Chapter 6 – Taxonomies of Problems and Generic Skills

Abstract

Generic skills as problem-solving processes

Generic skills as active meta-knowledge

Generic skills within learning objectives

An integrated cycle of skills for Education

Comparison of taxonomies of skills

Concept of generic skill

The aim of this chapter is to define what we call "generic skills," i.e. structured sets of intellectual actions, attitudes, values, and principles that are at the heart of human competencies. We will first examine the various systems that offer different yet convergent views regarding skills.

One multi-viewpoint approach to the concept of skill first analyses the taxonomies of generic problems developed in software engineering. Generic problems correspond to human problem-solving skills as described in cognitive science. Another viewpoint is the concept of active meta-knowledge that situates skills in the realm of meta-cognition, i.e. as knowledge acting on other knowledge. A third viewpoint considers research in education that presents skills in the form of taxonomies of learning objectives in relation to cognitive, affective, social, or psychomotor domains.

We will conclude the chapter with a comparison of the various analysis systems and a definition of generic skills, thus forming the basis for an integrated taxonomy of skills that will be developed in the next chapter.

6.1 Generic skills as problem-solving processes

The notion of "generic" problems, tasks and methods, is at the heart of research in software and knowledge engineering (expert systems). Generic problems, tasks, and methods are three widely interchangeable terms representing different viewpoints of the same reality. They will be given specific meaning using the MOT representation system.

The notion of generic problems or tasks was already present in one of the first reference books about knowledge-based systems (Hayes-Roth, Waterman & Lenat, 1984, Waterman 1986, Paquette &Roy 1990); in this work, we find a first classification of generic problems into ten categories. In pioneer studies about generic tasks at Ohio State University (Chandrasekaran 1983; 1987) these are defined through a problem description and a resolution method, which is a specific information processing algorithm. It introduces the idea of combining a small number of generic methods to solve large classes of more complex problems. Other work on generic problems (McDermott 1988), and the "expertise components" approach (Steels, 1990) must be mentioned.

The KADS method (Schreiber, Wielinga & Breuker, 1993), and its most recent version CommonKADS (Breuker & Van de Velde, 1994), is a synthesis of these studies. It actually constitutes a complete methodology integrating knowledge acquisition for expert systems with concepts of project management, organizational analysis, knowledge and software engineering. In KADS, an engineering software project materializes by building seven models. Four of them are of interest here: the “domain model”, the “inference model”, the “task model” and the “strategic model”.

In the *inference model*, we find a decomposition of the generic task into a task tree and a set of inference schemas associated to the leaves of this tree. The *task model* provides control principles, i.e. rules to manage the order of execution within the tasks. The “strategic model”, corresponds to heuristic principles that guide tasks execution. Together, these three models correspond to the notion of a generic process, applicable to various application domains (called “domain models” in KADS).

A **generic problem** is characterized by one or several goals or results to be produced (which are meta-concepts); initial data (also meta-concepts) and a number of operations (meta-procedures) that transform the initial data into results or goals. One recognizes here the notion of a process, one of the categories of problem presented in Chapter 3.

The KADS method defines eight classes of generic problems presented in Table 6.1.

Generic task	Generic problem	Input (data)	Results (goal)
Classify	Determine an object’s category	Classes hierarchy; Object’s attributes	Object’s classes
Diagnose	Determine the cause of the problem	Symptoms, system’s component model	Defective components
Predict	Determine the future state the system	System’s components; attributes that will vary	States: classes of the system’s possible instances
Supervise	Determine a deviation class between a system’s instance and another which is said to be normal	System’s components and attributes; normal instances	Instance class according to the difference with the norm
Repair	Modify a system’s component so it is in working order	System’s model; maintenance standards	Modified model
Plan	Break down the task into steps	Deliverables, sub-tasks, time constraints	Process: sequence of tasks, input and output
Design	Build an object (artifact)	Artifact properties, constraints to be met	Object model
Model	Build a behavioral system model	Goals, constraints, components, viewpoints.	Model of a system’s processes and evolution strategies

Table 6.1 – Taxonomy of problems in the KADS method

To each generic problem corresponds a **generic task**, which is a goal to be attained by applying a generic procedure to the input and to produce results, as indicated in Table 6.1. Breaking down this generic procedure into sub-procedures results in the KADS tasks tree. After a number of levels, terminal-level tasks are reached, to which the KADS method associates an inference schema that details a simple procedure to be executed in a single step.

Figure 6.1 shows a MOT model for the generic problem of diagnosis similar to the example in figure 3.14. The Control principles, similar to those on figure 3.13, correspond to the task model in KADS.

The model is composed of an input: the model of a system of components to be diagnosed. The model main knowledge objects is a generic task, “make a diagnosis”, and an expected result or problem solution: a list of defective components. The generic task is broken down into sub-tasks, up to terminal tasks such as “decompose the model”, which generates some hypothesis about faulty components. An inference schema, selected in the KADS library, is associated to this terminal task. Using these schemas, the generic task can be applied to an application domain such as “test a stereo system”.

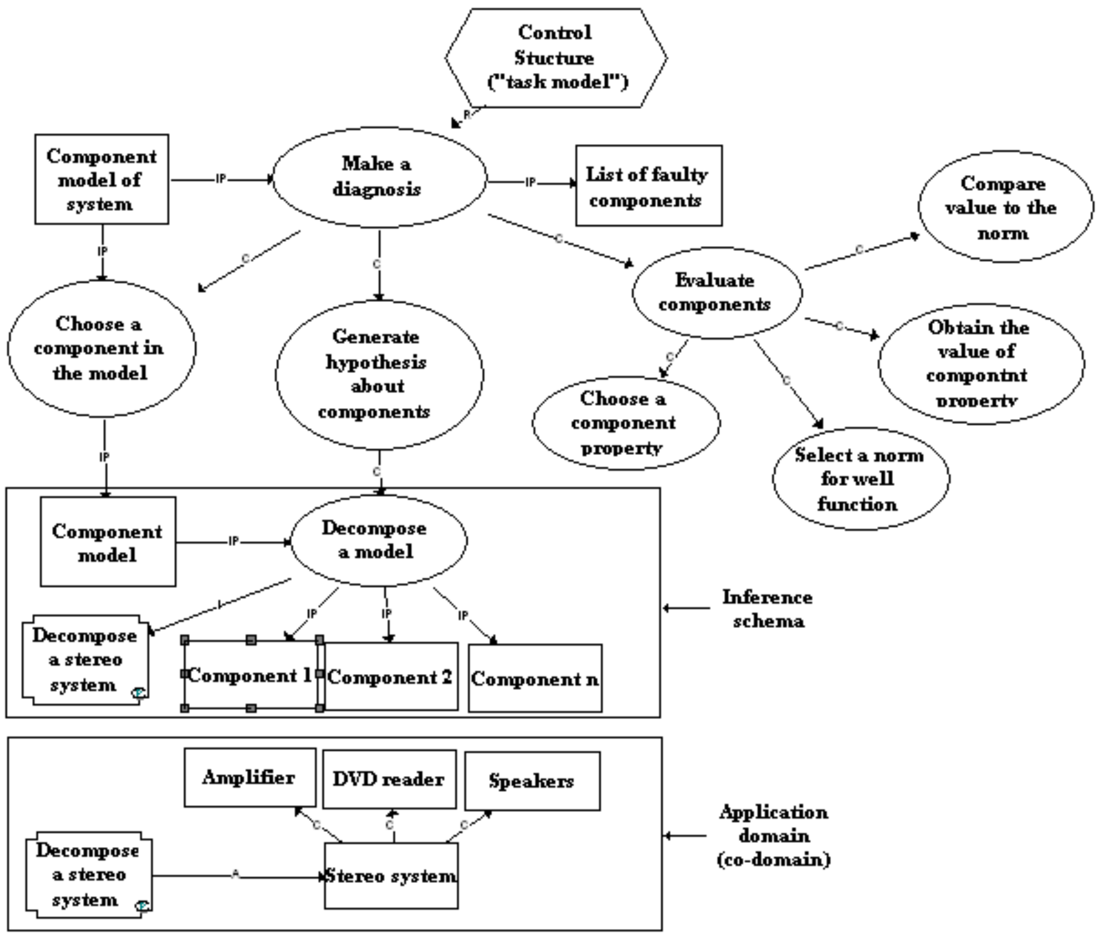

Figure 6.1– Example of a generic process: Diagnosis

The model in Figure 6.1 uses the concepts of co-referencing presented in Chapter 4. The meta-procedure “Decompose a model” is instantiated to “Decompose a stereo system” which, in the application domain, applies to the stereo system to produce its sub-components: amplifier, DVD reader, speakers.

Each terminal task can thus be associated with an inference schema drawn from the KADS library. The KADS method provides library of inference schemas that can be associated with terminal tasks of generic problems. Table 6.2 is an adaptation of the library presented in Breuker

& Van de Velde (1994) where the operations are described in detail and can be used for programming purposes.

Class	Inference schema	Description
Generation operations allow creation of a new knowledge object from another	**Instantiation**	A value is given to all attributes of a concept, thus generating an instance, a facts system.
	Generalization	A concept is identified that, once instantiated, should provide one or several instances.
	Abstraction	A more general concept is obtained from another through elimination of attributes or attributing values to a less attributes than in the original concept.
	Specification	A more specialized concept is obtained from another one by adding attributes or by giving values to more attributes than in the original concept.
Restructuring operations allow transformation of an input model	**Assembling**	A new model is obtained in which the components are the input model to the operation
	Decomposition	A set of sub-models is obtained that are components of an input model
	Transformation	A model is obtained from the input model by adding or removing one or several components.
	Sorting	A model is obtained from the input model by reordering its components according to an order relation, a precedence relation
Differentiation operations generate new knowledge by comparing concepts or models	**Comparison**	Attribute values of two concepts are compared and result in a decision ?
	Matching	Two models are compared and a model formed with common components is built
	Selection	One or several models are chosen from a set, according to a observations sets that serve as filters
Transfer operations allow communication between the process and an external agent (user)	**Obtaining**	The resolving system obtains information by requesting it to an external agent
	Presenting	The resolving system decides to present information to an outside agent.
	Receiving	An external agent decides to provide information to the resolving system
	Sending	An external agent request the sending of information to the resolving system

Table 6.2 – Inference schemas of the CommonKADS system

This way of describing generic problems, tasks, and methods is fundamental to software engineering, but is it suitable for describing human activity and especially the concepts of skill and competency as they apply to human actors?

To answer this question, we refer to the founding work of cognitive psychology. We will cite but two authors whose work is strongly consistent with the material presented above.

Like his compatriot Vygotsky (1978), the Russian developmental psychologist Leontiev (1976), advanced the theory that human activity is a voluntary interaction between subjects having intention and who are defined by their social contexts (actors) and material or symbolic objects that these subjects wish to acquire and/or transform. Leontiev's model consists of three interdependent levels:

- The highest level involves the *elaboration of intentions*. Intentions help to focus attention and set goals based on one's needs, values, and motivations.
- The middle level involves *action as a logical unit of inner transformation.* At this level, strategies and plans are formulated through goals/means analyses based on the above set goals.
- The lower level involves *necessary operations for achieving action plans*. At this level, expertise and basic procedures for often-automated routines come into play.

In KADS language, the three levels correspond respectively to strategic models, inference and task models, and inference schemas. What we call "generic skills" will be represented by a combination of these models in the form of a generic processes.

This theoretical hypothesis converges with the work of American psychologist Bruner (1973), considered one of the founders of cognitive psychology. For Bruner, the full cycle of a deliberate action consists of a transformation from an initial state to a final state (level of action and operations) guided by a certain number of higher mental operations such as:

- *temporal sequencing*, which provides an imprint of the activity's path from initial state to final state.
- *goal-directed sequencing,* or intermediary states
- *autonomous anticipation and voluntary persistence*, which help subjects set and reach states they have chosen for themselves
- the use of strategies that are *sensitive to context* and to changes in the initial intention
- *interactive management* of strategies through internal comparison of expected and actual outcomes and through external evaluation.

This approach is also similar to that of Newell & Simon (1972) in their building computer models of problem solving to better understand human problem solving.

In this framework, skills become components of problem solving methods in the form of processes whose products are intermediate and final goals and whose inputs are initial states or intermediate states resulting from the use of other skills.

6.2 Generic skills as active meta-knowledge

Although many studies involve meta-knowledge, most of the time, the term is not explicitly used. These studies can be found in various domains such as mathematical logic (Thayse, 1988), scientific methodology (Popper, 1967), problem resolution and its teaching (Polya, 1967), education (Romiszowski, 1981), learning environments (Paquette 1991; Merrill, 1994), software and cognitive engineering (Chandrasekaran, 1987, Breuker, Bredeweg, Valente, & van de Velde, 1993), artificial intelligence (Anderson, 1990, Minsky, 1988, Pitrat, 1990, 1993).

Jacques Pitrat has produced an important synthesis in which he distinguishes several meta-knowledge categories and proposes the following definition : "meta-knowledge is knowledge about knowledge, rather than knowledge from a specific domain such as mathematics, medicine or geology." (Pitrat, 1993, p.55, translated by the author)

Romiszowski (1981), talking of meta-knowledge that he calls "skills", expresses very well the simultaneous phenomenon of knowledge acquisition in a particular domain, and meta-knowledge building : "The learner follows two kinds of objectives at the same time - learning specific new knowledge and learning to better analyze what he already knows, to restructure knowledge, to validate new ideas and formulate new knowledge », an idea expressed in another way by Pitrat (1990) "meta-knowledge is being created at the same time as knowledge".

In other words, meta-knowledge develops while it is applied on knowledge in various field. Anybody learning new knowledge uses meta-knowledge (at least minimally) without necessarily being aware of it. However, using meta-knowledge should really be a learner's conscious act. This is what meta-cognition is about (Noël, 1991).

Meta-knowledge is knowledge that eventually leads individuals to improve the way they learn, thus facilitating transfer operations from known application domains to new ones and enabling them to learn more autonomously.

By examining a large corpus of literature, Pitrat (1990) describes the various types of meta-knowledge, which consists in transforming information into knowledge:

- by attributing values to knowledge from other domains : truth, usefulness, importance, knowledge priority, competence of an individual towards a knowledge object, etc.

- by describing "intellectual acts", processes that facilitate knowledge processing in other domains: recall, understanding, application, analysis, synthesis, evaluation, etc.

- by representing strategies to acquire, process and use knowledge from other domains : recall techniques, heuristic principles for problem solving, project management strategies, etc.

Of particular interest for our definition of competency is the distinction between passive and active meta-knowledge: “Some meta-knowledge plays an active role; for example, in a self-regulating system, knowledge about using knowledge allows the system to choose the best testing procedures to improve its immediate effectiveness, while knowledge about discovering knowledge allows it to create new knowledge for improving its future effectiveness (...). Active meta-knowledge requires knowledge about processed knowledge, resulting in a second type of meta-knowledge—properties about knowledge. To store knowledge, it is better to have an idea about the importance and credibility one attributes to it. Active meta-knowledge creates this other meta-knowledge, which is then used by other active meta-knowledge.” Pitrat (1990, p.205, translation by the author)

Active meta-knowledge is knowledge that processes other knowledge and, as such, can be integrated into artificial intelligence programs. Pitrat defines six types of active meta-knowledge; their interactions are presented on figure 6.2 using a MOT model.

- **Knowledge acquisition** consists in examining and diagnosing available information and knowledge, completing it, if incomplete or inconsistent with other knowledge previously acquired, and reformulating it, as needed, so it may be stored in memory.

- **Knowledge storage** consists in deciding where and how to register knowledge in a structured way in memory so it can become quickly available when needed, following the shortest association chains, without having to systematically scan memory.

- **Knowledge search** is essentially a set of knowledge reconstruction operations to extract from memory the knowledge needed to solve a problem or accomplish a task.

- **Knowledge discovery** regroups a set of operations like instantiation, specialization or analogy, which allow transformation of acquired knowledge into new knowledge.

- **Knowledge use** regroups a set of operations required to apply knowledge that has been extracted or reconstructed in memory, in order to build a solution for a problem, designing and managing solution plans and results explanation.

- **Knowledge expression,** is the inverse of acquisition, to communicate acquired knowledge to another information processing system, generally a human being; these operations enable us to choose what to say and how to say it, according to the recipient’s model.

Figure 6.2 shows the relationships between different kinds of active meta-knowledge. *Discovery* is the only meta-knowledge that produces new knowledge from raw data or information. *Acquisition* is the meta-knowledge that follows to evaluate knowledge and decide if and how it will be stored in memory. Through the acquisition process, resulting knowledge is structured, reorganized and assessed, notably as regards its validity and interest. *Storage* meta-knowledge help decide how new knowledge from the study domain as well as improved active meta-knowledge will be integrated in memory. The storage actions will facilitate subsequent knowledge identification together with the associated meta-concepts values, evaluated during acquisition, thus increasing the available knowledge pool. Reverse operations may then be followed: *search* for knowledge in memory to communicate it through *express* meta-knowledge and to apply it through and *use* meta-knowledge.

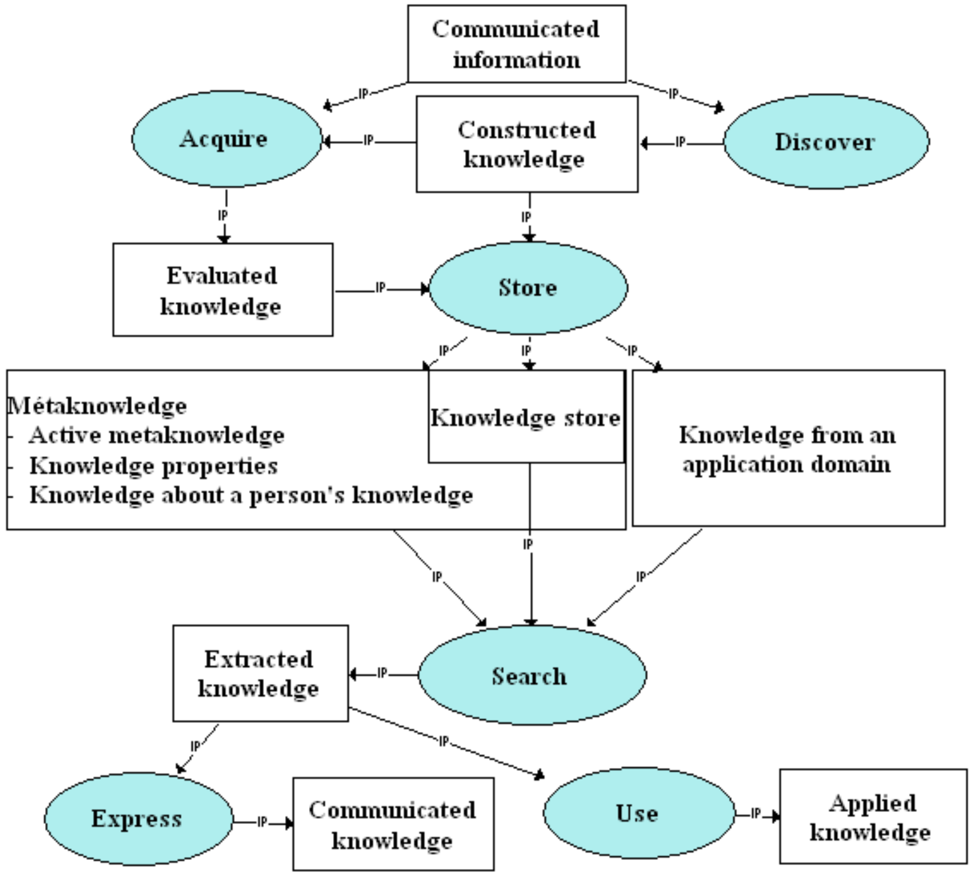

Figure 6.2 Relationships between active meta-knowledge

Like the generic problems it serves to solve, active meta-knowledge also corresponds to skills. This approach allows skills to be situated in a "meta-domain," i.e. one that studies knowledge and is parallel to the application domain. This provides us with another perspective on the concept of skill, and a way of representing skills in co-domains of application domains.

6.3 Generic skills as action verbs related to learning objectives

Theoretical work in education during the 1960s and 70s has led researchers to classify learning objectives and outcomes into three categories or domains: the cognitive domain, involving the knowledge and skills that regulate rational behavior, the affective domain, involving attitudes and emotions, and the psycho-motor domain, involving physical behavior and actions. Authors also talk about multiple intelligences: cognitive and rational intelligence, emotional intelligence, and physical and behavioral intelligence.

As noted by Martin & Briggs (1986, p. 9) : "This subdivision was, for the most part, arbitrary since psychologists and educators agree that, in actuality, that is, in teaching and real-life learning situations, no true separation of cognitive, affective, and psychomotor states was possible."

Despite this recognition of the holistic nature learning, practical and theoretical work has concentrated on one domain or the other without taking into account interactions between domains. For example, Joyce & Weil (1980) produced a summary of teaching models for educational practitioners in which each model is presented by its contribution to learning in terms of it effect on the cognitive or affective domain but never both.

On a theoretical level, taxonomies of educational outcomes reveal the same polarization of domains.

The first taxonomy of objectives in the cognitive domain was developed in the 1950's by a group under the direction of Benjamin S. Bloom; a taxonomy of objectives in the affective domain followed, published by Krahtwohl et al. in 1964, and a third one, in the psychomotor domain, by Harrow in 1972.

The first two taxonomies are presented in Tables 6.3 and 6.4.

In Bloom's *taxonomy of educational objectives in the cognitive domain* (1956), behaviors are organized into six main categories from simple to complex and divided into sub-categories. Each category can be associated with a set of action verbs that allow the learning objectives or competencies to be expressed, for example, in the following way: The student should be able to *recognize* (Category 1) the correct rules in various contexts" or "The student should be able to *validate* (Category 6) a text without help."

Educational objectives (cognitive domain)	Action verbs
1.00 KNOWLEDGE 1.10 Knowledge of specifics 1.11 Knowledge of terminology 1.12 Knowledge of specific facts 1.20 Knowledge of ways and means of dealing with specifics 1.21 Knowledge of conventions 1.22 Knowledge of trends or sequences 1.23 Knowledge of classifications and categories 1.24 Knowledge of criteria 1.25 Knowledge of methodology 1.30 Knowledge of the universals and abstractions in a field 1.31 Knowledge of principles and generalizations 1.32 Knowledge of theories and structures	Identify, define, recall, recognize, find
2.00 COMPRÉHENSION 2.10 Translation 2.20 Interpretation 2.30 Extrapolation	Explain, reformulate, interpret, translate, illustrate, distinguish, predict
3.00 APPLICATION	Relate, use, transfer, select, simulate
4.00 ANALYSIS 4.10 Analysis of elements 4.20 Analysis of relationships 4.30 Analysis of organizational principles	Distinguish, classify, categorize, compare, deduce, detect
5.00 SYNTHÈSIS 5.10 Production of a unique communication 5.20 Production of a plan, or proposed set of operations 5.30 Derivation of a set of abstract relations	Form, write, plan, create, model, produce, construct, repair
6.00 ÉVALUATION 6.10 Judgment in terms of internal evidence 6.20 Judgment in terms of external criteria	Judge, argue, criticize, validate, standardize

Table 6.3 – Taxonomy of the cognitive domain (adapted from Bloom, 1956)

Educational objectives (affective domain)	Action verbs
1.0 Receiving (attending) 1.1 Awareness 1.2 Willingness to receive 1.3 Controlled or selected attention	Become aware, pay attention, perceive
2.0 Responding 2.1 Acquiescence in responding 2.2 Willingness to respond 2.3 Satisfaction in response	Show willingness, be involved, take satisfaction
3.0 Valuing 3.1 Acceptance of a value 3.2 Preference for a value 3.3 Commitment (conviction)	Accept, prefer, commit
4.0 Organization 4.1. Conceptualization of a value 4.2 Organization of a value system	Construct, organize
5.0 Characterization by a value or value complex 5.1 Generalized set 5.2 Characterization	Self control

Table 6.4 – Taxonomy of the affective domain (adapted from Krathwohl et al., 1964)

In Krathwohl, Bloom & Masia's taxonomy of *educational objectives in the affective domain* (1964), behaviors are more difficult to classify than in the cognitive domain. The authors use the principle of internalization of values, in which “the ordering of components (of the taxonomy) moves from simple perception to the ability to control one's behavior” (p. 27). The categories are defined in terms of concepts such as emotion, degree of acceptance or rejection, interest, attitude, and appreciation and integration of values.

Various researchers have assessed the hierarchy of categories in both domains. They seem to be more firmly established for taxonomies of the cognitive domain than for those of the affective domain.

Taxonomies of the cognitive domain are sometimes criticized for over-developing the first category but under-developing the other categories. Other limitations concern the non-inclusion of affective-type constructions. Some categories overlap between the two types of taxonomies, particularly “knowledge” and “reception”, and “assessment” and “valuing”. The fact remains that these two taxonomies have been and are still widely used in educational practice.

Relatively few studies have dealt with the integration of cognitive, affective, psychomotor domains. There are, however, studies in which the domains are defined somewhat differently than in the work of Bloom.

For example, Gagné (1977) has proposed taxonomy of learning behaviors in five domains, the first three of which correspond to the cognitive domain.

- *Intellectual skills:* ability of learners to use symbols for organizing, interacting with, and understanding the real world.
- *Cognitive strategies:* abilities guiding behavior related to recall, problem solving, and learning.
- *Verbal information:* factual information stored in memory allowing one to name things and facts, memorize sequences, and organize information.
- *Motor skills:* ability to execute movements.

- *Attitudes:* mental state or tendency influencing one's choice of physical or mental actions.

As well, Foshay (1978) describes six learning domains, the last four of which appear to include affective components:

- the *intellectual* domain: similar to Bloom's cognitive domain
- the *physical* domain: psycho-motor skills; development of physical self-concept
- the *emotional* domain: development of feelings and emotions
- the *social* domain: development of social behavior
- the *aesthetic* domain: formal, technical, or expressive sensory response to the examination of an object
- the *spiritual* domain: the search for deeper meaning

These approaches do not seek integration but an exhaustive description of human abilities.

6.4 An integrated cycle of skills

The classification of skills proposed by Romiszowski (1981) is different from the one proposed for taxonomies of objectives because it supports an integrated treatment of four categories of skills: cognitive, affective, social, and psychomotor.

His definition of a skill is: "intellectual or physical actions, or even reactions, that a person produces in a competent manner to reach a goal. To do so, knowledge stored in memory is used (...). Any skill may be composed of four activities : perception, planning, prerequisite knowledge recall, and finally, execution of the action (performance)". (p. 253).

He also distinguishes between reproductive and productive skills. Reproductive skills in the cognitive domain correspond to the first three categories of Bloom's taxonomy of the cognitive domain and the first three categories Krathwohl et al's taxonomy of the affective domain. Productive skills correspond to the last three categories of Bloom's taxonomy and the last two of Karthwohl et al's taxonomy. This dual classification results in Table 6.5, in which the author provides examples for each type of skill.

	Reproductive Skills **Applying procedures (algorithms)**	**Productive Skills** Applying principles and strategies
Cognitive Skills Decision-making, problem-solving, logical thinking, etc.	Applying a known procedure to a known category of 'problem', e.g. dividing numbers, writing a grammatically correct sentence.	Solving 'new' problems; 'inventing' a new procedure, e.g. proving a theorem, writing creatively.
Psychomotor Skills Physical action, perceptual acuity, etc	Sensori-motor skills, repetitive or automated action, eg typewriting, changing gear, running fast.	'Strategy' skills or 'planning' skills ; arts and crafts, e.g. page layout design, 'road sense', playing football,
Reactive Skills Dealing with oneself ; attitudes, feelings, habits, self-control.	Conditioned habits and attitudes, e.g 'attending, responding and valuing' (Bloom taxonomy), approach/avoid behaviors (Mager)	'Personal control' skills, developing a 'mental set' or a value system (Bloom), 'self-actualization' (Rogers)

Interactive Skills Dealing with others	Social habits ; conditioned responses, e.g good manners, pleasant tone, verbal habits.	'Interpersonal control' skills, e.g leadership, supervision, persuasion, discussion, salesmanship.

Table 6.5 –Classification of skills (Romiszowski)

Rather than categorizing skills according to the type of individual response to a stimulus (new knowledge, affective attitudes, social behavior or motor actions), Romiszowski characterizes them according to their functions in the information treatment cycle through which one perceives and transforms knowledge in a given situation.

It is here that Romiszowski departs from the behaviorist approach by examining what happens between stimuli and actions. At first, the non-observable mental actions triggered by stimuli consist in the recall of useful knowledge stored in memory by virtue of the skill's reproductive components. Then, responses are planned through the skill's productive components. This leads to a cycle of skills in 4 phases and 12 basic skills that may or not be present as individual components of complex skills (p. 257). As indicated in Table 6.6, these four phases describe a cycle of information processing that uses skills belonging to several domains.

Phase	Skill	Description
Perception	Attention	Ability to concentrate on a task
	Perceptual acuteness	Ability to recognize the stimulus
	Discrimination	Ability to recognize the stimulus among other similar ones
Recall from memory	Interpretation	Knowledge of the stimulus language
	Procedure recall	Presence of an adequate algorithm in memory
	Schema recall	Presence of relevant concepts and principles in memory
Planning	Analysis	Ability to restructure the problem
	Synthesis	Ability to generate alternative solutions
	Evaluation	Ability to assess alternate implications
Performance	Initiation	Ability to make decisions and act accordingly
	Continuation	Ability to carry through with action
	Control	Ability to self-adapt and self-correct

Table 6.6. Classification of skills proposed by Romiszowski

This cycle of skills applies to the four domains defined above: cognitive, psycho-motor, affective, and social; it is presented as an analysis tool for identifying causes of poor performance of a complex skill. For example, the inability to diagnose engine failure or an imperfect dive depends on of the 12 causes, or components of the skills, presented in Table 6.6.

The author presents the cycle as follows: "It is a language for analyzing skills—a taxonomy if you prefer. But there is no hierarchical relationship of dependency. A complex skill may require, to varying degrees, a combination of the 12 factors or basic skills" (p. 257).

6.5 Comparison of the taxonomies related to generic skills

Despite the different goals and approaches, it is possible to establish a comparison between the various taxonomies presented in this chapter. Table 6.7 presents an integrated comparison based on a list of skills compared with 10 basic categories to be further discussed in the next chapter.

Generic processes (competency levels)	Generic problems (KADS)	Inference schemas (KADS)	Active meta-knowledge (Pitrat)	Taxonomy of cognitive objectives (Bloom)	Taxonomy of affective objectives (Krathwohl)	Skills cycle (Romizowski)
1. Pay attention				Knowledge	Receiving	Attention Perceptual acuteness
2. Memorize		Instantiation Obtaining Presenting	Knowledge storage Knowledge Search	Knowledge	Responding	Perceptual discrimination Interpretation
3. Explicitate		Matching Comparison Selection	Knowledge expression	Comprehension	Responding	Procedures recall Schema recall
4. Transpose			Knowledge use	Comprehension		
5. Apply		Specification, Sending, Presenting	Knowledge use	Application		
6. Analyze	Classify Diagnose Predict Supervise	Decomposition Sorting	Knowledge discovery	Analysis		Analysis
7. Repair	Repair	Transformation Sorting	Knowledge discovery	Synthesis	Organization	
8. Synthesize	Plan Design Model	Generalization Abstraction Assembling	Knowledge discovery	Synthesis	Organization	Synthesis
9. Evaluate			Knowledge acquisition	Evaluation	Characterization	Evaluation
10. Self-control			Knowledge acquisition	Evaluation	Characterization	Initiation Continuation Control

Table 6.7 –Comparison of skills' taxonomies

It should be noted that these correspondences are approximate. The purpose of the table is to show an important level of convergence between the taxonomies. The concept of generic processes presented in the first column can be used to reconcile these classifications. To establish associations between the different systems, we must consider the type of input and product (output) for each term, as well as the process a description of the process to be applied.

Acquisition meta-knowledge is difficult to position because its nature is perceptual as well as evaluative. It involves meta-cognition and the attribution of properties to acquired knowledge. This is the main reason why it is classified at the evaluation and self-control levels.

The libraries of inference schemas and generic problems in KADS are positioned at different levels of granularity. Inference schemas correspond to terminal generic processes operations. On the other hand, KADS generic problems library is of a very high level. Their correspondence is solid as regards to the terms "analysis", "repair" and "synthesis" used in the first column.

6.6 The concept of generic skill

We have adopted the concept of (generic) skill as central to the taxonomies presented in this chapter. We will now further develop this concept.

When we acquire specific knowledge in any domain, and while acquiring it, we learn various related skills. For example, we may be able to recognize that a quantity is a fraction but not necessarily be able to apply its definition in everyday life or evaluate whether or not the concept is valid. In a different domain, an individual may be able to recognize a recipe for "canard à l'orange", while another may be able to apply it; however, an expert chef is not only able to apply the procedure, but is also able to evaluate and compare different similar recipes and even invent new ones. In yet another domain, an individual may have an idea of the relative value of a particular type of investment, but a financial expert is able to analyze the client's situation, evaluate different investment vehicles, and create a portfolio tailored to the client's needs.

The above examples illustrate the following properties of generic skills.

Generic skills vary among individuals and are learned throughout life. Like other knowledge, generic skills are developed at different times in our lives. First, we develop attention and recall skills; then, we learn how to recognize and apply knowledge, perform physical tasks, and work in teams; finally, we learn how to use "higher" skills such as analyzing, integrating, and evaluating knowledge, engaging ourselves, communicating, and adapting. Moreover, we learn to practice a particular skill such as analyzing in increasingly varied and complex domains.

Generic skills are defined in terms of the knowledge to which they apply. Though they exist in themselves, skills are defined in relation to the knowledge to which they apply. Saying that someone is able to make a diagnosis or develop an integrated approach is a simplified way of saying that they are able to exercise these skills in relation to a diversity of knowledge and in domains that may be relatively new to them; nevertheless, they exercise these skills in relation to one or more application domains.

Generic skills are developed through several domains. We develop generic skills, such as the ability to diagnose, through our interactions in several knowledge domains. It is in this sense that they are "generic". We can diagnose simple problems such as paying an overdue bill, or we can diagnose more complex problems such as "debugging" a computer program or assessing a medical condition. Despite their differences, these diagnoses have several characteristics in common, so that mastering a skill in one domain can lead to its transfer, at least partially, in another domain.

Skills are meta-processes. Skills are essentially procedural in nature; they are processes that allow us to perceive, recall, understand, apply, assess, produce, and communicate knowledge. According to the definitions given in Chapter 2 and 3, they are meta-processes in the sense giving by the MOT system to this word. A skill is normally decomposed into sub-tasks that are other skills, their organization being regulated by principles of execution. Each skill also has its own inputs and products that are types of stimuli or knowledge resulting from the application of the skill.

One example is a generic skill "simulate a process". It has a specific process in an application domain as its input and an execution trace of the process as its product, which is the result of the simulation. One of its possible instances is "simulate the procedure to solve a linear equation". This is this instance of the skill that we will use in the Algebra domain in order to solve a particular equation of the form ax+c=b," where a=3, c=8, and b=2. In this case, the simulation trace would be: start with 3x+8=2: a procedure of subtraction of 8 on both sides (first task of the process) yielding 3x = -6; then a division action by 3 on both sides (second task of the process), yielding x = -2.

Psychomotor, affective, and social skills are also learned generic processes applied to knowledge in a variety of domains. All skills are developed through the participation of individuals in the various situations they encounter during their lives. These situations consist of objects, events, people, and interrelations that can be described by facts, concepts, procedures, or principles. For example, a psychomotor skill such as "ride a bicycle" is a process and a cycle of physical actions that lead to a specific goal: keeping one's balance; this result can be described by facts or knowledge. In the same way, an attitude of rejection or disinterest for a certain task, can itself be described by facts and knowledge or by comparing it with knowledge, values, and previous situations stored in memory. Finally, a social skill such as developing solidarity among team members around a common goal can be described as a process that begins with the sharing and comparing of points of view, the agreement on common goals, and the seeking of mutual benefit.

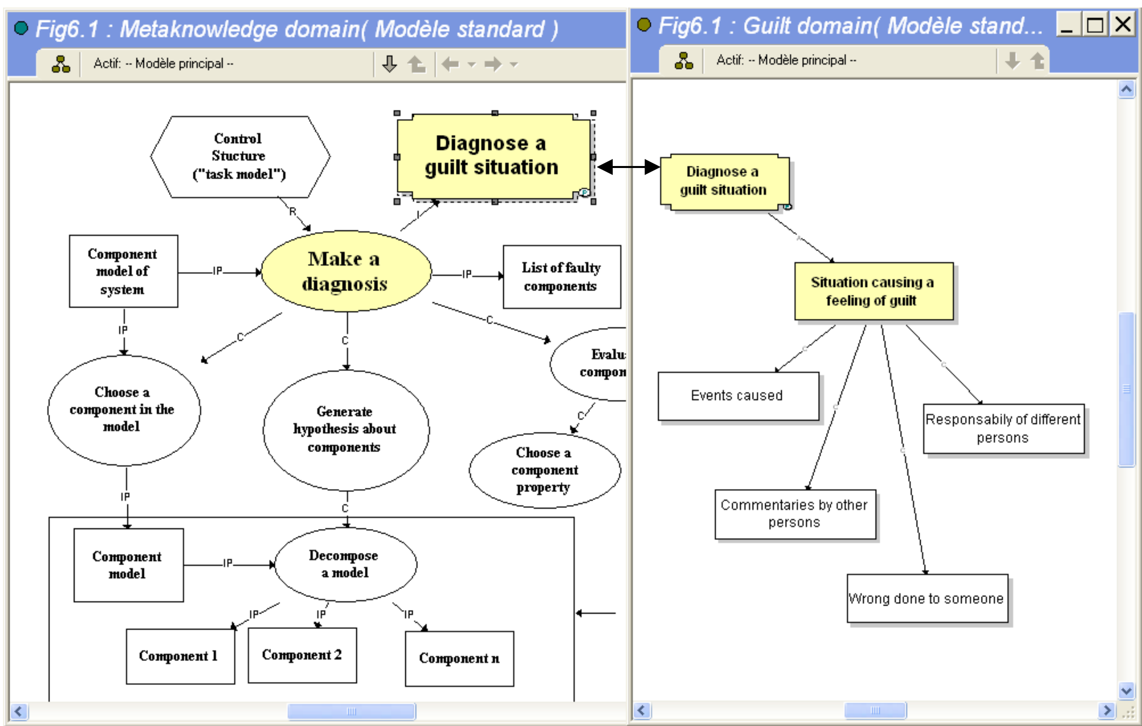

Figure 6.3 – Diagnosis skill applied to an affective situation

Figure 6.3 shows a generic process of diagnosis similar to that of Figure 6.1 but one that applies to a feeling of guilt that may be experienced in a certain situation. The diagnosis consists of decomposing the situation and evaluating each of its components in order to identify the cause of this affective state. This example demonstrates how generic skills are primarily described as a function of information processing, in which a person perceives and translates knowledge into acts and interacts in a given situation, rather than as a response to stimuli such as new information, physical actions, personal and social attitudes, etc. These are rather the product, the result of applying the generic skill to the inputs, whether they are information, physical action or attitudes.

Neurologists tend to situate the higher cognitive faculties in the neo-cortex. Others demonstrate the existence of an emotional memory leaving traces in other regions of the brain called the limbic system (LeDoux 1996; Goleman 1995). Here we make no particular psychological or neural hypothesis about cognition or affect, only seeking a unified way to model generic skills.

What we have here is a unified approach to classifying generic skills, seen as generic processes. Contrary to their traditional use in the definition of learning objectives, skills, as used in this book, are learning objects—knowledge that can be described, analyzed, and assessed per se or in relation to knowledge in other domains. As such, they should be included in knowledge models as targets of learning activities in the same way that knowledge objects are treated in any domain.

Conclusion to Chapter 6

Many studies in cognitive science, cognitive engineering, and education support the hypothesis proposed here that *human skills can be described as generic processes.* To be sure, the description of skills in this perspective is highly schematic and represents only a portion of reality. Nevertheless, representing skills in the form of processes provides a graphical, structural, and operational point of view and one in which skills can be integrated into a competency-driven instructional engineering or knowledge management methodology. Further more, to each generic problem or task corresponds a solution method. This method is a generic process that describes the skill that a human or artificial system must apply to solve a problem or perform a task.

Active meta-knowledge also describes generic processes and therefore skills. Viewing skills in this way allows us to situate and study them in a particularly important domain—that which studies knowledge. The relationship between skills and the knowledge to which they apply thus occurs in two domains: the domain of meta-knowledge and an application domain. This view is consistent with the multidimensional nature of human skills and competencies in their regard to different domains of knowledge.

Taxonomies of learning objectives in cognitive, psychomotor, and affective domains also describe skills. These taxonomies can be reused in the development of curricula and learning and assessment tools. Viewing taxonomic categories as generic processes frees them from their behaviourist origins. The stimulus-response aspect is no longer our main area of concern. Beyond the input/product relationship, a generic process model describes its components, its operations, the intermediate products and the principles that regulate the execution of the process. This amounts to describing the *internal functioning* of an actor performing such a skill-process, which is basically a cognitivist viewpoint.

Reinterpreting taxonomies of educational objectives in this way means that we no longer separate the psycho-motor, affective, or social domains, but that we distinguish these views only by the kind of stimulus and respond, not by the internal process that characterizes the generic skill. merely by the way in which a response manifests itself. For example, similar repair processes can be applied to modify a model (cognitive), an attitude (affective), a physical action (psychomotor), or a social behavior.

This is the basis upon which we will develop, in the next chapter, a taxonomy of generic skills substantiated by a library of corresponding generic processes.

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