MISA: A knowledge-based method for the engineering of learning systems

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MISA, A Knowledge-based Method for the Engineering of Learning Systems

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Abstract- *MISA, the learning systems engineering method presented here, aims to apply cognitive science principles to the field of instructional design. It is represented by a model that describes its processes, its products and its principles in a structured and graphical way. Its purpose is to produce a learning system that is characterized by three models : a knowledge model defining the objects to be learned; a pedagogical model that specifies a process model for learning and training scenarios ; a media model that defines learning materials, tools and technological infrastructures that support learning. MISA is particularly well suited to the design of technology-based telelearning and self-training environments but is however intended for designing any general learning environments. It results from a five-year effort that produced the first version of the method as a computerized workshop. The method was thereafter validated with instructional designers and content experts in nine organizations and was rebuilt according to results and observations gathered during the validations.*

1- INTRODUCTION : ORIGIN OF THE METHOD AND THE SUPPORT SYSTEM

In spite of the growing importance of training needs, an large number of experts agree it is difficult to find on the market a method and commercial task support tool capable of supporting rapid program and course development and, at the same time, ensure a product quality that will be propitious to skills development in the target audience. Gerry (1991) points out that " *traditional ID practices are too slow and costly for many situations, electronic performance support systems (EPSS) must be developed* ". On the other hand, Gustafson (1993) states that " *while there have been moderate additions to the tool set and some changing of perspective from a behaviorist to a cognitive psychological orientation, to date they do not represent a fundamental change in the tool set* ". He adds : "*ID methodology is just incomplete and inadequate for facing many of the challenges of the next decade and the coming millennium* ".

Tools And Methods For Learning Systems Design

- At the moment, the market offers four main categories of computerized tools intended for pedagogical design : 1) authoring systems ; 2) Instructional design support tools; 3) pedagogical design expert systems ; 4) specialized instructional design job aids. Each one offers only partial solutions to pedagogical design support.
- Authoring systems support the production of educational software but they are not of much help in the design of large and diversified learning systems such as a learning program made up of several courses composed of different kinds of learning material, integrating several media and training methods. They do not embed enough pedagogical knowledge to ensure consistency through the more complex design tasks.

- Instructional Design support tools support task analysis and design processes by providing forms, tables, input screens. Most of them use a traditional and procedure-oriented design approach and contain little strategic design expertise.

- Expert systems aim to replace in part the designer by automating the design process. Some existing prototypes can be useful for the rapid prototyping of small-scale courseware applications related to strongly structured fields. However, they cannot help solve general and complex pedagogical design problems. Moreover, these systems are " black boxes ", their pedagogical content cannot be examined by the designer to help improve his ID knowledge and practice.

- Specialized design tools, for learning objective specification or task analysis, make it possible to realize one or several specific tasks without addressing the global process. Non-integration of these tools makes it difficult, if not impossible, to maintain consistency between design decisions. Moreover, data transfer from one tool to another often causes errors and a loss of productivity.

MISA, the learning system engineering method presented in this document, proposes an integrated solution to these problems. It is the result of an effort that started in December 1992. A first version [Aubin et al, 1995b] was produced while concurrently developing the AGD workshop, a computerized didactic engineering set of tools [Paquette et al, 1994a, b]. This workshop is different from other computerized design support systems [Lecavalier, 1991 ; Gustafson et al., 1993 ; Merrill, 1994 ; Spector et al., 1993) notably because it integrates operational principles to pedagogical design through an intelligent advisor system [Paquette and Girard, 1996]. In 1995, AGD and its underlying method were tested in nine organizations and firms [Aubin et al, 1995a]. The current version was completed in April 1997 and validated by six teams at Télé-université.

1.2 Method And Didactic Engineering Workshop (AGD) Development

The AGD project (didactic engineering workshop) started in November 1992. Developing such a system brought us to rethink the pedagogical design methodology on new grounds, in order to :

1. Improve the quality of learning systems and ensure the consistency between design decisions pertaining to content, learning needs, pedagogical strategies, learning scenarios as well as pedagogical materials.

2. Extend the spectrum of strategies, tactics and media used by designers in learning systems.

3. Facilitate maintenance and reusability of a learning system's components.

4. Reduce analysis and design time, efforts and costs.

5. Contribute to the pedagogical training of content experts involved in training.

The project's first phase was realized within a partnership between our research center and the DMR group, in collaboration with CRIM and Laboratoire Héron (U de Montréal). It resulted in the first computerized didactic engineering workshop and the first version of the method.

The AGD workshop contains productivity tools, an advisor system and contextual help for designing learning systems :

- Productivity tools aim to reduce tasks-related efforts and costs, while maintaining consistency between the various learning system's components by indexing them with a graphical knowledge model describing knowledge types and links between knowledge units.

- The advisor system guides the user in his decisions along the design process

- The contextual help provides the user with a definition of all the main terms and concepts used within the method as well as a description of the main operations.

Productivity is enhanced by the fact that information is entered once and only once, all tools adjusting themselves automatically. This prevents errors and facilitates consistency. At the end of the process, AGD automatically generates a global or specific report that will serve as an integrated blueprint, useful to the different teams who will produce pedagogical materials.

1.3 AGD System And Method Validation

A first version of the workshop and the method was completed in December 1994. In 1995, a second project was undertaken so that Télé-université's and industrial designers could validate the system and the method. The various training sectors covered were :

1. Workplace training of people enrolled at Télé-université and at Eduplus-Tecsult Inc., Canada's most important firm in the field of training systems.
2. Training to Medivision, SIDOCI's medical care plan software, in a hospital environment.
3. Financial training at the Learning Institute, Bank of Montreal, in Toronto.
4. Training in the field of information technology, at Groupe DMR Inc., at Ericsson.
5. Training for the defense sector of the Canadian Government and at Armstrong Laboratory.

Due to the variety of projects, this experimentation enabled us to verify the method's and tools' efficiency in view of our initial objectives. Above all, validation results confirm the usefulness of a method that is centered on knowledge modeling.

- *Michael Spector, from Armstrong Laboratory (U.S. Air Force), a recognized expert in the field of computerized tools for instructional design, has used the system and gave the following assessment : " I was able to use AGD with minimal guidance and training and generate an initial course plan and analysis in three days(...) The ISD model implemented in AGD is recent, up-to-date, comprehensive and quite robust. AGD has broken new grounds by implementing a portion of Tennyson's ISD4 model and Duchatel's Design Critic. "*

Here are some comments from designers who used the system :

- *" AGD enabled the layout of the design framework in probably one-tenth the time our process usually requires and was also more thorough. " (D. Peach, Learning Institute, Bank of Montreal)*
- *" The system of linkages requires you to document each step, whereas a designer may keep the same thing in her/his head, believing it to be self-evident (...) "*

Moreover, most content experts who used AGD stated they were happy about the pedagogical knowledge gained while using the system. Pre-tests and post-tests results equally confirm the considerable progress accomplished regarding didactic engineering knowledge.

During the project, the knowledge modeling technique adapted for training demonstrated its usefulness and efficiency; an advisor system endowed with pedagogical expertise was successfully integrated and a noticeable time and costs reduction were reported.

Despite these positive validation results, several needs for improvement were identified and a second development effort was undertaken in January 1996.

AGD's central tool, MOT, the knowledge model graphic editor, was completely rebuilt. New graphic edition capabilities have been added. Multi-level modeling and multiple view on the model are now possible. OLE links with most software application adding important documentation capabilities, making it a learning tool, as well as a design instrument.

Concurrently, a new version of the MISA method was developed. It regroups activities and products from the didactic engineering process into five phases and four axes, which makes it possible to define a learning system's specifications and components. LICEF's research team, in collaboration with industry partners, is now involved in the production of a commercial version of AGD, called the integrated didactic engineering workshop (AGDI). Based on to the MISA method, and built around the MOT knowledge model editor, the other AGD tools will be rebuilt and new tools will be defined to facilitate, among other things, the planning and the cost analysis of a project, as well as bridges to rapid prototyping software.

2. INSTRUCTIONAL DESIGN, AN ENGINEERING VIEW

The MISA method aims to systematically describe overall processes, generally gathered under the expression of " pedagogical design " to facilitate design, production and implementation of learning systems. Figure 1 shows the area covered by MISA. Management/exploitation and distribution are not covered by the method.

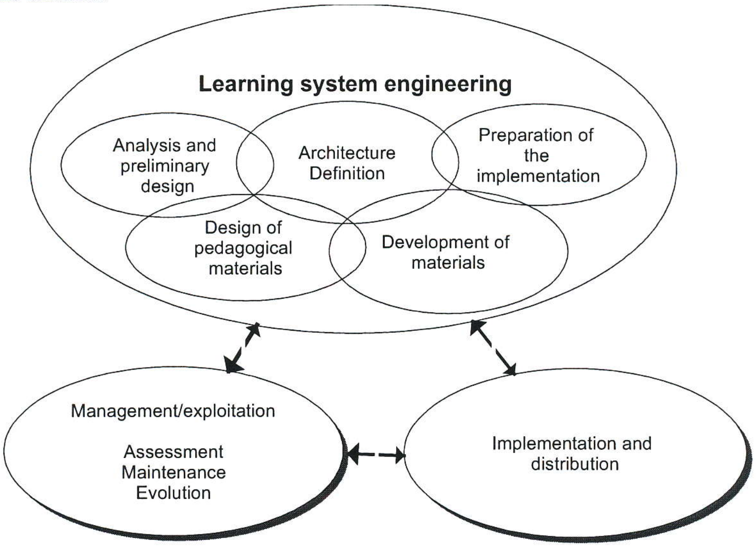

Figure 1 : Learning systems engineering scope

Instructional Design is complex in terms of human communication since many specialists contribute to the process: content experts, pedagogy specialists, media specialists and management specialists.

But first of all, it is a complex problem solving process as defined in cognitive sciences [Newell and Simon, 1972] and sometimes studied as such in the Education field [Romiszowski, 1981 ; Reigeluth, 1987 ; Tennyson, 1988 ; Merrill et al, 1992].

Instructional Design (ID) can be defined as a methodology that aims to resolve a particular class of problems: training and learning problems [Pirolli et al, 1988, 1990]. Instructional problems are problems first and next, they are design problems (similar to those in the field of architecture or mechanical engineering), then they are Instructional Design problems with their particularities and finally, they are Instructional design problems within one or several didactic disciplines. Our approach was based on a careful study of the first three of these four levels of problems, gaining a useful generic reference frame.

The MISA method presents the ID processes and tasks according to an engineering perspective. It is a complex process decomposed at several levels, into sub-processes. Each sub-process has its inputs and its products and at last, the whole process generates its final output, a learning system. The method also innovates by using cognitive modeling techniques to represent knowledge as well as pedagogical and media processing. These three aspects of a learning system (LS) are clearly differentiated but they also are interelated through specific associations making the engineering process visible and structured, to facilitate quality control of the processes and their products.

2.1 The Learning System Concept And Its Components

The learning system concept produced by MISA is quite comprehensive. It makes it possible to develop single learning events (course, module, activity) as well as to develop a complex network of learning events (program or curriculum composed of several courses). The methodological approach aims to take into account all types of academic, industrial or business training without prejudging the types of media support (print, audiovisual, multimedia, tutorial, teleconferencing, telematics, computerized advisor system) needed to facilitate learning, nor the tools or technological and organizational infrastructures necessary to use them.

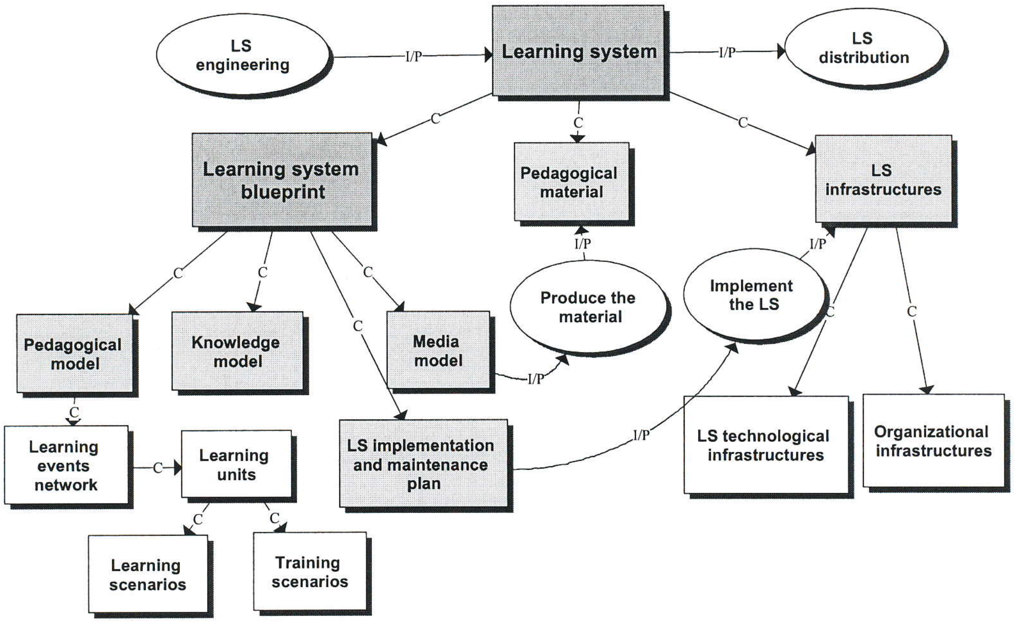

Figure 2 - Learning system concept

As shown on figure 2, a learning system is composed of : the learning system blueprint, the pedagogical materials developed according to the blueprint and the technological and organizational infrastructures that support it.

The blueprint of a learning system is itself composed of the following elements :

- A **knowledge model** represents graphically the learning system's contents.
-
- A **pedagogical model** represents graphically the network of learning events, and the learning units for which we define a learning scenario gathering learning activities and resources available to the learners, and a trainer's scenario to support the learning process.

- A **media model** defines how instruments are assembled into pedagogical materials on different types of support, outlining the structure of these materials : storyboard, metaphor, units and media elements, organizational and media rules, as well as technological tools and infrastructures that permit their use.

- Finally, the learning system **implementation and maintenance plan** allows us to plan the implementation of technological and organizational infrastructures needed to distribute the learning system.

Engineering Process And Sub-Processes

- To efficiently carry through the engineering process, phases or sub-processes are necessary and must be formalized in order to:

- Provide landmarks while following work advancement from the very beginning of the project until the implementation of the final product.

- Take adequate decisions in the management of the engineering process.

- Obtain more concrete material representations of the learning system as we progress from the design process towards the realization and preparation of the implementation.

Organizing the engineering process is important since it provides the different designers in the project with structured activities that allow them to coordinate their work to meet the learning system's objectives. Using an engineering method appears necessary to support sharing and common understanding. The learning system engineering approach presented here is based partly upon results from scientific studies of the pedagogical design process [1]. It also draws from methodological principles and information systems engineering practices, in order to benefit from their systematic approach.

As indicated on figure 3, MISA is a general process that is composed of sub-processes which are ruled by principles and generate outputs: the documentation elements.

The main task, " Engineer the learning system " is broken down (through composition (C) links) in two complementary ways : according to progress phases or axes.

- **Progress towards the LS** aims to advance the production of a learning system through 5 processes called phases : (1) carry out analysis and preliminary design ; (2) build the learning system architecture ; (3) design materials ; (4) Develop and validate materials ; (5) Prepare the learning system implementation.

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[1] About this subject, see the work of Goel and Pirolli.

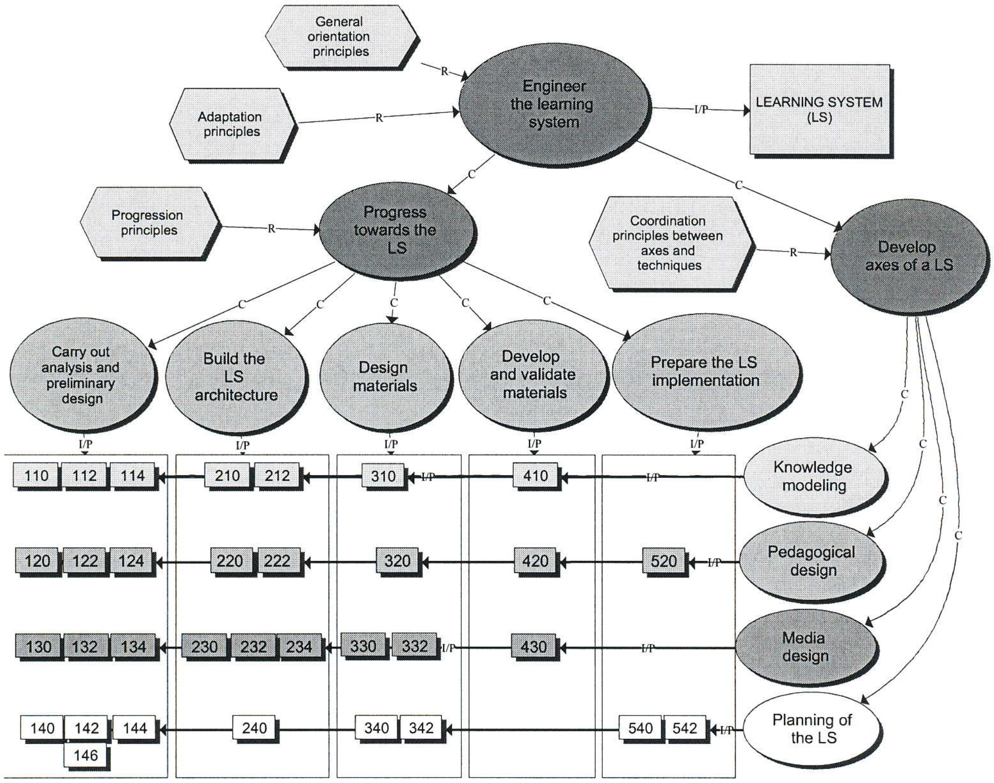


Figure 3 - Graphic presentation of MISA's main components

- **Develop axes of the LS** provides an orthogonal progression mode according to four dimensions : knowledge modeling, pedagogical design, media design and planning of the LS.

Globally, processes can be broken down into steps and activities that produce (by using I/P links) 33 documentation elements that are represented by rectangles (figure 3). Their distribution shows that the method is more focused on designing the blueprint of the learning system than on the development of the LS components. During production, other micro-design and development techniques will have to be used according to the type of pedagogical materials (print, audiovisual, tutorial, multimedia, etc.)

Moreover, as shown on figure 3, documentation elements are equally distributed among the four axes.

Four groups of principles rule the use of the method and will be discussed later on :

- ***General orientation principles*** specify theoretical approaches on which the method is based.

- ***Adaptation principles*** allow the selection of a path within the method according to the training problem and foreseen solutions.

- ***Progression principles*** allow the definition of how we proceed from one phase to another, notably the development cycles that target deliverables and is accomplished through spirals or iterations.

- *Coordination principles between axes* define interaction between the three main components of a learning system, the knowledge model, the pedagogical model and the media model as well as the coordination of these activities with the planning tasks.

3. DESCRIPTION OF THE ENGINEERING PROCESS

This section describes the method's engineering process, first in a procedural way. We then present the declarative aspect, that is the description of the documentation elements (data, schema, descriptions, etc.) that are transformed themselves as the process evolves to its final term.

3.1 Phase sub-processes, steps and activities

As shown in figure 3 the method includes five phases :

1. The analysis and preliminary design phase enables us to decide whether we should undertake the development of the learning system.
2. The architecture phase aims to answer all the functional and organizational questions regarding the learning system as a whole.
3. The pedagogical design of materials.
4. The development of pedagogical materials.
5. The implementation of a learning system.

As in software engineering, Phase 3 and 4 are repeated again for each new delivery segment. For instance, if a learning system is composed of 10 courses, a delivery segment might be one, two or three of these courses. Deliveries can be developed sequentially or in parallel.

All together, the five sub-processes of a phase are broken down into twenty steps, which in turn are broken down into 33 activities, each activity generating exactly one documentation element.

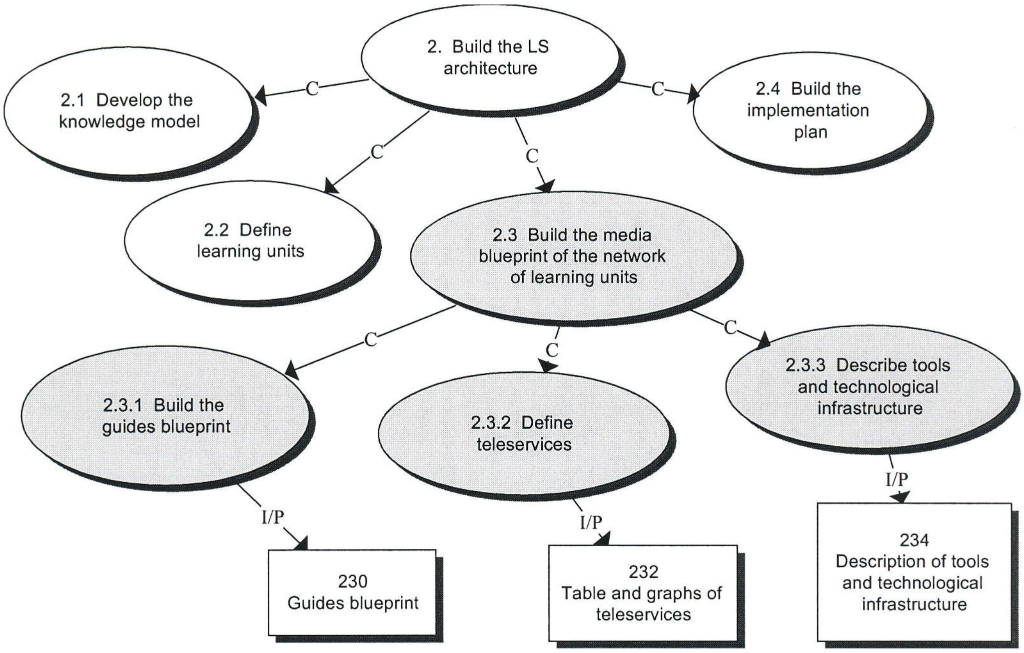


Figure 4 – Phase, steps, activities and documentation elements

As shown in figure 4, we get a three-level hierarchical structure. Here is a partial view that illustrates a part of the phase 2 process. Step 2.3 contains 3 activities, each one producing a documentation element : 230, 232 or 234. In the method, the complete operational description of the process also contains navigational principles (not show here) that clarify linkages and movements to and from various activities of the process.

Phase 1 - Analysis and preliminary design

The analysis and preliminary design is a phase grouping all the elements needed to decide if it is profitable to undertake the development of the learning system project. It is set in motion by a request to develop or improve a learning system, as it is already perceived as a relevant answer to the training problem or need. The documentation elements in this phase must define the learning system to be developed clearly enough to justify the choice of a media solution and subsequent development orientations.

Phase 2 - Learning system architecture

The architecture phase marks progress in defining the general operating mode of the learning system. It determines the pedagogical operating rules, organizational rules affecting the learning and training guides and rules that govern the learning system's tools and technological infrastructure. The architecture phase also marks a progression in developing the knowledge model and permits the matching of knowledge sub-models to learning units. The detailed architecture effort starts when the analysis and preliminary design report is approved. The purpose of its products is to have the general functioning of the learning system approved and to better communicate to development teams the rules that govern its operation and production.

Phase 3 - Design of the pedagogical materials

Designing pedagogical materials is a phase resulting in a detailed description of all pedagogical materials that are part of a learning system delivery segment. This phase starts following the approval of the architecture and delivery plan of the learning system. Its products enable the client to approve the description of all pedagogical materials as well as the tools and infrastructure that support them. The products generated in this phase also permits development and piloting teams to begin producing the materials.

Phase 4 - Development of the pedagogical materials

This phase is dedicated to the development, testing and revision of the learning materials comprised in a delivery segment of the learning system. It starts following the approval of the development plan of the pedagogical materials. Its products must permit the client to approve pedagogical materials following testing, and to prepare for the implementation of a delivery segment or a complete learning system. In a project where uncertainty is high, this phase may result in storyboard or an exploratory prototype for a small segment of the LS, before the complete LS is developed.

Phase 5 - Preparation to the learning system implementation

This phase in necessary to install tools and technological, as were as organizational infrastructures that will support the learning system and to prepare exploitation, evolution and maintenance of the learning system. This phase starts when delivered materials are validated. Its products must permit the client to move forward to the implementation either of one delivery segment of the learning system or the whole of the learning system. It also organizes the assessment and maintenance of the learning system.

3.2 Documentation Elements And Their Influence Links

The method's phases, steps and activities produce documentation elements that are the concrete products of the engineering process. We emphasize the definition of these products because it seems more important than the detailed description of the activities that are required to generate them. This approach also leaves more space to individuals, it stimulates their creativity as much as their participation and gives rise to better productivity.

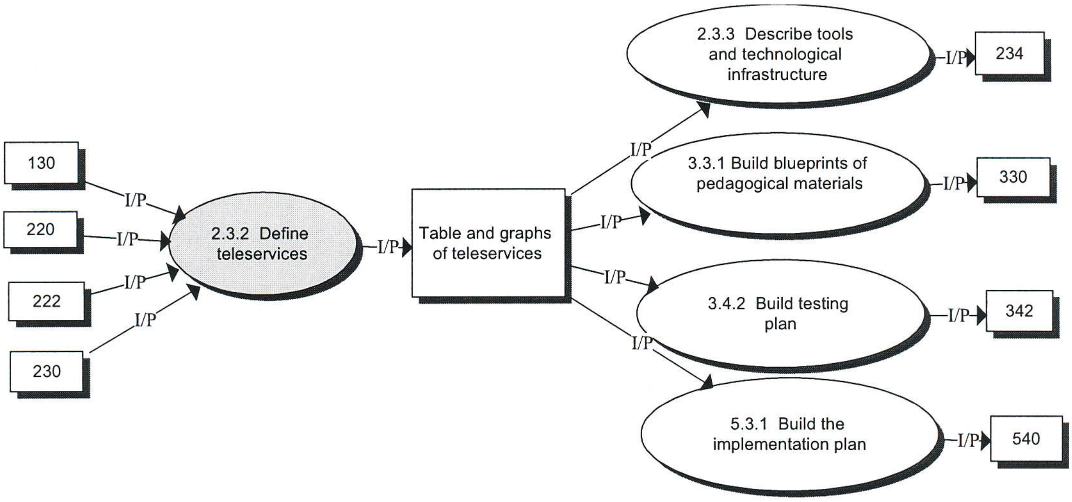
Whether they concern knowledge models, pedagogical blueprints, media blueprints or planning products, documentation elements produced in a phase are gathered within only one modular and polyvalent phase file. This gathering facilitates communication between architecture, development and piloting teams.

Some documentation elements are described as " evolutionary " when they are completed through the addition of details from a subsequent phase. They keep the same identification number but can be transferred from one phase file to another while being completed.

Documentation elements are composed of attributes and sub-attributes that designers must specify using graphs, tables, schema or text descriptions. Each documentation element is an activity's output and becomes an input to several other activities. This circulation of inputs and outputs captures the dynamics of the method and confers flexibility as well as rigor to the process.

The method's 33 documentation elements globally contain 310 attributes and sub-attributes that have mutual influence. These influence links have been analyzed and described explicitly so that the designer knows what attributes he must take into account and why.

Figure 5 is an example of the way each documentation element is described in the method. First a schema summarizes influence links (upstream and downstream) for the documentation element that is represented at the center. Here the table and graphs of the teleservices in a Learning System is described, produced by activity 2.3.2. The graph shows that the designer must complete documentation elements 130, 220, 222 and 230 sufficiently to be able to define tables and graphs of the teleservices. This definition is then used as an input to four activities and influences the corresponding documentation elements 234, 330, 342 and 540 that are generated respectively in phase 2, 3, 4 and 5. The name of the documentation elements are given below, and each is described in the same way.



SOURCE	
130	Media solution chosen
220	LS pedagogical working rules
222	Learning units (LU) pedagogical scenarios
230	Blueprints of the guides (learning and training)

➢➢➢➢➢➢➢➢➢

DESTINATION	
234	Description of tools and technological infrastructure of the LS
330	Blueprints of pedagogical materials
342	Experimentation and tests plan (pedagogical, contents, functional)
540	LS implementation plan

Figure 5: A documentation element and its influence links

3.3 Attributes of Documentation Element

The specification of the attributes of a Documentation Element can take many forms:

- Texts that summarize a situation, for instance the description of organizational constraints (144) or the learning system implementation plan (540)
- Choices to be made within a list of possibilities, for example types of tools and technological infrastructure (234) or types of media support (330)
- Tables, such a the table of learning needs (114) or a cost analysis (146)
- MOT graphs, such as the initial knowledge model (112), pedagogical scenarios (222) or the blueprint of pedagogical materials (330).

Most of the time, the documentation element is subdivided into attributes and includes descriptions that gather more than one of these forms. Documentation element 232 attributes are shown on figure 6.

Table and graphs of teleservices 232

Evolutionary

Goal

Teleservices documentation shown as table and graph will permit :

- to complete the definition of tools and infrastructure required by the learning system.
- to guide pedagogical decisions regarding the blueprint of materials.
- to prepare for tests and learning system implementation.

Description

A. Build the graph of generic tasks for the use of each teleservice
A1 Identification and name of the teleservice (frequently ask questions, teleconferencing,…..)
A2 Graph of the teleservice users tasks, links between these tasks, user identification, inputs and products generated by these tasks
A3 Instruments and/or instructions that are the inputs to the teleservice

B. Build the table of teleservices
B1 Identification and name of each teleservice in the LS
B2 Learning units that uses the corresponding teleservice
B3 Users of teleservice and type of interaction between senders and receivers
B4 Transmission channel (modem, ISDN, ATM, cable distribution, etc.) taking into consideration the volume of information to be transmitted and the desired interaction between users
B5 Tools (software and hardware) required for communication and file transfer
B6 Type of communication : synchronous or asynchronous; duration; periodicity

Figure 6. Documentation element's attributes

The method also supports the designers' task by providing indications, hints and examples gathered into three techniques. In this particular case, information can be found in the section that concerns the media modeling technique.

4. MISA'S MODELING AXES AND TECHNIQUES

The method covers four axes, each one corresponding to one major product of the learning system's blueprint. Knowledge modeling allows the definition and organization of the content; pedagogical design concerns the activities and resources necessary to make learning efficient ; media design brings the learning system to reality by making it available to the learner through pedagogical materials and tools, while planning aims to describe the execution of the design, development and delivery processes.

The knowledge model represents the axis that gives the learning system its stability. The learning and training process as well as the supporting media may be modified without changing the knowledge model structure. This approach makes it possible to update the pedagogical strategy and the learning materials without having to do a complete reengineering of the content of the learning system.

The relative importance of the three models varies according to the purpose of the learning system : the nature and number of skills to generate. For example, a low-level learning need coupled with skills for memorizing facts, could lead to a very complex media model if a multimedia environment is used but the pedagogical model could remain simple enough since learning expectations are not very high. For similar reasons, the knowledge model might be limited to a small number of concepts related through composition or specialization links, and instantiated to groups of facts to learn.

4.1 Knowledge modeling

The knowledge modeling technique integrated into the method describes how to build models that are adapted to each training situation's characteristics.

Knowledge modeling starts with the identification of main knowledge and links. The method offers a library of 17 types of models from which the designer can start the modeling process. Once the type of model has been selected, it is a matter of choosing initial knowledge and links according to the training purpose. Then, we can add meta-knowledge that represents cognitive or affective skills to be developed with regards to this knowledge.

As we progress in the method, we further develop the model by creating sub-models and increasing the level of detail in the knowledge domain while taking into account the size of the desired learning system and the types of knowledge units required, according to the training objectives that have been set in the preliminary analysis.

Later on, knowledge units are grouped into sub-models, preserving the links structure, that are associated to the different learning units that compose the pedagogical model as well as to the learning instruments that will subsequently be defined in the media model.

4.2 Design of the pedagogical blueprint

Designing the pedagogical blueprint consists in building a model of the learning activities that will be proposed to the targeted users. A pedagogical strategy is first defined based on training needs. Basic components called " learning units " can be conveniently regrouped within higher-level learning events (module, course, programs, etc.). We then obtain a hierarchical structure called the " learning events network "supported by learning units (LU) at the base. Learning units are defined during the architecture phase. It is within the LU that the description of the learning and training process appears.

Each learning unit is centered around a pedagogical scenario. A scenario contains a detailed description of the learner's and trainer's activities, as well as a plan of all required instruments. The method provides for scenario adaptation by trainers and learners. The Learning scenario part describe all learning activities according to four categories (production, consultation, organization and assessment activities) related in such a way that it facilitates the articulation between activities. Instruments needed for an activity are added as inputs to the scenario. The learner's expected productions are also added as products of the activities.

The first part of figure 7 illustrates a learning scenario where a research report must be produced by a team. The second part of the figure presents the trainer's corresponding activities. This example shows the interaction between the trainer's activities and the learner's activities.

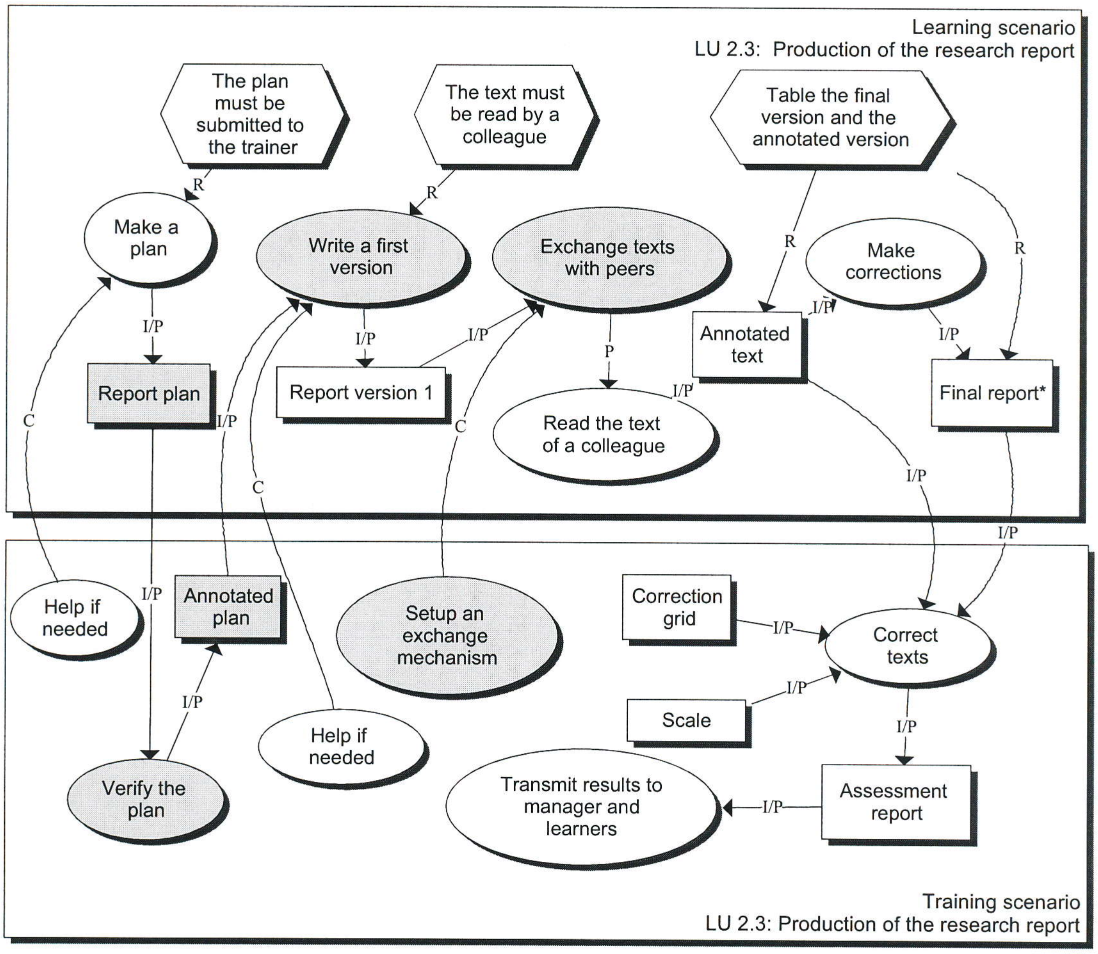


Figure 7. Learning and training scenarios

4.3 Design of the media blueprint

Instruments and scenarios plans produced by following the pedagogical design axis must be defined. The resulting media model is composed of the following :

- Pedagogical materials, including learning and training guides as well as learning instruments are gathered according to their affinity on the same or different media support.
- Teleservices that support various forms of communication between users.
- Hardware and software tools that will enable the users of the learning system to use pedagogical materials and the teleservices.
- Technological infrastructure that establishes physical links and permits access to pedagogical materials and the teleservices.
- Links and rules to regroup materials, teleservices, tools and technological infrastructure into a delivery model.

For every material of the learning system, the media model [2] identifies the different components and media units that compose the system and the media elements that compose each media unit. The model also permits the association of a metaphor and organization rules to guide the development of a pedagogical material as well as analogies and more specific organization rules that have an impact on the components and media units of the material. Finally, it facilitates the specification of screens and templates associated to units and media elements that compose it. Moreover, it makes it possible to determine what support is chosen for each of the pedagogical materials and then, what tools and components of the technological infrastructure are required to use materials and teleservices. This information is mainly used by the teams who are responsible for the development of pedagogical materials and for the implementation of the learning system.

4.3 Planning Development Work

Planning intervenes all along the five phases of the process. In phase 1, the planning axis is concerned with the gathering of all relevant data (actual context, desired situation, constraints) and the production of a global analysis. In the other phases, planning extend to the development, experimentation and revision of learning materials, and to the delivery model of the Learning system.

Planning is not done only once at the beginning of the project. It is in fact an iterative activity that repeats itself several times along the project in order to supply, in the last phase, the plans needed to deliver the learning system.

Planning development in terms of deliveries suggest a project organization according to which teams are product-oriented rather than function-oriented. Teams are made up with people that come from several fields and who work together to develop one or several LS components. Each individual has a specific role and responsibilities within the project in order to succeed in delivering the product for which his group is responsible. It is important to clearly assign roles and responsibilities so that everyone knows what to do and when. Moreover, it contributes to improve communication and productivity by avoiding duplication of efforts.

In large-scale learning systems engineering projects, several teams can be involved in the learning system design and development : the administrative support team, the management support team, the architecture team, the learning systems exploitation team, the development team, the piloting team, the distribution team, etc. As a group, each one adopts a role and responsibilities towards the project.

CONCLUSION

We presented a pedagogical engineering method that makes cognitive science research work operational, using a knowledge representation method. We observed, following validations done in nine organizations, that this method is applicable to various fields of knowledge where it:

- Facilitates communication between design teams members.
- Promotes rigor in tasks execution and consistency of the productions.
- Promotes diversity in defining knowledge objects.
- Stimulates diversity in the choice of pedagogical strategies and media, as it calls on the creativity of the designers, an indispensable quality element of a learning system.

Moreover, clear distinction and coordination of the three models are important elements in the method. They facilitate a better understanding of the various specialists roles, which reduces design time and supports reusability of a learning system's components. For instance, the same knowledge model can be used as a basis for new learning scenarios that are sometimes very different from the original one and they can easily be improved when new technological tools or media become available.

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[2] The media model only addresses macro-design of didactic material. The result is a set of blueprints that will permit micro-design of didactic material, according to the media chosen.

The quickly evolving information technology and the difficulty to foresee future trends naturally impose limits to the method, mainly as regards to a finer micro-design media technique. The nature of all communication tools, whether software or hardware, is constantly changing and the impossibility to predict what they will be, even in the short term, prevents us from inserting in the method prescriptions that would be too specific.

On the other hand, work is being done to further develop the method, notably through the definition of a library of generic processes that could serve as a basis for pedagogical scenario building. Moreover, identification of specific pedagogical engineering principles is continuing, in order to establish the ground for the advisor system that will be integrated into the next version of the AGDI workshop based on the present method. Finally, a learning system project management method would be a very useful extension to the planning axis of the method.

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