design, as the design of any enterprise aspect or view, should only be attempted when using a holistic Active Knowledge Model approach to model the enterprise. Most properties and critical flow parameters can only be defined in or deployed on the process hierarchy. The process hierarchy supports methods for property interpretation, qualification, discrimination and parameter definition. Whereas the methods to calculate, aggregate, propagate, transfer and manage parameters and value-sets are mostly performed on the aspects of product, workflow, organization and system. Aspects are structural variants and views of meta-models needed to create, calculate, test, simulate and manage value-sets.

Process design and re-engineering depend on our knowledge of the four flows of any process, and to what extent we are able to separately describe, calculate, synchronize and automate these flows. One and the same process may have many different workflows (physical implementations) depending on availability of competencies, resources and supporting technologies. Capturing observable workflows alone will therefore seldom provide us with adequate knowledge and consistent descriptive information about any process.

2.1 Definition of Active Knowledge Models

Active Knowledge Models describe an activity or enterprise in many interrelated knowledge dimensions through aspects and views.

Activity or process detailing, simultaneous decomposition, specialization and concretization, yields the dependencies and establishes relationships between and among the flow logic and other enterprise aspects.

Enterprise aspects of product, process, organization and system, interrelated by the flow logic, represents a holistic description of the enterprise that can handle alternative structures, cascaded methods and parameters and multiple valuesets. An example of a simple knowledge model of an enterprise (enterprise model) is shown in Figure 1 on page 3.

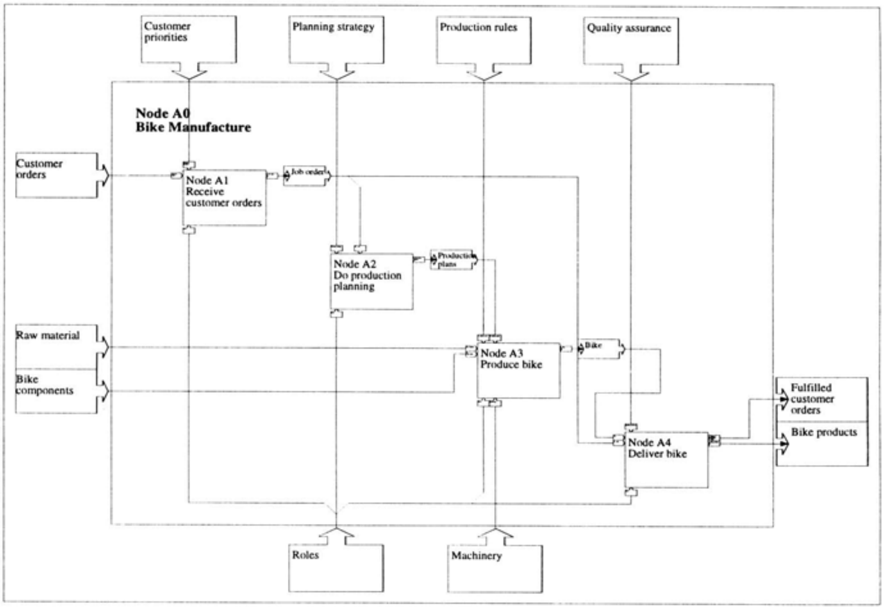

Figure 1 A holistic view of a simple knowledge model of an enterprise. The flow logic integrates the other aspects.

2.2 Terminology and definitions

AKM's combine process and object oriented methods in reflective, self-adaptive and self-managing models and IT solutions. Terminology and ontology used throughout the papers are:

- ***Detailing*** implies any blend of decomposition, specialization and concretization.
- An ***Object*** is multiple types and instances at the same time. Actually in process oriented thinking we should rather talk of descriptive and operational data.
- An ***Aspect*** is a specific projection (representation) of enterprise knowledge (structures) created to support a specific method or need.
- A ***Process*** has four flows with multi-level flow descriptions that may be repeated in the process hierarchy. Processes are reflective and can have many workflows.
- An ***Active Knowledge Model*** of an enterprise has at least one process hierarchy in it, to capture the Flow Logic of the model, and can have multiple aspects of product, workflow, organization and system all depending on the purpose of the model.
- The ***Flow Logic*** is the connectivity net created when designing the process hierarchy with the four flows of each process.
- ***Holistic Approach*** means collecting knowledge in reflective aspects of product, workflow, organization and system and interrelating the aspects directly or via the flow logic.
- ***Reflection*** means that the execution of one process leaves operational data that describe creation and development of another process and result. Process operational data can thus document evolution and change.

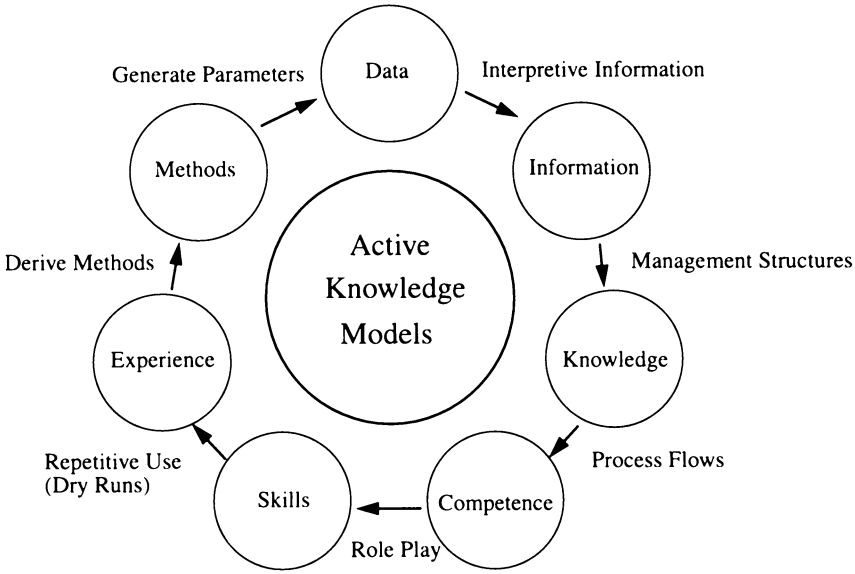

Figure 2 Active knowledge model based human learning in seven steps from data to information to knowledge and finally to new or improved methods and data. This model-supported learning process is a reflective model. It integrates the three models of Piaget and complies with modern learning theory.

2.3 Aims and experiences

One of our aims is to be able to develop high quality processes and highly effective workflows using active knowledge models to design the processes, to simulate and deploy workflows, to support human co-participative learning and training, to generate the enacting software and to tune the allocated resources.

The quality and effectiveness of a process can be measured as the ability of the process team:

- to realize products meeting customer requirements and expectations, and adding value to the business processes of the partners.
- to do things right all the time, engaging all available team insight, knowledge and competencies and skills, avoiding undesirable changes but accommodating late customer changes.
- to balance quality, risks, costs, resources and human factors, minimizing environmental waste and distortion, maximizing human learning and promoting collaborative cultures.

The industrial needs for process design and re-engineering knowledge and capabilities are great and imminent. Todays industrial processes, such as:-strategies, business operations, product realization, life-cycle support and others are ad-hoc processes. There is a lack of scientific principles and guidelines available that can help us gain more insight, grow our understanding of, or improve on our implementation of processes as best-practise workflows.

Single process methodologies and applications, such as BPR, CE and WS, are dominating the scene, but none of them are founded on scientific principles and few contain substance worth teaching. The methodologies and their supporting tools are mostly based on workflow capture and engineering diagramming methods and tools, and traditional development and use of IT systems. There is a need for a holistic approach that supports all these methodologies and that takes advantage of the relations between processes and operational aspects and the reflective nature of processes.

3 SCIENTIFIC DISCOVERIES

Some enterprise process design discoveries are briefly described and explained. The significance of discoveries and their implications are also discussed. A more complete and comprehensive description and discussion will be provided in [1].

1. The world is process- and object- oriented. Our knowledge of it is incubated, assimilated and accommodated by observing and participating in process workflows, and the knowledge is represented and cultivated in decomposition, specialization and concretization hierarchies of processes and objects.
2. Any process has potentially many workflows. A workflow is the physical enactment of process that can be observed and recorded. Workflow has been or can be implemented using the available resources managed in the different enterprise aspects of product, workflow, organization and system.
3. Any process, information or material handling, has four flows. Each flow will, according to given rules, be repeated many times in the process hierarchies of the same enterprise and in process hierarchies across enterprises.
4. Process hierarchies are replicated and used for buying, borrowing, copying and managing knowledge and operational capabilities, workflow solutions, and competencies and skills.
5. Process hierarchies provide the Flow Logic (connectivity net) between the knowledge and the descriptive information in the different aspects (structural views) of product, workflow, organization and system.

3.1 Reflective processes

To illustrate how processes are reflective by producing mutually descriptive and operational data when executed on an example is considered.

The two processes are:

- A. How to improve product assembly.
- B. How to perform product assembly.

Both processes are focussed on the product assembly, but have different purposes. The description of A, its procedure and information flow, is directly influencing the execution of B. The procedure and information flows of A become synchronization and control flows of B.

The reverse is also true. This is a very important discovery, if we can model both processes as an active knowledge model then traceability and predictability is attainable. The only limitation is the available process knowledge.

3.2 Practical implications

Enterprises have still to master temporal relationships and time-dependencies as required to manage evolution and change of any time-dependent process. Present data-model based IT solutions will never be able to cope with this challenge. Active knowledge models combining process and object oriented capabilities as described can solve these problems to varying levels of automation.

Practical solutions to challenges, such as information life-cycle management, configuration control (variants and versions), and change management can now be accomplished.

The object oriented manifests should be reconsidered. In particular complex inheritance, overriding, handling of alternatives and multiple value-sets, and their definitions of class.

Systems development can be gradually automated and can eventually lead to self-documenting, self-adjusting and self-managed solutions. Process-orientation and active knowledge models could lead to model managed computing.

4 THE WORLD IS PROCESS AND OBJECT ORIENTED

The world is dependent on and driven by natural processes. You and I are dependent on and driven by personal, subjective processes. In between there are numerous processes on which we depend as groups and that are driven by common needs, ambitions and goals. They are society and enterprise processes, influenced by and influencing both natural and personal processes.

All objects are created, operated on and managed in processes. Being able to describe any object in order to represent its different life-cycle roles is the challenge to satisfy to achieve object consistency and life-cycle behavior.

What is the significance of inheritance? Is there something called complex inheritance, or should it be replaced by learning and technology transfer processes (support processes). Inheritance in software class hierarchies is important, but automatic, copying and involuted replications in and between process hierarchies are factors of magnitude more powerful and practical.

Most of our competencies and skills are learned by collaborating with others, where knowledge, competencies and skills are exchanged by many different mechanisms. Inheritance is still a useful mechanism, but let us keep it simple.

4.1 The 4 mechanisms of Problem Solving

The four mechanisms are intrinsic operators that are used to design both the most general and abstract as well as the special and concrete process flows.

The four mechanisms are methods used to design the process hierarchy, the flow logic, the simulation and enactment and the workflow representations of process. The mechanisms are process, object, relation, property and method description operators.

- De- and recomposing, means splitting or joining items.
- Specialization and generalization, means adding or subtracting properties.
- Concretization and abstraction, means using names, symbols and multimedia representations that are correct for context and knowledge content.
- Projection and holistic views, means hiding or showing inter-aspect relationships, selecting or agglomerating methods and viewing details.

4.2 Industrial classes

Industry sectors, in particular mechanical industry, has used classes of knowledge for decades. Examples of object classes are product protocols, tools registers and document archives. Examples of process classes are group technology, and process planning schemes.

What distinguishes industrial classes from the class definition in object oriented manifests are the practical use of a class. To industry a class is a specialization hierarchy, a family description, guaranteeing exchangeability and reuse. A class has order and rank as defined by the methods governing the design and use of the class. Decomposing any object in a class means splitting the class.

4.3 Process Knowledge Management

Process knowledge exists in the heads of competent people and as formal documentation of instructions, procedures, control routines, system and tool handbooks and job descriptions. This knowledge must be captured, correlated, expanded and grown in a sharable knowledge and information memory using a visual, reflective design and manipulation enviromnment[5]. This would enable us to predict, control and measure workflows before deploying the resources and the enabling software.

Development and use of active knowledge models will provide agile, global enterprises with the understanding, the knowledge, the competencies and skills, the memory and the capabilities to achieve all this and much more.

5 THE PROCESS HIERARCHIES

The enterprises of the world can be described in and represented by one or more process hierarchies. This is acknowledged by more and more scientists and knowledge and information workers [2].

In an enterprise there are many process-hierarchies, each with possibly many variants, depending on the enterprise needs to characterize, categories and classify knowledge. Each hierarchy has a specific purpose, with clear objectives, goals and methods. Most industries have three distinct process hierarchies: business or value-chain, knowledge and information management, and innovation and change. The most important process hierarchy in any enterprise is the business process hierarchy.

The purpose of characterizing, categorizing and classifying processes in hierarchies results in many interrelated sub-hierarchies. The business process hierarchy (the value-chain) provides the Flow Logic for an enterprise model.

5.1 The flow logic

The flow logic of the business process hierarchy of an enterprise has many important functions in an enterprise model:

- It is the knowledge network, representing the names and identities of all object and relationship types found in the aspects
- It represents and connects all the knowledge dependencies and the aspect descriptive information (types) of an enterprise model.
- It helps us avoid undesired types and inconsistent descriptions.
- It helps us develop new methods to interpret and deploy literate properties, such as requirements, wants and experiences.
- It helps us copy, transfer, manage and reuse models.

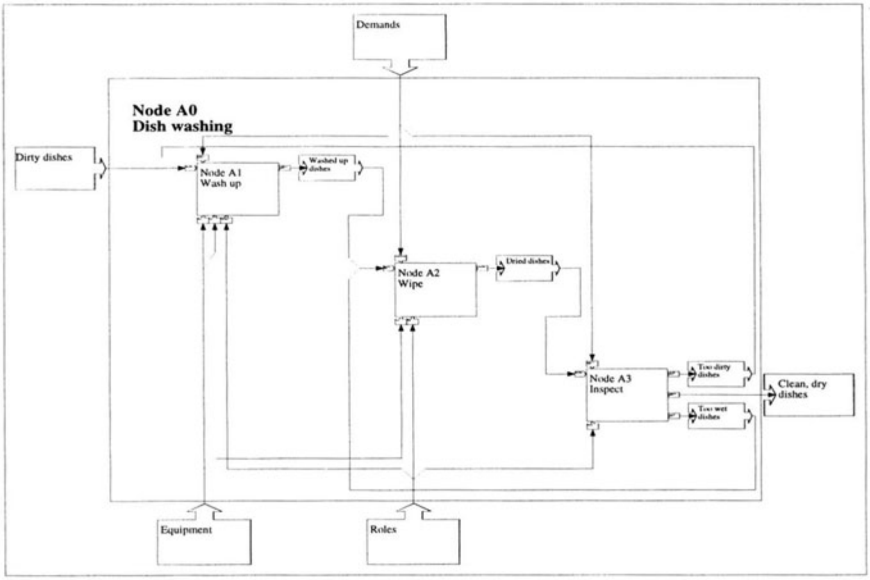

Figure 3 The flow logic is described using a language similar in notation to IDEF0, but fully implementing decomposition, specialization and concretization of activities and ICOMs (Inputs, Controls, Outputs and Mechanisms).

To understand how properties, expressed in natural language (literate knowledge), are detailed and deployed using the Flow Logic, and calculated and measured using multiple aspect structures simultaneously, we need to develop a coherent, consistent and holistic knowledge model.

The methods required or used to interpret and translate literate knowledge, through levels of flow descriptions, until flow parameters are definable and measurable in aspect structures are presently not known in industry and must be developed. This is not possible without designing the Flow Logic of the enterprise as part of an Active Knowledge Model of the enterprise.

5.2 The 4 Flows of Process

Describing processes implies being able to separate any process into four distinct flows. There are many reasons for this. The most important being that of process knowledge representation.

The four flows are:

- Ingredient / Result Flow, describing the detailing of material and information required to produce (to be transformed into) a descriptive detailing of results, denoted IR-flow below.
- Procedure / Operation Flow, describing the detailing of procedures into activities, tasks jobs and operations, denoted PO-flows below.
- Control / Mechanisms Flow, describing the detailing of information and resources needed to perform the methods flows, denoted CM-flows below.
- Synchronization / Coordination Flow, describing the detailing of rendezvous required to

merge and implement the three other flows into workflows, denoted SC-flows below.

The three first flows are all resources input and output from the process. Synchronization flows are internal to the given process milestones, decision-points, choices and events depending on which flows and flow parameters to compare and possibly adjust.

The rules of process flow replication in the process hierarchy are being investigated. This is how far we have come:

Suppose P is an ordered set of processes, e.g. a process hierarchy, containing processes A; B, C etc., and if, process A has IR-flow: "A.IR", PO-flow: "A.PO", CM-flow: "A.CM", and finally SC-flow: "A.SC", and similarly for processes B, C, etc., then the hypothesis is that the flows are replicated in process hierarchies obeying these rules and possibly others still to be discovered:

1. An IR-flow can be a CM-flow for processes at a lower level of the hierarchy."One man's floor is other men's roof", says the consultants.
2. Inversely a CM-flow can be IR-flows at a level lower.
3. A PO-flow can be SC-flows at lower levels of the hierarchy
4. Inversely an SC- flow can become PO-flows at lower levels.

Rules 1 and 2 are controlling what the process needs in terms of information, knowledge and materials.

Rules 3 and 4 are controlling how the process performs in terms of methods and operations. This is the basis for the reflective behavior.

Developing and formalizing these rules is extremely important. It will help us develop methods to transfer, reuse and manage models.

This repeatable behavior of flows is particularly useful for model designers and designers of model-based solutions and for reuse of IT solutions, methods and software.

5.3 Simulation and Enactment

To support simulation and enactment a process description must support:

- Recursion - repeating execution of flows.
- Cycles - allowing and handling feedback loops.
- Involution - propagating change throughout levels of process description.
- Flow control - allowing parallelism, diversion and synchronization of all flows.
- Alternative flows must be supported.
- Multiple value-sets must be handled.
- Multiple, cascaded parameters should be supported.

Project and work planning processes typically have a need to handle time, cost, due-date and risk parameters as-planned, as-reported, actual, as-calculated and as-contracted.

5.4 The integrating Process Template

At the meta-model level it has been possible to develop a common method for representing all meta-models needed for the different knowledge levels of industrial processes, please see Figure 4 on page 10.

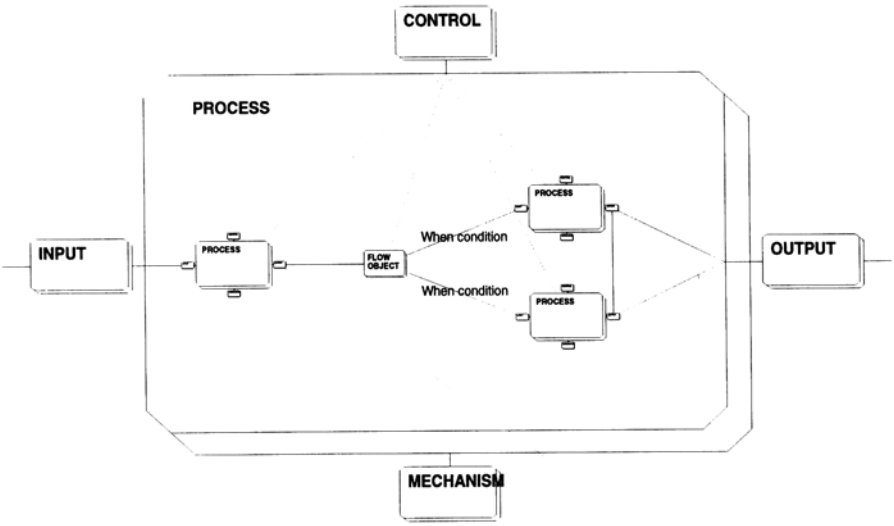

Figure 4 The template (meta-model) above can be modified to develop all desirable process meta-models and applications.

In METIS GEM [7] this template is the basis for the meta-models of the flow logic, workflow capture and deployment and process instrumentation, simulation, enactment and eventually the development of methods for automation.

6 THE INDUSTRIAL PROCESS DESIGN PROCESS

There is presently no known scientific approach to process design. To the knowledge of the authors, this is the first attempt published.

A holistic methodology model is being developed for commercialization later this Spring. It will provide all details of the approach, the methodology and the software tools required.

6.1 Process Methodology Activities

The following numbered activities should not be understood as a sequential procedure, but rather as activities in the enterprise model building process. The process flows are decided by the availability of the knowledge (methods) and the information needed in each step.

The activities are represented as interrelated processes in the flow logic of the methodology model.

1. Capture workflow
   There are many techniques for observing and capturing workflow: -a sequence of pictures with literate descriptions, film or video and functional flow diagrams. The METIS GEM language

has capabilities to support some of the ones mentioned and required. If there are no workflows to capture then start with the process hierarchy, activity 3.

2. Synthesize workflows
   Analyze workflows for consistency and correctness as input to designing the process hierarchy. Workshops may be required to complement the descriptive information gathered. GEM supports multiple workflows of the same process
3. Build the business process hierarchy
   Decompose, specialize, concretize and relate flows to aspects to collect supplementary information and knowledge on how to get the most consistent and correct flow logic.
   Identifying repeated flows is a major task. GEM provides the Flow Logic language for creating the process hierarchy.
4. Develop and connect aspects
   Product, workflow, organization and system aspects are developed to the right level of detail and connected to the correct levels of the Flow Logic. Flow parameters and value-sets may be made accessible for analysis or simulations.
5. Define flow parameters
   Discrete parameter definition (copying from aspect structures), interpret and deploy literate expressions and propagate and aggregate measured manufacturing, assembly and operating parameters. GEM will get new capabilities shortly.
6. Measure flow parameters
   Methods to calculate and provide parameters and value-sets are developed and connected to the flow logic and the aspects
7. Simulate and analyses flows
   Flows are calculated, simulated and analyzed. Methods and flow logic may be varied to give different value-sets for evaluation.
8. Repeat from activity 4
   Cycle from activity 4, changing aspects such as workflows, to gain insight and develop new knowledge. This is doing what we call dry-runs on the model.
9. Find best-fit flows
   Alternative but acceptable aspects and flows are simulated, verified and visualized using graphic techniques, such as Valuemetric charts.
10. Develop improved workflow
   The workflow enactment technology is chosen and workflow instrumentation methods are selected.
11. Generate and deploy solutions
   The resources are described and deployed, and the affected aspects are updated with descriptive information. Cycles from activity 9 will be performed to find best -fit resources and best-fit solution.
12. Describe workflow enactment system
   This aspect may be further detailed to allow for automatic software and user dialogue generation.
13. Generate supporting software
   The software required to enact the workflow may be partly or wholly automatically generated.
14. Tune user interfaces
   The user interfaces of the enactment platform needs to be tuned to the individual users.

6.2 Industrial achievements

Many industries are developing active knowledge models mostly for learning, understanding and knowledge sharing. Some industries has modeled enterprise processes to a level of detail where workflows can and have been enacted. One company performed model managed roleplay of the bidding process, another of the engineering change process and a third of the product delivery process. Some objectives and goals were common:

- By roleplay and simulation there are no more one-of-a-kind processes. Industry can dry-run any process varying flows and values to find the best-fit solution.
- By model-managed workflow planning, operation and monitoring work can become reflective processes.
- Competence and skill structures can be developed and integrated with positions, roles and people to enhance most human aspects.

6.3 Process automation

Developing and using active knowledge models that exploits process oriented thinking and process reflection can lead to the development of methods that automatically improve both descriptions and operations. Self-managed, flexibly adaptive processes and IT-solutions can be achieved.

7 FURTHER RESEARCH AND DEVELOPMENT

This technology and the enterprise modeling approach developed is still in its infancy. We are in a paradigm shift from information to knowledge and competence and skill technologies, see Figure 2 on page 4 for the model based learning process.

Active knowledge models are not about artificial intelligence, virtual reality, fuzzy logic and playing games. It is mostly about real intelligence, real and virtual concepts, flow logic and roleplay for human experimentation and learning. Vast new fields of research in all established sciences open up. Scientists and experts from diverse disciplines can now contribute their methods to shareable knowledge models avoiding natural language contingencies.

Sosio-technological aspects as well as cultural and political issues must be put on the agenda. There are many hurdles still to pass. Through world-wide collaborative partnering we will succeed.

REFERENCES

1. Frank Lillehagen: "10 scientific discoveries and their implications", a series of overheads to be published as articles in 1996.
2. IMS and the Globeman project descriptions, documents available from the authors.
3. Frank Lillehagen, NCR ED&D Solutions: "AKMs of Enterprises", paper to be published in 1996.
4. Thomas Malone, MIT: "The Process Handbook", confidential information delivered to main author, June, 1994.
5. Ron R. Hysom, NCR ED&D Solutions: "Agile Enterprise Technology", private communications since June 1994.
6. Olav Aasebø, A holistic approach to product modeling, thesis at the University of Trondheim, December 1995.
7. Jarle Høyte and Dag Karlsen, METIS product development and documentation.

BIOGRAPHY

Frank Lillehagen is a born Norwegian, but received his Bachelor degree from the University of Strathclyde, Glasgow, and his Masters degree in Computer Graphics from the University of Utah, 1973.

Mr. Lillehagen was an international authority and consultant on computer aided design and a member of IFIP WG5.2 during the 70's and has filled most project roles in the development of several commercial systems. He has published over 50 papers and has coauthored three books.

In 1979 he was a cofounder of ICAN, a design workstation manufacturer in Norway. He left ICAN in 1985 and founded METIS to pursue some of the challenges and visions developed with international society colleagues during the early 80'ies. For the last 10 years his energy has gone into making METIS a success and realizing those visions. METIS was acquired by AT&T in 1994 and is now part of the new NCR.