Chapter 7 - A Taxonomy of Generic Skills

As mentioned in the previous chapter, research in cognitive science, cognitive engineering, and education all support the idea that human skills can be described as generic processes. These processes develop through learning and working situations in various domains where knowledge is processed. In their relationship to knowledge, generic skills are the active part of human competencies. Depending on the viewpoint we use, generic skills are problem-solving methods, or active meta-knowledge working on other knowledge, or learning objectives to be acquired. The generic skills framework that will be presented here has been built in order to provide a clear view of the relation between knowledge in any application domain and the "intellectual actions" that enable a person to process and build knowledge. When someone has many such opportunities to exercise generic skills, they the re-construction of their own private universe of generic linkages and connections is made possible.

In this chapter, we will develop an integrated taxonomy of generic skills. It will incorporate previous work in cognitive science, software and cognitive engineering, and pedagogical design, some of which was presented in Chapter 6. It is an integrated taxonomy because it can apply to different manifestations of human activity: cognitive, emotional, social, or motor, representing generic skills in the form of process-type knowledge models constituting an operational library that can be used for projects in instructional engineering.

7.1 Presentation of the Taxonomy of Generic Skills

Figure 7.1 is an overview of the taxonomy of generic skills we propose. From left to right, there are three levels, from general to specific.

Each of the general skills (those directly linked to the root) represents a phase in the information processing cycle. Despite differences in terminology, there is a fairly broad consensus regarding the life cycle of generic skills that make up human action and learning.

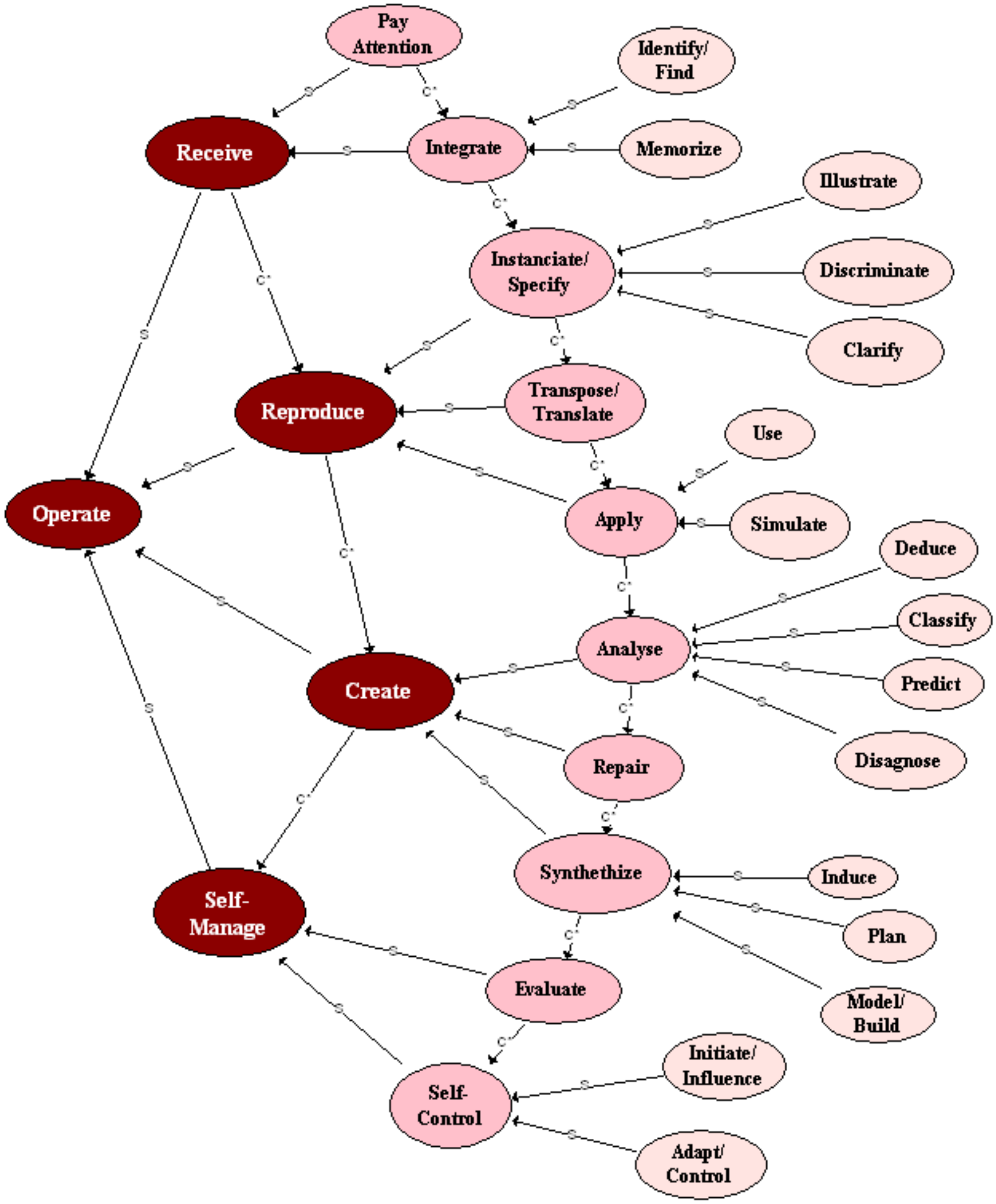

Figure 7.1 – Taxonomy of Generic Skills

- The first phase is that of *reception*, in which perception is mobilized in response to external stimuli: attention is placed on objects, information is located in memory to give meaning to each stimulus, and some of the information is memorized.
- This phase is usually followed by a phase of *reproduction*, in which memory is managed in such a way as to select relevant knowledge, in preparation for an eventual response, through the processes of clarification, translation, and application.

- Then, the higher intellectual processes of *creation/production*, analysis, repairing, synthesis, and assessment are mobilized to create/produce a plan for an eventual response and to produce the response or solution itself.
- The expression of this response in the environment leads to the *self-management* of one's mental, physical, emotional, and social actions through mediums of communication such as speech, movement, expressions, etc. The process begins by an assessment of the situation, which helps one to orient one's self, influence others, control the situation, and adapt to the circumstances. This is called the *self-management* phase.

Table 7.1 synthesizes definition and examples of skills corresponding to these four phases, irrespective of the facts that the inputs and products can be situated at the cognitive, affective, social or psychomotor dimensions of intellectual processes.

Name of the Generic Skill	Inputs	Products	Examples
Receive	Internal or external stimulus	Facts or knowledge retreived or stored in memory	Pay attention to an event, to a movement, to an emotion, to a social context. Identify knowledge, associated impressions. Memorize knowledge, impressions.
Reproduce	Knowledge and models	Facts obtained through instantiation or knowledge obtained through reformulation	Use examples to explain or illustrate a concept, a procedure or a principle. Use a model to explain facts. Simulate a process.
Create	Knowledge and models	New knowledge or models resulting from analysis and synthesis	Classify objects according to a taxonomy. Repair defective system components . Plan a project. Model and build a system.
Self-manage	Knowledge, models, meta-facts or values about knowledge	Knowledge, models, meta- knowledge linked to domain model	Assess knowledge validity or self competence. Initiate a change process after assessing the situation. Apply a generic strategy to improve learning and performance.

Table 7.1 - Main generic skill classes of the taxonomy

Receiving Skills

The first phase is **reception.** Perception is mobilized following an external stimulus, attention is paid to knowledge objects, memorized information is flagged and identified in order to make sense of the stimulus. Then, memorizing takes place. The generic skill to exert such intellectual acts may be considered as an awareness of knowledge objects involved.

At a first level of complexity, persons:

- **Pay attention** to knowledge objects, i.e. simply express a certain response to facts and information that is presented , for instance, participation in activities related to this information and demonstration of interest in the facts presented.

At a second level of complexity, a person starts to integrate the stimuli, data or information by mobilizing two inverse generic skills :

- **Identify/locate** knowledge elements, already stored in memory in relation to the information-related knowledge (type of fact) present in the stimulus.
- **Memorize** knowledge through restructuring mental association, according to already acquired knowledge, and record it in memory in association with existing knowledge or facts that were previously located there.
-

Name of the Generic Skill		**Inputs**	**Products**	**Examples**
Pay attention		Internal or external stimuli	Facts showing attention paid to input stimuli	Pay attention to someone's attitude change or related events
Integrate	**Identify/ Locate**	Internal or external stimuli	Knowledge located in memory in association with input stimuli	React to the situation description ; Repeat a dance step; recognize a context.
	Memorize	Internal or external stimuli	Knowledge stored in memory in association with stimuli	Record information; avoid repeating socially unacceptable behavior, memorize a melody .

Table 7.2 - Definitions and examples of the reception generic skills

Reproduction Skills

The second phase is characterized by a set of **reproduction** activities involving knowledge objects, where memory is managed to process knowledge liable to be used to explain, apply and produce more specific knowledge. The generic skill to exert such intellectual acts may be considered as a familiarization with the knowledge objects involved.

At the lowest level, a person **instantiates or specifies** concepts, procedures or principles provided to them in the following ways:

- **Illustrate** concepts, procedures or principles by producing examples, traces or statements obtained through instantiation.
- **Discriminate** between two or several concepts, procedures or principles, by producing instances of each one of them that is not an instance of the others.
- **Clarify** the description of knowledge by adding attributes to concepts, procedures or principles or by showing links that are not explicitly given initially.

At a higher level of complexity, knowledge is redefined to produce a new definition or a new representation in following ways :

- **Transpose** concepts, procedures or principles, by producing knowledge that is similar or presented in another form.

At an even higher level of complexity, the **apply** generic skills go further by the production of elaborated facts systems obtained by instantiating a given model, adding implicit links to the model. This can be done in the following ways.

- **Apply or use** knowledge or models, by producing goal-driven instances.

- **Simulate,** using the model of a process, or a set of principles to systematically produce instances by setting values for certain independent concepts, and obtaining the corresponding values of other dependent concepts.

Name of the Generic Skill		Inputs	Products	Examples
Instanciate/ Specify	**Illustrate**	Concepts, procedures or principles	Examples, traces or statements obtained by instantiating input	Provide examples of a calculation process. Give examples about gravitational laws.
	Discriminate	Two or several concepts, procedures or principles	Instance of each input that is not an instance of the others	Give examples allowing distinction of one vertebrate family from others.
	Clarify	Concepts, procedures or principles	Knowledge with more links than the one in input	Add attributes to a concept definition to define its meaning. Complete a procedure by adding a step.
Transpose/ Translate		Concepts, procedures or principles	Analogical knowledge or presented in another form	Represent a statement in natural language by a schema or a graph. Describe a situation like an event.
Apply	**Use**	Abstract knowledge or models	Instances of input knowledge obtained to reach a goal	Use a table to calculate interest. Choose a professional category according to the problem to solve.
	Simulate	Models of a process or a system of principles establishing a relation between concepts	Instances produced systematically by instantiating some concepts and getting values for other dependent concepts	Vary ecosystems parameters and examine the impact on populations evolution; Follow up, step by step, the execution of a purchase process in a organization, in different cases.

Table 7.3 - Definition of Reproductive Generic skills

Production and creation generic skills

The third phase involves higher-level intellectual processes of analysis and synthesis in the **creation** and **production** of new knowledge. The generic skill to exert such intellectual acts may be considered as a <u>mastery</u> of the knowledge objects involved.

- First, let us consider the main analysis intellectual skills such as: **Deduce**, i.e. produce a sequence of permitted operations, logically relating initial data to an original goal.
- **Classify** an object by determining taxonomy classes to which it belongs. .
- **Predict** the result of a given process, based on various classes of possible products.
- **Diagnose** a components system, by producing a list of components that do not meet certain performance standards.

At an intermediate level of creation, between analysis and synthesis, we find **repair** skills. Similarly to analysis, repair skills starts with an existing knowledge model, but the result is a modification, an improvement of the model.

- **Repair** a system, by replacing some components to achieve better results.

At a higher level of creation, the **synthesis** skills, at the opposite of application and analysis processes, do not take as input an existing model, but aim to construct one from instances, components or partial models. Depending on the type of inputs and products there are many kinds of synthesis skills suche as :

- **Induce** a concept, a procedure or a principle from a set of examples, traces or particular statements.
- **Plan** a process, by producing a set of products that respect time and resource constraints.
- **Model or build** a new model that integrates facts, abstract knowledge or partial models initially provided.

Name of the Generic Skill		**Inputs**	**Products**	**Examples**
Analyze	**Deduce**	Goal, data, operations	Series of operation that relate initial data to the goal	Deduce possible options according to budget analysis. Determine the shortest path between two locations.
Analyze	**Classify**	Taxonomy and facts to classify	Taxonomy classes to which each fact belongs	Determine the category of a certain car. Identify the procedure type for a proposed decision mechanism.
Analyze	**Predict**	Processes, classes of process products, process input to be classified	Class of the process products to which the input corresponds	Predict the possible result from a medical intervention according to the patient's characteristics. Predict one's behavior in a certain type of situation.
Analyze	**Diagnose**	Component-based system, norms that regulate each component,	List of faulty components compare to norms	Identify one's errors while executing a movement. Find defective components in an electrical system breakdown.
Repair		Models, model components to improve	New improved model	Reorganize connections in an audio-video system. Prescribe a medical treatment to remedy a health problem.
Synthesize	**Induce**	Set of facts: examples, traces or statements	Concept, procedure or principle where facts are instances	Induce a scientific law linking two or several variables from observations. Build a taxonomy allowing classification of computer types.
Synthesize	**Plan**	Set of products (concepts) and constraints (principles)	Processes generating the products and respecting the constraints	Plan a project execution. Plan a skating session.
Synthesize	**Model/ Construct**	Facts, abstract knowledge or models	New model that integrates the facts, knowledge and models	Build a complex computer system. Design a course. Draw the architectural plan of a new building.

Table 7.4 - Definition of Production and Creation Generic skills

Self-management generic skills

The fourth phase, **self-management** manifests itself through acts that involve generic knowledge, for example assessment of a situation, action or communication, and finally, self-adaptation for behavior control. The skill to exert such intellectual acts may be considered as expertise as regards the knowledge objects involved. Among other things, an individual can :

- **Evaluate** knowledge by attributing values as to its interest, usefulness, relevance, validity, etc. These values are obtained by instancing the corresponding generic concepts.
- **Initiate and influence** one's own or others' evolution, for example by expressing knowledge for a precise goal and one or several recipients, or by accomplishing a series of actions that will lead to knowledge progress, new attitudes, new social behavior, for oneself or others.
- **Control events and adapt to them** by displaying leadership, willpower, perseverance and adaptation capabilities, using knowledge and its assessment to improve one's own or others' knowledge and generic knowledge.

<table>
<tr><th colspan="2">Name of the Generic Skill</th><th>Inputs</th><th>Products</th><th>Examples</th></tr>
<tr><td colspan="2">Evaluate</td><td>Knowledge or models</td><td>Knowledge attributes (generic concept) associated with each knowledge object or model</td><td>Evaluate reliability or validity of statements .
Evaluate one's own competence level in a task.
Identify self-esteem or confidence needs in a group.</td></tr>
<tr><td rowspan="2">Self-control</td><td>Initiate/ Influence</td><td>Knowledge or models assessed by their cognitive properties</td><td>Intervention processes (communication or action); new cognitive properties</td><td>Try to convince someone about knowledge validity and usefulness.
Initiate an exercise program intended to improve body flexibility.
Start to improve attitudes and social climate in an organization.</td></tr>
<tr><td>Adapt oneself/ Control</td><td>Knowledge or models assessed by their cognitive properties</td><td>Intervention processes (communication or action); modified cognitive processes (action and strategy)</td><td>Decide on developing project management skills.
Improve one's learning strategies in a domain.
Analyze self or someone else's generic skills and define an improvement program.</td></tr>
</table>

Table 7.5 - Definition of the self-management skills

7.2 Generic skills and Meta-domains

It may seem ambitious to propose a taxonomy integrating the cognitive, psychomotor, emotional and social domains, while so many practitioners in education use separated taxonomies of generic skills for these meta-domains. We believe on the contrary that it is important to integrate them. As underlined by Martin and Briggs (1986): "This subdivision (in different domains) is relatively arbitrary because the psychologists and the educators agree that, in the reality of educational practice, no real separation between the cognitive, emotional and psychomotor states is possible " (p.10). Martin and Briggs quote in support to this assertion several other authors, notably some having produced important taxonomies such as the ones by Bloom (1975) and Gagné (1970).

Although recent developments in neuro-physiology suggest that regions of the brain are specialized in cognition, emotions or psychomotor commands, research in this domain shows evidence of an integration between the various constituents of the brain in each of our activities. As an example, Daniel Goleman (1997) underlines that "our emotional faculties drive us constantly in our choices; they work of concert with the rational spirit and allow - or forbid - the exercise of the very thought processes. Also, the cognitive brain plays an executive role in our feelings." (p. 53)

Table 7.6 shows that this taxonomy can be interpreted in each of the four meta-domains (cognitive, psycho-motor, affective or social). For example, we can repair theories and movements, as well as attitudes or social relations. What differentiate these four meta-domains is essentially the type of input to a generic skill and its resulting production. If the stimuli or the result concerns rational thought, motor capacities, affectivity or social interactions, we will label the generic skill to be cognitive, psychomotor, affective or social.

More generally, we could say that somebody is "intelligent" on the rational, physical, emotional or social dimension if it he or she is capable of applying in most of cases, all types of generic skills for that dimension. This is basically what the American psychologist Howard Gardner (1993) suggests by taking into account multiple intelligences as the basic conceptual structure of the intellect.

However, in practice, when we analyze the performance of a generic skill in a person, it usually involves a mix of cognitive, emotional, psycho-motor, and social components. When a person perceives a stimulus, all these different functions are usually called upon, and when he or she effectuates a response, it is very often cognitive, emotional, social, *and* psycho-motor.

When we represent a generic skill in the form of a generic process, such as diagnosing, we ignore this aspect. It may be significant, however, when we instantiate the generic skill in an application field (see for example Fig. 6.4).

This is for purely practical reasons. Remember that our goal is to provide useful concepts for instructional engineering. When we represent a generic skill without considering the type of intelligence involved, we are not claiming that diagnosing engine failure is the same as diagnosing an emotional state. The diagnostic process is simply a useful model for instructional engineering, allowing one to understand the distinction between generic skills and showing their interactions. It is a tool for instructional engineering, not an exercise in psychology.

		Generic Skills	Meta-Domains			
			Cognitive	**Psycho-motor**	**Affective**	**Social**
Receive	1	**Pay attention**	Be interested in a political situation	Perceive a bad position in front of a computer screen	Be favorably impressed by a synphony	Perceive a tense situation in a group
	2	**Integrate**	Recall or memorize a list of dangerous products	Remember a yoga position or learn a new one	Remember or note a useful strategy for managing anger	Remember or note a method for working in a group
Reproduce	3	**Instantiate/specify**	Specify a procedure by adding a stage or giving examples	Describe the movements of a well-rehearsed choreography	Distinguish between a joke and an insult	Make a small change to a previously adopted role in a group
	4	**Transpose/ translate**	Graphically represent a procedure presented orally	Brake a truck based on one's reflexes for braking a car	Flee (or control) a previously experienced unpleasant situation	Take a leadership role in a familiar group situation
	5	**Apply**	Use a well-known formula for new data	Correctly perform a backhand in tennis using a new position	Control one's anxiety with a known technique	Simulate crisis management through a recognized approach
Create	6	**Analyze**	Identify the objectives, data, and constraints of a certain type of problem	Diagnose errors in the execution of a movement	Predict one's emotional response to an action	Analyze and classify group dynamics according to various models
	7	**Repair**	Add new features to an inefficient method	Correct certain movements of a golf drive	Change one's emotional response to a tense situation	Propose a method for improving the atmosphere in a classroom
	8	**Synthesize**	Construct a classification or action plan through examples	Learn to juggle three balls for the first time	Adopt a completely new attitude in a difficult situation	Find a constructive way to behave in a group
Self - control	9	**Assess**	Assess the strength, validity, or relevance of an argument or statement	Compare one's piano playing in a music class	Assess one's emotional state after an argument with friends	Determine the quality of work and productivity of a group one is involved in
	10	**Self-manage**	Decide to completely change one's way of assessing a situation	Follow a systematic plan for assessing and improving one's physical condition	Manage one's emotional attitudes by assessing them regularly in order to improve one's well-being	Take responsibility for improving the attitudes of participants and the social climate of an organization

Table 7.6 – Generic Skills and Meta-domains

7.3 Towards a Library of Processes for Generic Skills

We will now present process models for some of the generic skills defined in the preceding sections. These examples are part of a structured and extensible library that concretizes the notions of Generic Skill and Competency. In the following chapters, we will see how this library can be used to build activity scenario, orient knowledge modeling of select resources according to a user's competencies.

A Generic process for Identification

Perception involves operations that call on the learner actor's senses as well as memory; without memory recall, he would be incapable to recognize facts and knowledge that are presented to him.

The location and identification generic process first mobilizes an attention sub-process in order for the actor to retain some information originating from internal or external stimuli. Figure 7.2 presents such a process[1].

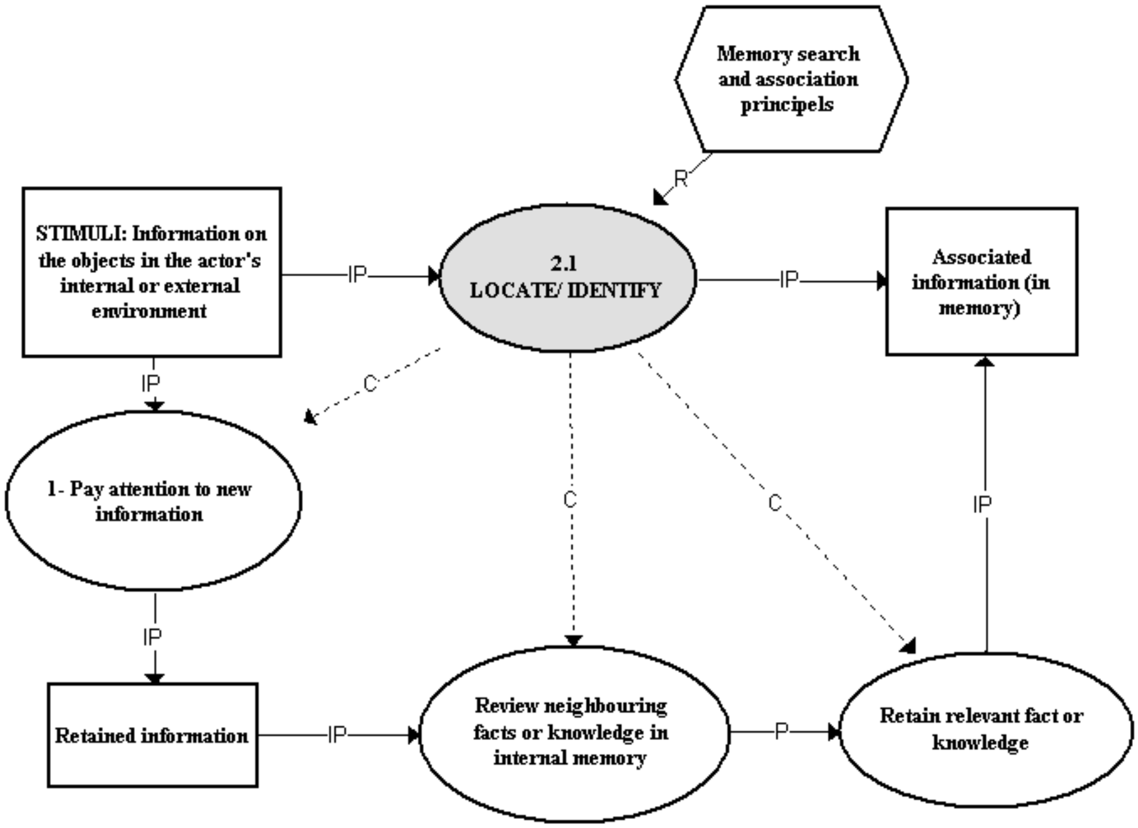

Figure 7.2 – An identification generic process

Then, two other sub-processes are used to process the retained information. The first one searches memory for knowledge that could be associated with new information. We could describe this search as a pathway in a chain of associations from knowledge in memory that contributes to retention of information. The other sub-process preserves the association links that seem relevant and generates the results from the location and identification generic process: association links between existing knowledge and new information.

Memory search and association principles that regulate the generic process can be more or less numerous, complex and efficient, according to the actor's intellectual development, i.e. the extent of actual learning realized. For instance, an actor may search only one domain within three associative links of the information in stored memory, while another will search several domains.

[1] The numerals before a skill's name are chosen according to figure 7.1. For example "pay-attention is numbered 1 and "synthesis is numbered 7.

A Generic Process for Deduction

To deduce a solution consists in applying a number of procedures (operators) to instances of concepts called « data », in order to produce an instance of a concept called « goal ». For example, applying algebraic operators to an equation with two unknown variables to infer a solution; applying solutions allowed by the Rubik cube to an initial state of the cube, to get the final state that meets the game conditions ; creating new schedule out of last year's schedule, by applying substitutions that satisfy the new constraints.

Figure 7.3 is a model of a generic deduction process (6.1), a particular case of the analysis skill process (6).

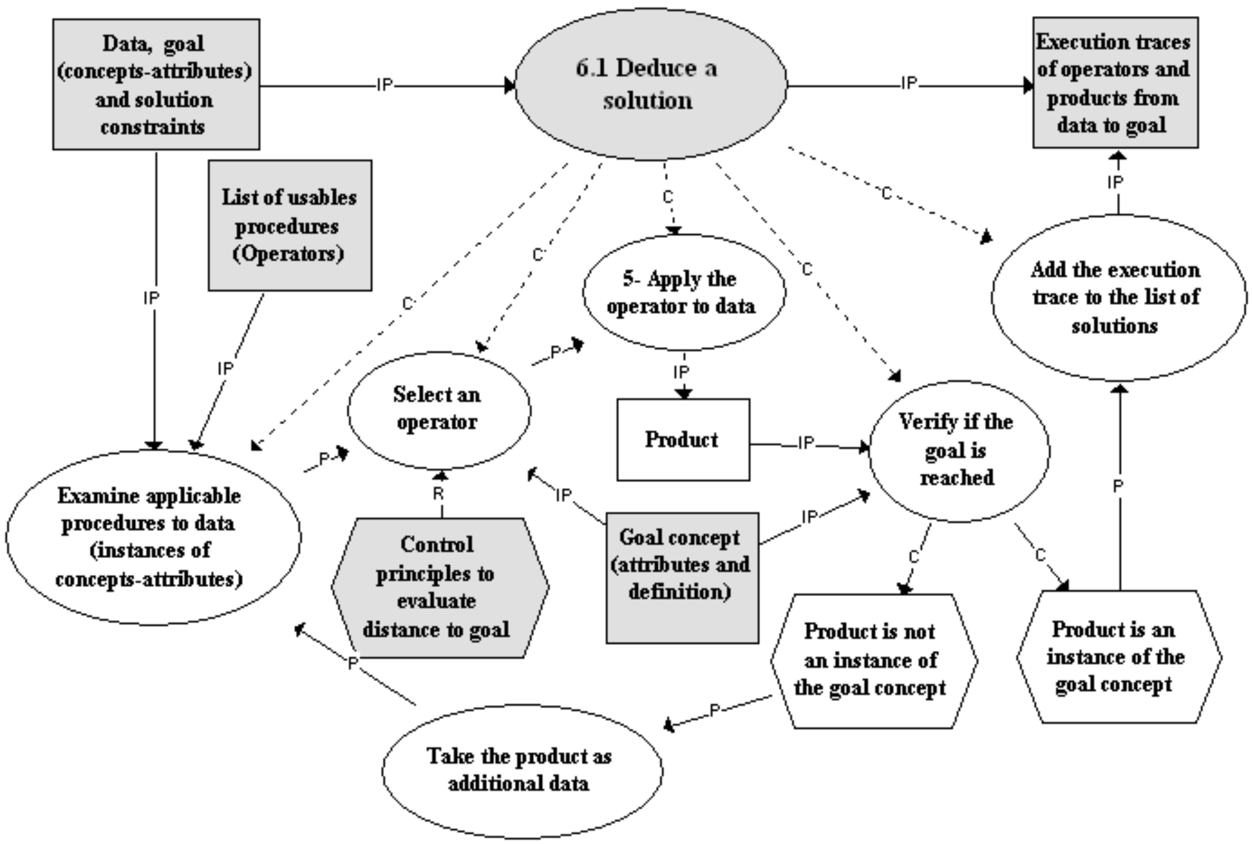

Figure 7.3. – A deduction generic process

The first procedure of the generic process consists in examining procedures (operators) that are applicable to data. Then, one of these operators is chosen and applied to data. If the product generated by the procedure is an instance of the concept-goal, there is a one-step solution. Otherwise the process is repeated by looking for an operator to be applied to the product, and so on, until the solution is obtained, i.e. the execution trace of a sequence of procedures transforms data (instances of concept-data) into a goal (instance of concept-goal). Artificial intelligence literature (Laurière 1986, Winston 1984) abounds in such control principles : breath first or depth first search, heuristic evaluation of the distance to the goal, etc.

A Generic Process for Building a Taxonomy

Creating a typology or a taxonomy is a particular modeling process (8.3) that consists in defining a way to classify instances of an abstract knowledge object (concept, procedure or principle), called the taxonomy's object. First, using a set of instances that is as diversified as possible, the object's critical attributes are identified. Then, using conditions involving these attributes, instances are regrouped into two classes or more that are disjoint two by two and cover all possible cases. A taxonomy can then be created by subdividing each first-level class the same way (this is the same as building a one-level taxonomy for knowledge that corresponds to each class). For instance, we can create a taxonomy of buildings by first defining the concepts of home, workplace and public place. Then we subdivide the home class by defining the concepts of family cottage, duplex or triplex in a row, detached duplex or triplex, multiple apartment buildings.

Here is a model of such a generic process

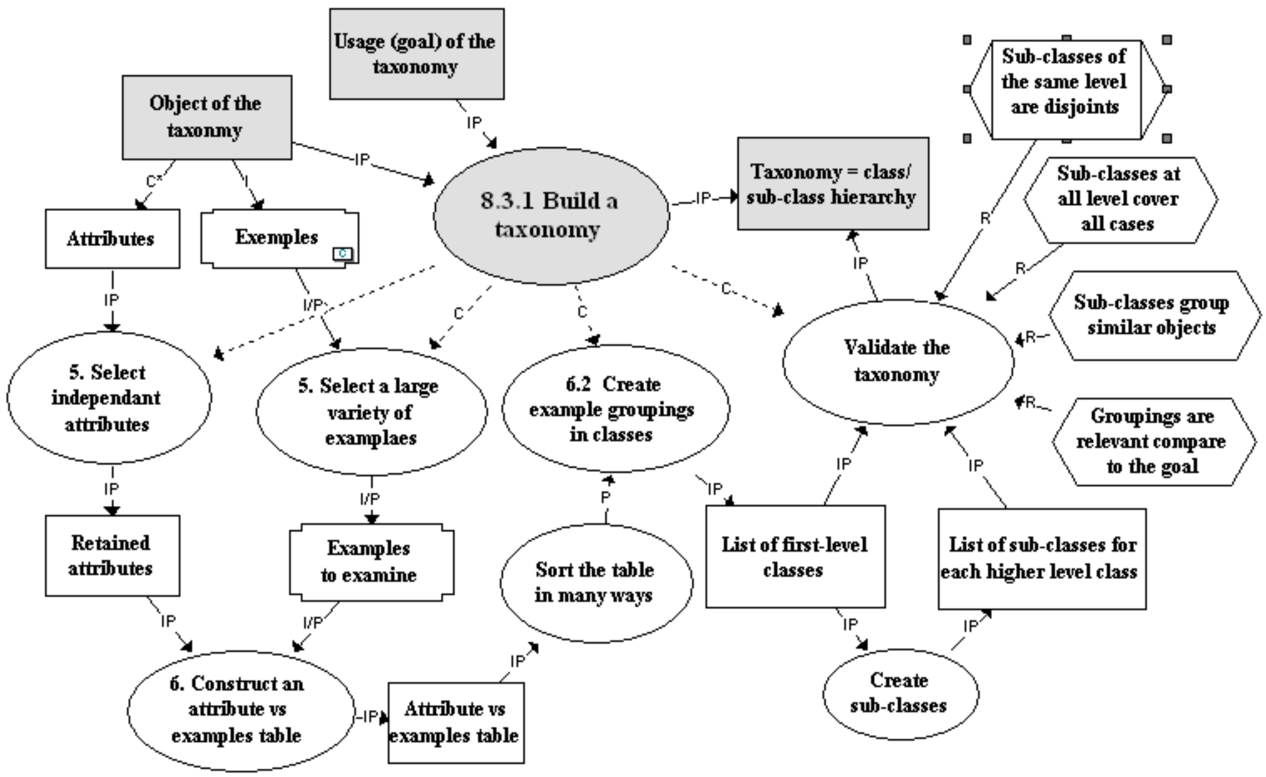

Figure 7.4- Generic process for building a taxonomy

The generic process shown on Figure 7.4 starts with two interrelated sub-processes: selection of independent attributes and selection of a large variety of examples to be classified.

For each retained attribute, a list of possible values is established. If the values are not yet defined, a typology must be built for the attribute by taking it as the object to which the process is applied again, until its values are satisfactorily defined. A table containing the retained attributes values for each example can then be built.

Then, we can sort the table in different ways to create groupings of examples, according to the attributes values, and verify that examples « deserve » to be put in the same grouping class. When the result seems satisfactory, groupings are defined and become first-level classes. If necessary, a second level can be created by subdividing each first-level class in the same manner.

The taxonomy remains to be validated by checking the definition principles : classes are disjoint two to two and cover all cases ; each class gathers similar examples, according to the typology goal (expected use).

A Generic Process for Evaluation

To evaluate one's or someone else's knowledge acquisition consists in diagnosing the understanding level of a person as regards knowledge objects in an application field. For example, one individual knows how to apply a procedure in simple situations, the other, in complex or strange situations. This generic skill is a form of diagnosis, except that the diagnosis result is not a list of objects in the application domain, which would be the defective components of the system being studied, but rather a list of values associated with knowledge. These values are generic concepts that represent the degree of knowledge acquisition by oneself, another person or a group of persons. So this generic process is necessary for learning assistance, to oneself or to other individuals or cognitive systems.

Figure 7.5 presents a simplified model of this evaluation generic process. It is one of the possible models that can capture the concept of « overlay model » used in several intelligent tutorial systems (Wenger 1987).

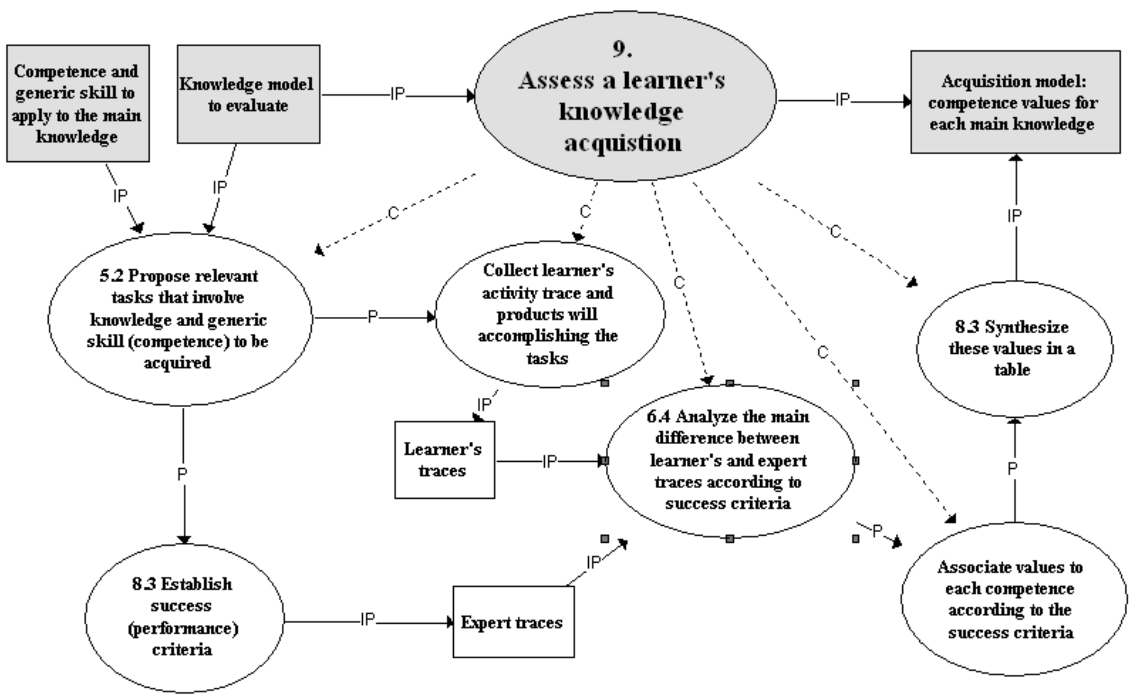

Figure 7.5 -A generic process for evaluating knowledge acquisition

The starting point is the model of the knowledge object to be acquired, for example a taxonomy, a components system or a process. Each model possesses a main knowledge object around which other knowledge objects are articulated.

The expression « acquire knowledge » is too vague to be of any use here. We make it more precise by specifying the competence level to reach and a generic skill corresponding to this level, which the learner should be able to exert on the main knowledge object and its related knowledge objects.

A good way to assess the learner's competence as regards the generic skill to be applied to a knowledge object (main), consists in instancing the generic skill's process in the application domain.

For example, knowledge about the car's electrical system is assessed at a « diagnose » competence level, by proposing various diagnosis tasks to the learner. On the other hand, if knowledge about the same system is to be assessed at the « design » competence level, the learner will be provided with a car's electric system design tasks.

In each case, a « correct » trace of the task is defined, an instance of the appropriate generic process, provided by an expert or built by the system. The trace resulting from the learner's activity is then collected and compared with the « correct » trace. Differences between the two are noted. If there are any, identification of the tasks and links between tasks that were not executed correctly is attempted. After a certain number of traces, competence values can be attributed to the learner relative to the main knowledge object, and to each component of the skill's generic process being applied to the knowledge object.

A Generic Process for Control and Self-adaptation

The model on Figure 7.6 represents a control and self-adaptation generic process (10.2). The corresponding generic problem consists in obtaining the description of a project or change process in a particular domain, as well as success criteria specific to this domain. The generic process produces a model of the new situation created at the end of the generic process.

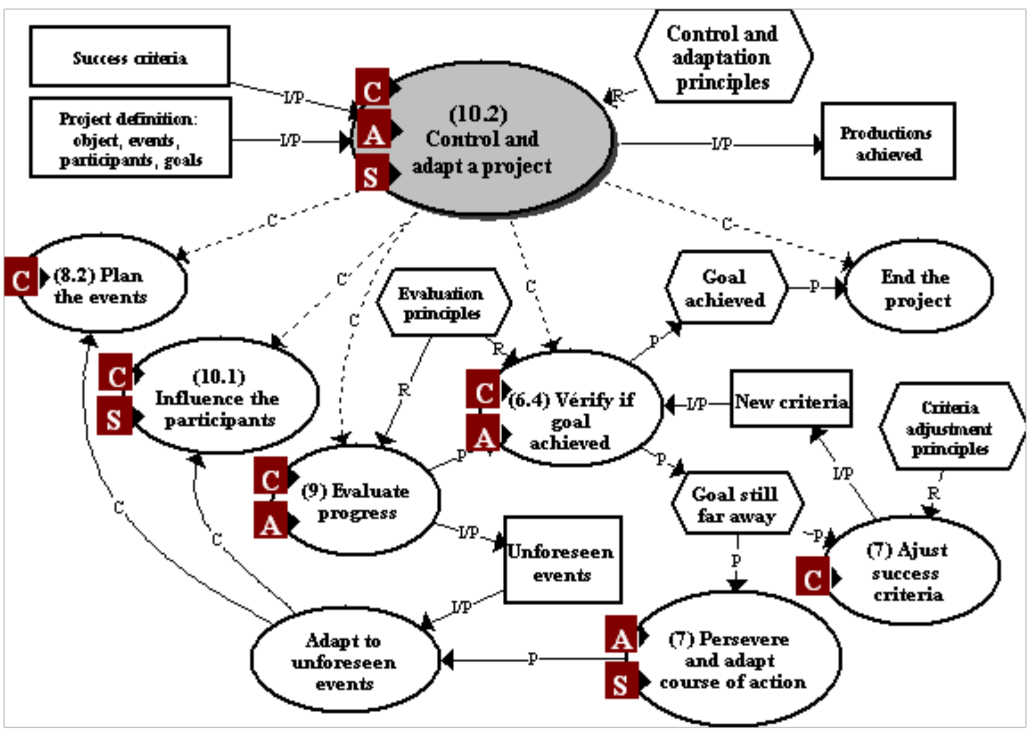

Figure 7.6. –Control and adaptation generic process

In the first phase, events are planned and participants are influenced so they coordinate themselves to carry through the project activities and meet the success criteria. Progress is continuously monitored and re-assessed. In the case of unexpected events, adaptation is required, course events are reordered, participant roles are redefined, and even success criteria may be modified.

Regularly, distance to the goal is evaluated according to the success criteria at a given moment. If the distance is too big, the goal is readjusted so that chances of success are increased. An alternative is to change the success criteria.

Planning and evaluation principles are necessary to guide particular tasks. The criteria's adaptation principles are used, for example, to « give some slack » when it becomes clear that success criteria will not be met, and to define, in spite of this, an acceptable success level. Control and adaptation principles monitor the transition between sub-processes, for example, by specifying when progress and success must be assessed or when criteria must be adjusted, or when the generic process should be terminated.

This generic process can be applied in domains as varied as research (cognitive domain), psychosomatic therapy (affective domain), organizational re-engineering (social domain) or sport training such as diving (psychomotor domain).

7.4 Relations between Generic skills: Specialization and Composition

The models presented above show an ordering of generic skills form simple to complex. Higher-level generic skills (located in the lower part in Figure 7.1) usually involve the use of those that precede it. More specifically, the generic process describing a skill contains sub-processes of the generic skills that precede it in the list. Here are some examples:

- The locating/identifying skill of Level 2 involves the attention skill of Level 1 (Fig. 7.2);
- The deduction skill of Level 6 involves the application skill of Level 5 (Fig. 7.3);
- The taxonomy creation skill of Level 8 involves the application skill of Level 5 and the analysis skill of Level 6 (Fig. 7.4);
- The assessment skill of Level 9 involves application, analysis, and synthesis skills (Fig. 7.65);
- The control/adaptation skill of Level 10 involves application, repair, synthesis, and assessment skills of Level 9 (Fig. 7.6).

Increasing Order of Complexity

These examples illustrate that there is an increasing order of complexity of generic skills, at least with regard to the first and second levels of the generic skills tree (Figure 7.1). In other words, we can refer to levels 1 to 10 as increasing levels of complexity. This assertion is not evident and was sometimes disputed in the case of taxonomies presented in Section 1. For example, the authors of the KADS method have preferred to put emphasis on the organization of sequences of generic tasks than of a hierarchical order among them.

On the other hand, Bloom has insisted on the hierarchical organization between educational outcomes: "Our attempt to order the educational behavior from simple the complex is based on the idea that a given simple behavior can become integrated with another simple behavior to form a more complex behavior. Consequently, our classification can be perceived as that behavior of type A forms a class, behavior of type AB another class and behavior of type ABC still another class" (p.18). One finds a similar preoccupation in the elaboration of the taxonomy of the affective domain. "This organization of constituents seems to describe a process according to which certain phenomenon or value progress from one level of simple awareness to a level where it drives or controls the behavior of a person (Krathwoll et al., op.cit. p.27)."

Experimental studies have tried to verify this hypothesis. Tests have been given to a large number of students containing questions connected to various complexity levels in both taxonomies. With this experimental setting, one should notice a bigger percentage of failure for questions related to the higher taxonomy levels.

As far as the taxonomy of the cognitive domain, according to Martin and Briggs (1986), some studies support to a certain extent the hypothesis of the increasing complexity of levels. The evidence is stronger in the first levels than in the more advanced levels. One finds the same kind of conclusions in the case of the taxonomy of the emotional domain, even though there are fewer studies to support this.

We suspect that the limited evidence coming from certain studies is due to the absence of a meta-knowledge representation scheme for generic skills. For example, certain studies note similar results for analysis on one hand, and for evaluation and the synthesis on the other hand. But if one distinguishes synthesis from analysis by the ascent in abstraction, and if one distinguishes evaluation both from synthesis and analysis by the use of meta-values that are properties of knowledge, it is likely that one can maintain the hypothesis of an increasing order of complexity for Bloom's taxonomy as well as for the second layer of our taxonomy.

Here is a clear definition of a generic skill's complexity: *A generic skill A is more complex than a generic skill B if the generic process representing B appears as a sub-process in the model of the generic process A.*

Furthermore, as we descend to higher levels of specialization, the assumptions regarding ordering of generic skills become less likely. For example, it is difficult to say that the generic skills "induce," "plan," and "model/construct" are in order of increasing complexity. Our assumption is thus limited to the four generic skills of the first level and the ten generic skills of the second level.

The graph in Figure 7.7 demonstrates this notion of an increasing order of complexity through C links, signifying that a higher-level process can contain one or more lower level processes.

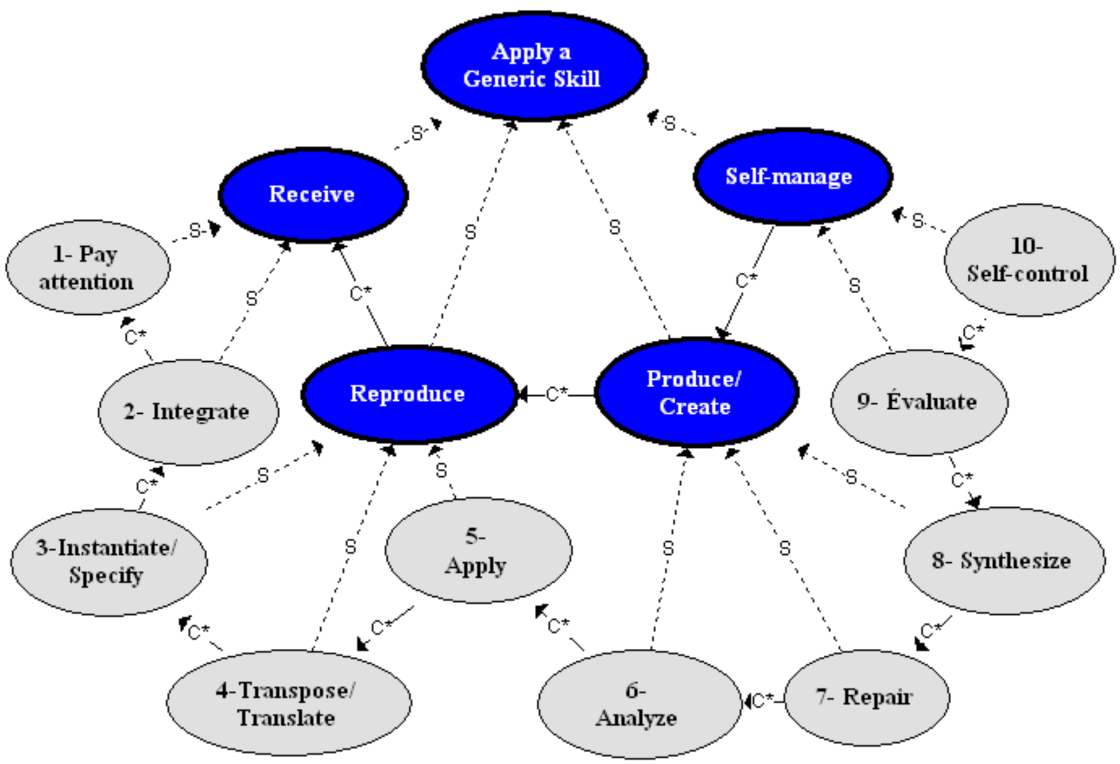

Figure 7.7 – Structure of the Library of generic skills (specialization and composition relations)

Specialization of Generic Skills

We can add further levels of specialization to the library of generic skills beyond the third level in Figure 7.1 as in the following examples.

Here are four reproduction generic skills. The first two involve forms of instantiating/clarifying; the third involves two specialized simulation skills:

- ***Validating a relational principle*** begins by first generating a set of instances of the conditions obtained when giving values to its attributes, covering all cases if possible, and then verifying in each case if the condition is true. For example, the following statement can be validated: « If an animal breast feeds its babies and has claws, it is a carnivore mammal » by establishing a set of instances that satisfy the condition (tiger, dog, raccoon) and by verifying that in each case, the conclusion is true.
- ***Delimiting a concept*** consists in generating a set of *examples*, each resulting from specifying the values of concept's attributes that respect the regulating principles. At the same time, *counter-examples* are generated giving values to the attributes that do not respect the principles. *Near-examples* are particularly useful to delimit a concept, since they result from the specification of the values of a concept's attributes, respecting the regulating principles, except for a small number of cases. For example : robin, sparrow, chaffinch are examples of birds ; « bat » is a near-example of the bird concept, while « dolphin » is a near-example of the mammal concept.
- ***Simulating a process*** first consists in generating a set of cases, each one gathering an example obtained by instancing each input concept to the process; then, procedures are executed by using values for each case, and action principles are instanced little by little. Execution traces are generated that constitute the simulation product.
- ***Simulating a conceptual system*** consists in instancing some of the concept's attributes by respecting regulating constraints, in order to examine the values taken by other attributes; for example, the simulation of an electrical system consists in setting up some attributes such as current intensity (I) or resistance (R), and noting the values taken by other attributes such as voltage (V) take based on V=RI (Ohm's law).

Here are two production/creation generic skills involving specialized forms of analysis:

- ***Retro-deduce a solution*** is a similar approach to deduction, but applied in a reverse way, starting with an instance of the goal-concept (the goal), finding procedures (operators) that can generate it and facts to which a procedure can be applied. This process is repeated backwards, until a set of facts, instances of the initial data-concept is obtained.
- **Monitoring** consists in using a given process, instanciated to get a trace corresponding to a real situation, then classifying this trace according to pre-established categories associated with the corrections to be brought. For example, supervising a nuclear complex consists in collecting values that represent the trace of the process and to determine if the process is safe or on the contrary, if it requires the adjustment of some of the system's parameters.

Here are three production/creation generic skills involving a form of synthesis, in particular, induction:

- **Inducing a concept** consists in examining a set of similar facts and defining an initial concept whose instances contain these facts as examples. Concept definition refines itself when counter-examples or new examples are used, or facts that do not correspond to the current definition of the concept, which can lead to its modification, through specialization, notably by adding conditions to the definition. Near-examples are counter-examples, but they contradict only one aspect of the concept's current definition. One must then wonder if the definition of the concept should be extended to include the near-example as an example, or if it should be restricted to exclude it. Adding new examples of the concept being defined can also lead to generalize the concept in order to « cover » new cases.

- **Inducing a procedure** is a similar generic process that consists in creating an initial procedure that produces expected results from some input data. Then, taking into account new data, to generalize the procedure so it can be applied to many more situations.
- **Inducing a principle or a law** consists in creating a relational principle that sets a relation (explain, summarize) between one or several concepts attributes. The results of the principle being instanced should be true statements, whatever the values of attributes.

Finally, here are four variations of the evaluation generic skill:

- ***Prioritizing*** consists in taking one or several knowledge objects, or even one or several models, and assigning a value to them as regards their usefulness in some situation: type of users, organization's needs, etc.
- ***Validating*** consists in assessing the reliability of knowledge, to attribute it a truth probability : does the procedure produce what it should ? Does the concept describe what it should ? Can the principle be instanciate by true statements, if not, in what cases ?
- ***Comparing-deciding*** consists in comparing two knowledge objects or two models according to criteria of usefulness, reliability, relevance, and keeping the one that seems the most adequate, according to these criteria.
- ***Standardizing*** consists in modifying a model, according to the results of an evaluation based on criteria such as simplicity, relevance, communicability, and making it conform to these criteria.

We can thus develop the generic skills library through increasingly specialized generic processes to account, for example, for the types of models to which it applies; for example, we can classify, construct, or evaluate conceptual systems, procedures, theories, processes, or methods. We can also obtain variations of basic processes for different domains of knowledge. A diagnosis in auto mechanics is not performed the same way as in medicine. As well, we can obtain variations of processes according to whether they produce or use results in the cognitive, psycho-motor, affective or social domains. Finally, we can obtain variations of processes according to a desired goal, for example, diagnosing some or all faulty components.

Here is an example of increasingly specialized generic skills connected specialization links.

Produce/Create
- Synthesize
  - Induce
    - Induce a taxonomy
      - Induce a taxonomy with multiple parents
        - Induce a taxonomy with multiple parents in the animal reign

At the end of a specialization chain, the generic skill may involve only one application domain. In this case, there is no advantage in representing it as a generic skill and one would simply integrate the process as part of the domain knowledge.

7.5 Giving an Operational Meaning to Competency Profiles

We will now present a first application of the taxonomy of generic skills presented above. As we have seen in chapter 5, most competency profiles are expressed as more or less precise natural language statements. Their interpretation is often ambiguous because they lack a precise structural definition.

We present here a process to analyze a group of existing of competency statements or to build them in a standard way. This process contains following sub-processes:

- determine one or several target actors for which the competency is defined;
- identify the tasks of these actors, as well as the corresponding knowledge and represent them in a knowledge model;
- identify the skills required by the actors that will be applied to the knowledge.

Identify Target Actors for the Profile

To illustrate this process, we will use as a case study the competency profile of a multimedia director that has been presented in chapter 5. This profile results from a general analysis of the domain of multimedia trades having lead to fourteen actor definitions and their corresponding competency profile. The profile for the multimedia director (see table 5.3) groups a variety of tasks and competencies that we aim to re-interpret using the same structure presented at the end in chapter 5: name of the actor, main generic skill and knowledge to which this skill must be applied.

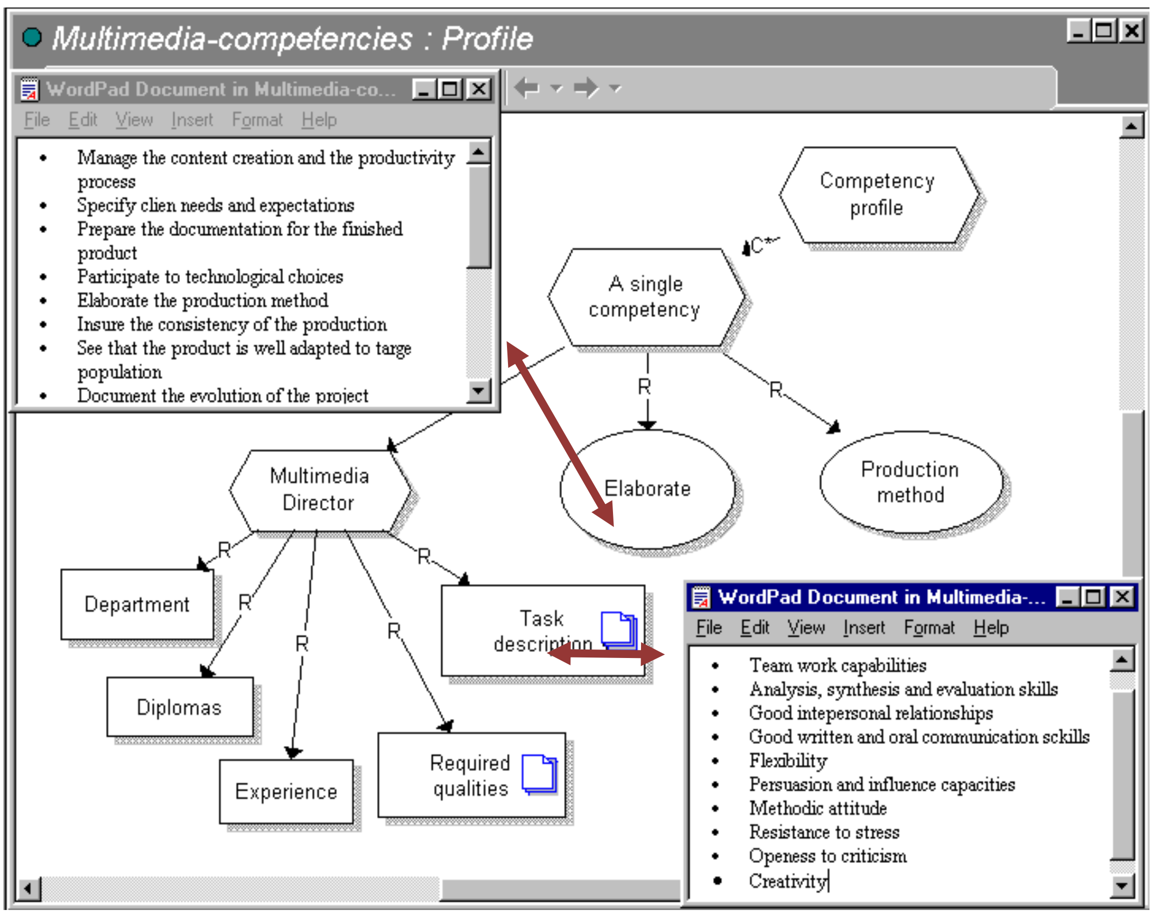

Figure 7.8 – Example of a competency profile

Figure 7.8 shows part of a competency model we have built in MOT+ from the profile description in chapter 5. Here the statement would read "A multimedia director must be able to elaborate a production method for a multimedia project". There are of course other competency statements like this in the model. Furthermore, the model is linked to a description of qualities required for the job and a task description that will help identify sub-skills for this job profile.

The task description on figure 7.8 is the most important to interpret an existing competency profile or build a new one. The task components are not competency statements but procedural descriptions that help identify the knowledge and the generic skills required from the target actor of the profile. For example: « Document the evolution of the project » contains no generic skills. It rather describes a role, a procedural knowledge the actor will have to apply to some unspecified degree.

Modeling the Target Actor's Tasks and Knowledge

A knowledge model for this domain is essentially procedural based on the tasks definition, but it can be completed by concepts and principles required to achieve the tasks. In this model, three main processes must be governed by the multimedia director: the elaboration of the method of production, the management of the creation / production process and the quality control of the product. Figure 7.9 presents a partial knowledge model corresponding to the task definition figure 7.8. The knowledge elements in this model will provide an anchor to associate the generic skills and competencies required by the actor.

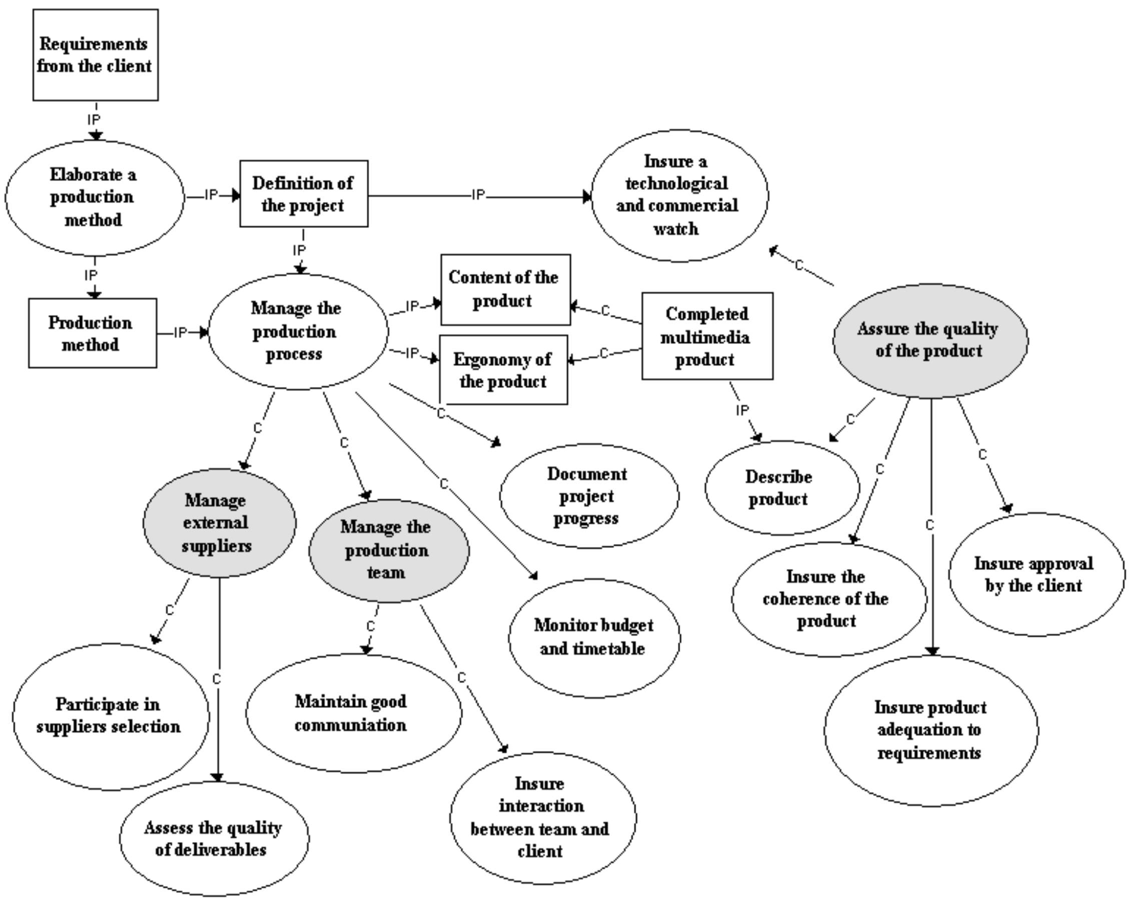

Figure 7.9 – A task and knowledge model for the multimedia director

Identify Generic Skills

We can now start to identify the main generic skills that need to be associated to this knowledge model, taking in account the qualities required from the multimedia director on figure 7.9. This analysis reveals that:

a) *The elaboration of the multimedia production method* requires mainly productive cognitive skills, that is: « analysis, synthesis and evaluation skills » and « creativity».

b) *The management of the production process* requires self-management cognitive skills, as well as affective skills such as « resistance to stress » and « flexibility », and mostly social skills such as « leadership, good teamwork capabilities, interpersonal capabilities, persuasion and influence capacities, openness to criticism».

c) *The quality assurance of the product mainly* requires cognitive skills such as « methodic attitude ».

Now that we know the type of generic skills, cognitive in (a) and (c); cognitive, affective and social in (b), together with their level in the generic skills taxonomy presented in this chapter : creation/production in (a), self-management in (b) and (c), it remains to be more specific on the type of these skills.

To achieve that, we can develop further the knowledge model on figure 7.9 to provide more concepts, procedures and principles to which skills can be associates. Figure 7.10 is one of the sub-models. The central task of this sub-model is to elaborate a method of production and a definition of the project from expectations and requirements of the client. Besides this knowledge, the task requires from the multimedia director the use of knowledge on the technical and graphic feasibility of the project, on the production steps of a multimedia project, on the possible audio-visual supports, on the tools for multimedia creation on PC, MAC AND UNIX, on various approaches to develop, implement and deliver a Web site and finally, on the use, potential and limits of the Internet and multimedia technologies.

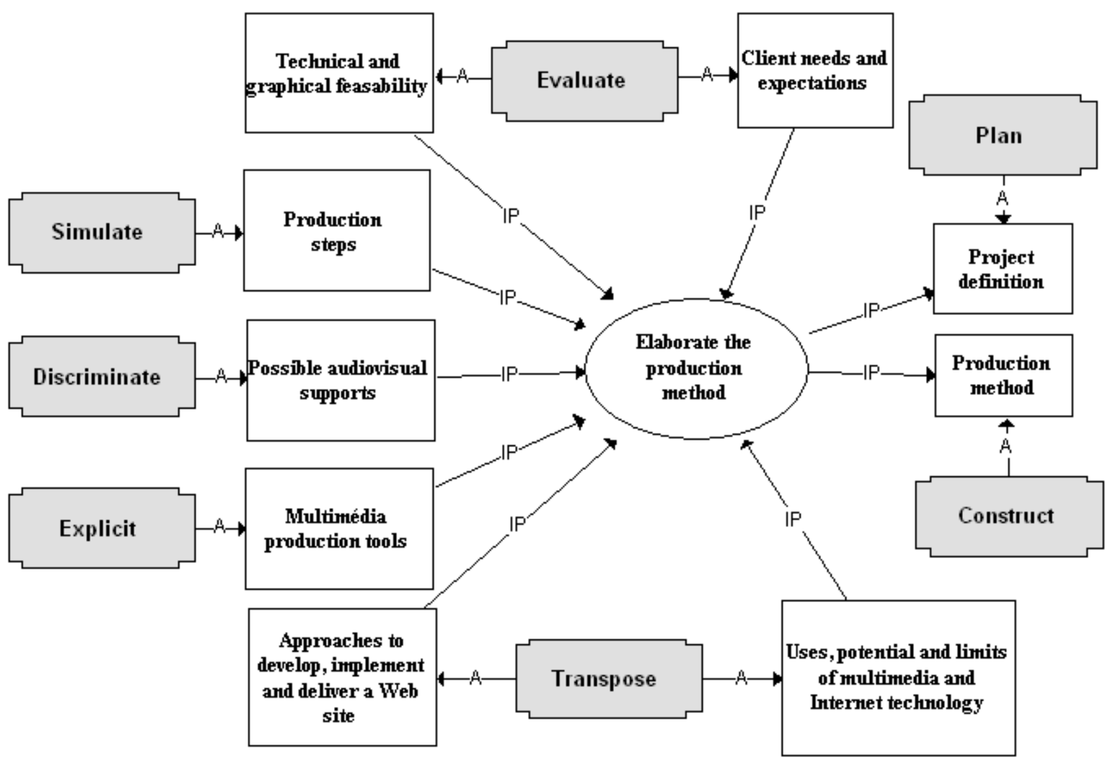

Figure 7.10 – An example of a knowledge sub-model and associated generic skills

To each knowledge element, we can associate a skill selected from our taxonomy. For example, for the production method, a suited generic skill is " to construct", for the definition of the project, "to plan ", and so on. For the possible audiovisual supports and the production tools, the multimedia director is not the one who will use them, so he needs a low level of mastery such as "discriminate" or "explicit". In other cases, he must possess a higher level of competency such as "simulate the production steps" or "evaluate the technical and graphical feasibility of the project".

Interpretation Examples

Table 6 presents the overall result of this competency analysis process. It shows the initial competency statement we started from, the reformulation that results from our analysis and the decomposition of each statement in a standard interpretation given by the definition and the meta-models in the generic skills taxonomy. Also, the process has revealed missing or ill-defined competency statements.

Competency statement		**Interpretation**			
Initial formulation	**Reformulation**	**Generic skill**	**Type**	**Parent skill**	**Knowledge component**
None	Model a production method	Model	C	8- Synthesize	Production method
None	Plan a project definition	Plan	C	8- Synthesize	Project definition
Capacity to evaluate the technical and graphical feasibility of a project	Evaluate the technical and graphical feasibility of a project	Evaluate	C	9- Evaluate	Technical and graphical feasibility of a project
Knowledge of each production step	Simulate a production process	Simulate	C	5- Apply	Production steps
Knowledge of audio-visual support	Discriminate between properties of audio-visual support	Discriminate	C	3- Instantiate	Properties of audio-visual support
Knowledge of the use, potential and limits of Internet and multimedia technologies	Transpose in the project the use, potential and limits of Internet and multimedia technologies	Transpose	C	4- Transpose	Use, potential and limits of Internet and MM technologies
Superficial knowledge of multimedia creation tools (PC/Mac/Unix)	Explicit the main properties of multimedia creation tools (PC/Mac/Unix)	Explicit	C	3- Instantiate	Main properties of multimedia creation tools (PC/Mac/Unix)
Knowledge on approaches to develop, implement and deliver a web site	Transpose to the project a useful way to develop, implement and deliver a web site	Transpose in a useful way	C	4- Transpose	Approaches to develop, implement and deliver a web site

Table 6 – Standard interpretation of competency statements from a meta-knowledge point of view

Conclusion to Chapter 7

We have developed, in this chapter, an integrated taxonomy of generic skills. The taxonomy has the following characteristics.

- It allows one to represent generic skills as processes; such processes are generic in relation to the application domains associated with them; they are also generic in relation to generic skill types, whether cognitive, affective, social, or psycho-motor.
- Generic skills can be represented by process MOT models, i.e. models containing a procedure (with its inputs, products, and execution principles) and its sub-procedures (with their own inputs, products, and execution principles).

- Processes representing generic skills can be associated, by co-referencing, with specific application domains in which the cognitive, affective, social, or psycho-motor skill types are indicated by the letters C, A, S, or P depending on whether they refer respectively to rational constructions, affective attitudes, social attitudes, or perceptions of movement.
- Generic skills are structured in relation to each other in a hierarchy from general to specific (through S links) until a final level is reached that is no longer a skill but a process specific to an application domain such as "diagnose a malfunctioning digestive system in a patient."
- The first two levels of the hierarchy in Figure 7.1 contain generic skills in an increasing order of complexity. For example, the general ability of self-management contains (involves) sub-processes of creation, which in turn contain sub-processes of reproduction, which in turn contain more basic sub-processes of reception. Such ordering is not necessarily valid for the other levels of the hierarchy.

In light of our definition of competency at the end of Chapter 5, we are now able to represent a competency in detail by specifying an application domain (through a MOT model), the generic skill that applies to knowledge in the application domain (through a MOT co-domain), and the actors and target populations that regulate the generic skill (through principles that are defined, as required, by another MOT co-domain). By combining target populations, generic skills, and one or more knowledge objects, we are able to arrive at a clear, constructivist concept of competency.

The next chapter will explore applications of this approach to various instructional engineering tasks such as modeling knowledge, developing task scenarios, selecting resources for actors in a scenario, or modeling actors in order to personalize learning or work environments.

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