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Intelligent Tutorial and Self Training System

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Intelligent Tutorial and Self Training System

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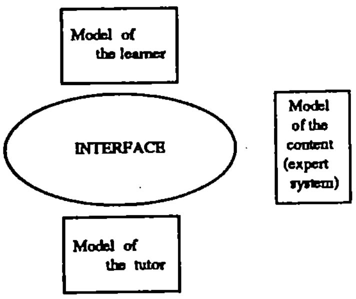
Abstract

Self training is presented as a challenge every citizen of modern society will have more and more to face. The issues and some existing trends or pathways are described in the framework of ITS. The paper ends with two models, one for ITS, and the other one for Monitoring and Tutoring.

A. COMPONENTS OF AN INTELLIGENT TUTORING SYSTEM

The majority of authors (WOOLF and Mc DONALD, 1984; DEDE, 1986) agree on decomposing an ITS into 4 main components, some of which taking advantage of A.I. techniques, resulting in so called Intelligent Computer Assisted Instruction (ICAI) :

a) an **expert model** (that contains both subject area knowledge and methods or heuristics) for solving problems);
b) a **student model** (that contains a representation of the learner's knowledge (prerequisite, antecedent acquisitions) and hypothesis concerning his learning preferences, weaknesses, etc.);
c) a **tutoring expert** (that contains rules and strategies for interactions between the system and the student);
d) an **interface**, i.e. "some kind of communication module" (that analyses (or parses) the requests and questions from the learner).



This paper will not be focussed only on the PROCESSES of learning and TUTORING, but also on the PURPOSE of learning. In the same way, it will not deal principally with the issue of HOW to tutor, but with the issue of WHY to tutor (on which basis) and with the relation of the two issues with each other. That will lead us to suggest modifications (conflexifications)to the above schema.

B. HOW SATISFACTORY IS ICAI ?

In each domain (e.g. transportation), there are often various technological solutions that overtop, in terms of cost/effectiveness ratios, all the others (e.g. the train, the plane, the car, the truck, the submarine, ...) in its fields of specificity (e.g. for repetitive ground liaisons, for air, for free itinerary, for heavy load, for deep see, etc.).

In their book "ITS, Lessons Learned", PSOTKA et al. (1988 p. 406) argue that "There is a real possibility in many instances that a CBI system that costs 20 % of an ITS could provide 80 % of the benefit" (NB : CBI = "simple" Computer Based Instruction). WOODWARD and CARNINE (1988) offer evidences that highly structured CAI is more beneficial for novices whereas more sophisticated students can take advantage of IA facilities.

It is obvious that ITS (or ICAI) is far more expensive to build than CAI that itself costed more than a classical lesson. But the efficiency depends on the problem that has to be solved. For instance, MEANS and GOTT (1988, p. 38), refering to simulation in electronic troubleshooting (apparently a field of specificity for ICAI), declare that "Considering the relative rarity of each particular fault within modern electronic systems, it is not at all unrealistic to think about providing the equivalent of 5 years of problem solving experience in just 50 hours with an automated tutor". Nevertheless, the users are expecting a high quality ouput from using ITSs. ROSENBERG (1987) argues that this has not even started to be proved, neither for CAI (but it is a matter of dispute with the opposite view point defended by KULIK) nor for ITS.

WOODWARD and CARNINE (1988) note that "Some writers (e.g. LIEBER and SEMMEL, 1985; SALOMON & GARDNER, 1986) ... warn that CAI may follow the same fate as educational television, teaching machines, and other innovative technologies of the last 25 years ...".

The same authors foresee such menaces for ICAI if they do not incorporate more "tutoring expertise". Others regret that "Given the computer science focus of ... ICAI, the attention given to learning and instructional theories has been minimal" (HAJOVY and CHRISTENSEN, 1987, p. 9).

ROSENBERG (1987, p. 7) may have an other (non exclusive) explanation to the fact that "most ITS papers ... reference little work in education", i.e. "ITS implementors are confronted with a paucity of pedagogical theory about tutoring. There is little consensus among educators - the experts - as to the best educational techniques. This might mean that education is a bad domain for an expert system - a computer systems that tries to replicate a human expert skill (such a tutoring)".

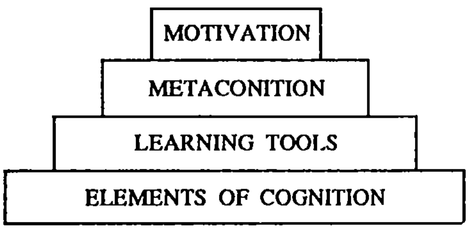
Since we define tutoring as "interactions to facilitate learning", it is obvious that the first concern must be for learning : what it is, and, then, what tutoring should and could be.

C. FOUR LEVELS OF LEARNING.

Human beings learn to be able to solve problems, either current ones or (essentially) future ones.

Among the future problems, some will always need the same type of (well known) solutions, of responses (the translation of words in a specific foreign language, the ways so solve equations, the physical concepts as defined by Newton, etc.).

Besides those situations, there exists a series of others that are impredictible, for which we ignore today exactly how they will be stated (in the future). In such a context, what trainers and educators can do is helping the learners to gain **internal resources** that will enable them, when time has come, to CONSTRUCT their solutions, adapted to the circumstances. These internal resources appear as a four levels mental "equipment".



1. The specific competencies (ELEMENTS OF COGNITION) deal with specific contents (geography, history, physics, language, ...) hardly transferable. These specific competencies are infinite and a human being can (and has to) know only some of them.

2. The **demultiplicative** competencies (LEARNING TOOLS) enable the learner to learn more specifics by him/herself : reading, listening, taking notes, communicating, interwiewing, using the computer to consult data base or to produce text, etc.

3. The strategic competencies are concerned with METACOGNITION, i.e. knowing oneself (as a learner, as an actor, etc.), one's weaknesses and one's excellences, and developing strategies to adapt to complex situations (for instance to chose which demultiplicative competency to use for learning, in given circumstances).

4. The dynamic competencies.are related to MOTIVATION, i.e. the pleasure a person takes in doing things, in learning specific, demultiplicative or strategic competencies. This level is the most vulnerable : it can be easily broken,. It is also the most "penetrating", i.e. the motor that drives the rest when facing a new domain in which the learner is to enter. That is the reason why we have represented those four levels as a bit (of a drilling-machine).

D. IMPLICATIONS FOR TUTORING.

Depending on which level is addressed, tutoring principles will differ. For instance, highly authoritarian CAI (inspired by skinnerian programmed learning) will essentially affect levels 1 (and sometimes 2). Moreover, they will frequently be successful only if levels 2 (reading) and 4 pre-exist, and if, during the process, the latter (4) is not diminished. This leads to consider the relationship between motivation and tutoring.

On the opposite side, methods that foster level 3 learning objectives (such as experiment and develop one's self learning strategies) may not garantee learning of specific contents (level 1).

1. MOTIVATION (level 4) and tutoring.

Famous defenders of ITSs are aware of the problem. For instance, BURTON and BROWN (1982, p. 91) state : "One of the most important constraints of the Coach is not to destroy the student's inherent interest in the game by butting in too often ... Some ... principles [have been] incorporated into WEST to **prevent it from being oppressive** [...] :

- Do not tutor on two consecutive moves, no matter what;
- Do not tutor before the student has a chance to discover the game for himself[...]
- Congratulate him;
- Offer him a chance to retake his turn, but do not force him to;
- Be forgiving [if the student makes a potentially careless error]; [...]
- If the student is losing consistently, adjust the level of play".

The third and the last principles (here over) reflect **the skinnerian paradigm of the reinforcing value of success**. This paradigm has been a great source of deception among experimenters who observed that for brilliant students, being correct to very easy questions is not reinforcing at all, but is boring and has the opposite effect to the predicted one.

Here, ATKINSON's (1964) views should be taken into account. For this author, **the reinforcing power of** (or the pleasure given by) **a success is complementary to the difficulty of a task** : U = 1-p (where U stands for "Utility of success" and p for "probability of success"). So, the expected utility of a success (EUS) is its utility (U) timed by its probability, i.e. EUS = p(1-p). This explains why "**success driven persons**", when given the choice, chose tasks of intermediate difficulty (p=0,5). This is not true for "**failure avoiding persons**" as O'SHEA (1982, p. 311) observes : "Some pupils had a very strong dislike of making mistakes and being told that a guess was wrong. They would guess rarely and reluctantly".

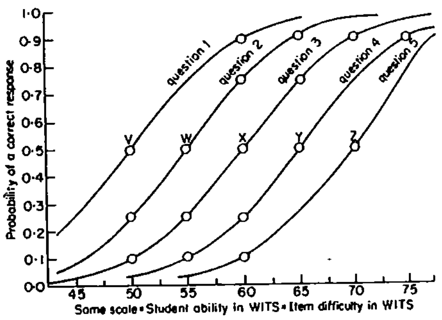
Typically, classical programmed learning texts (and CAI) wanting to "desinhibit" those kind of persons (the latters) are far too easy for the others (the formers). This is a first challenge for tutoring system.

Conceptual resources exist to face the issue. For instance, RASCH (1960) has described a model enabling to predict **the probability of success of a given student to a given question**, provided the student's capacity (C) and the question's difficulty (D) are known and expressed on the same scale (CHOPPIN recommending WITS scale (*)).

The general formula is :

$$p(1 \mid C,D) = \frac{W^{C-D}}{1 + W^{C-D}}$$

Each question has an Item Characteristic Curve (ICC), that is the fundamental information needed to provide "Adaptive Tailored Testing" (LECLERCQ, 1978).



2. METACOGNITION (level 3) and Tutoring.

Some gaming tutorial or evaluative situations request from the student a high level of metacognition. For instance, BROWN, BURTON and DE KLEER (1982, p. 236), in the SOPHIE gaming environment (where the "inserter" has to introduce a fault in an electronic circuit and the "debugger" must perform a sequence of measurements to find it), impose that "for each measurement the debugger makes, the inserter must predict whether the result of measurement will be higher, lower or approximately the same as that in a working instrument. The inserter is given a score of the total cost of the debugger's measurements multiplied by the percentage of times the inserter correctly predicted the outcome. Thus, **it is the advantage of the inserter to choose a difficult fault but not one so difficult that he can't predict its consequences**".

In other cases, the IA researcher must take into account that often the learners consider (answer) "I don't know anything about that ..." whereas their **partial knowledge** about the topic is important. As STEVENS, COLLINS and GOLDSTEIN (1982, p. 20) stated : "Instructions emphasized that even if the subjects felt they did not know an answer, they should try to answer the question nevertheless ... Subsequent probing revealed that often they knew a good deal more than they thought".

On the one hand, without answers from the students, the IA program could hardly collect substantial bodies of data on errors and misconceptions. On the other hand, when forced to provide an answer (specially when not certain) the learner should always be allowed to accompany it with a degree of confidence reflecting his **level of certainty**.

For the researcher, this **degree of subtility** is essential since it provides not only a better view of a given person's competency on a given topic, but offers also the possibility to measure **the individual's realism** (i.e. his skillfulness in an important aspect of metacognition).

The first objective is reflected by the type of instructions used by SOUGNE *et al.* (1990), concerning answering to a multiple choice question (figure 1) :

- for each alternative (here 5), answer by T (true) or False (F).
- then, give **ONE confidence degree of this set of (5) answers** using the following probability scale (recommended by LECLERCQ, 1988) :

SOLAR What are the parameters influencing the RECUPERATION of a building ?

T F Reference temperature (Ti)
T F Orientation
T F Ventilation (n)
T F Adjacency (g)
T F Free gains (Qi)

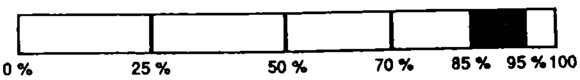


Figure 1 Confidence

(*)W = 1,24573. This number has been chosen because of his interesting properties such as $W^{10} = 9$, $W^5 = 3$, $W^{-10} = 1/9$ and $W^{-5} = 1/3$.

A graphic of **realism on this topic** can be drawn for this student (figure 2).

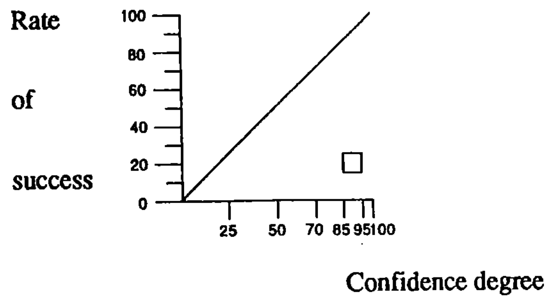


Figure 2

An other way of using confidence degrees is to ask students to **accompany each answer** (no matter it is an open-ended or a true-false or a MC question) **with one of the confidence degrees** of the same scale (figure 3).

What are the parameters influencing the SOLAR RECUPERATION of a building?

1. T F Reference temperature (Ti)
2. T F Orientation
3. T F Ventilation (n)
4. T F Adjacency (g)
5. T F Free gains (Qi)

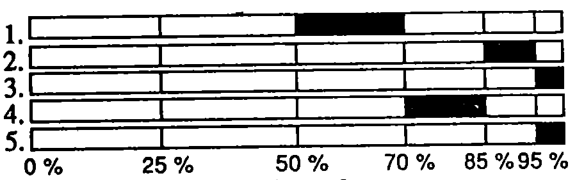


Figure 3

If the test has a sufficient number of answers (in the example of figure 4, there are 77 answers), it is possible to draw a graphic of the student's realism, and to compute indices of realism, of coherence, of centration and of acuity (LECLERCQ, 1990).

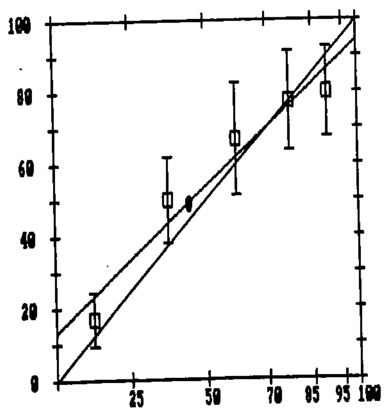


Figure 4

As DESCARTES (1628) already stated, **doubt** is the motor of knowledge. Because we doubt, we verify, we are cautious ... Doubt (partial knowledge) explains also why "a student does not always employ a skill which has just been explained", what GOLDSTEIN (1982, p. 73) calls "**learning conservatism**". This IA author introduced a "belief measure" combined with the hypothesis that "until belief in [a] piece of knowledge exceeds some treshold", it will not be employed.

In the IA program for the WUMPUS game, GOLDSTEIN had his "Psychologist module" (actually a part of his ICAI tutor WUSOR) "maintain a record of its estimate of the student's belief in a rule in terms of the types of explanations provided, their recency and their number".

We have shown that this kind of estimation could be confronted with the student's one. It must be noted that a series of **methodological conditions** should be fulfilled (see in LECLERCQ, 1983, the experimental description of validity, acuity, stability in time, role of instructions and payoffs, in confidence marking.

When the correctness of the answer may be judged **on a continuum** (e.g. for lengths, wheights, dates, numbers, ...), the learner can be invited to provide **an interval** as an answer, with the so-called fractiles method (PITZ, 1974).

The A.I. programs themselves use such subjective approaches. For instance, CLANCEY (1982, p. 209) notes that "GUIDON uses certainty factors for presenting the program's belief in something. Their value ranges between -1 and +1, with negative values signifying disbelief".

3. LEARNING TOOLS (level 2) and tutoring.

Besides the skills like reading, writing, etc. it is important that individuals master learning skills. It has become largely unsatisfactory to balance between two extremes : either being told what to know and what to do, or explore freely. It is urgent that the tutor and the learner **dialog on the learning process itself** while learning a content. There should be no shame in asking a student additional comment, because the system needs to know more about the learner's mental processes : "We should begin paying close attention to the student's understanding of the instructional system, in addition to the instructional system's understanding of the student's state of knowledge" (PIROLLI and GREENO, 1988, 190).

The student must be **a partner** in the learning process, accepting and even asking for dialoging possibilities such as the "entrapment technique" (CLANCEY, 1982, 219) forcing the student to make a choice that will reveal some aspect of his understanding.

In the same way, the learner should accept a process in which questions are **not explicit**, with the necessity for him to **detect** absurdities (revealed if not detected), lacks of data, impossibilities for correct solutions, wrongly stated issues, etc.).

LECLERCQ (1986) and BOXUS (1988) developed a special way of using multiple choice questions called **"Implicit General Solutions"**, conceived in order to measure "deep understanding of concepts and principles" (i.e. levels 2 and 4 of BLOOM's cognitive taxonomy) and **"cognitive vigilance"**. This technique enables the tester to measure the learner's comprehension with the latter being free to consult any book or document.

Estimation, by the learner himself, of parameters like the memorability of a task component and its complexity to understand, the degree of decay resulting from mental disuse, the prediction one's achievement, the estimation of one's current motivation, **should become** as **routine skills** as detecting orthographic errors or the length of a written passage, or the algorithms to use of a telephone book.

This should lower those skills (currently mostly located at level 3) to level 2, having them more and more automated.

Four factors request an increased efficiency of learning and tutoring methods :

- the increased amount and quality of learning an individual has to achieve through all his life;
- the increased demand of society in terms of learning achievements from all the citizens;
- the increased turnover of useful knowledge;
- the increased turnover of personel on a task.

To help learners **observe their cognitive strategies** (or learning styles) some amount of freedom must be offered to him. With a software called DELIN, LECLERCQ and BOSKIN (1990), enable the learner to select, for each frame (screen), to receive :

- a synthesis (overview of the context);
- an iconic (still) illustration;
- an iconic (video) illustration;
- a question to test one's understanding;
- an additional, more detailed, information by pointing to any word or part of drawing (i.e.) to navigate in a hypertext manner).

Experimental evidence shows that, in addition to interindividual differences in "preferred" cognitive style, a large amount of **intrapersonal variability** exists when constraints change.

Providing room to the learner for initiatives has not only advantages at learning levels 4 and 3. For instance, the opinion is largely shared that "if the student himself discovers solutions and methods of solution, this will deepen his understanding, promote his retention of the material and maintain his motivation" (O'SHEA, 1982, p. 310). This point of view is sometimes referred to as **"the discovery method"** (SCHULMAN and KEISLER, 1966).

This kind of assumption has a great influence on the tutoring system. A.I. authors like BURTON and BROWN (1982, p. 89) stress it in those terms : "Every time the Coach tells the student something, it is robbing him of the opportunity to discover it for himself ... preventing ... the cognitive skills that allow students to detect and use their own errors".

The last part of the sentence refers to level 3 learning. The same authors note that, on the opposite, "an untutored (unwatched) student may ... miss the potential richness of the game".

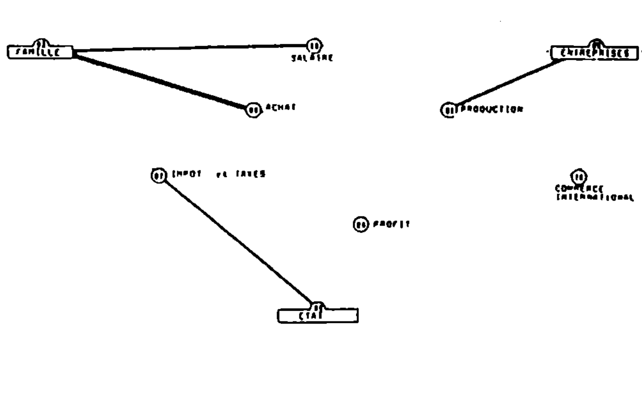
4. <u>ELEMENTS OF COGNITION (level 1) and Tutoring</u>.

Arriving at the conclusions of their A.I. paper, BROWN *et al.* (1982, p. 279), detect two different problem, a pragmatic one, and an intellectual one "the intellectual issue was our increased awareness that we did not really know **what it means to "understand"** how a complex piece of equipment works ... Much of our recent research has been directed at attacking this problem. It quickly became clear to us that the work that went into SOPHIE II and III on explanation put the cart before the horse".

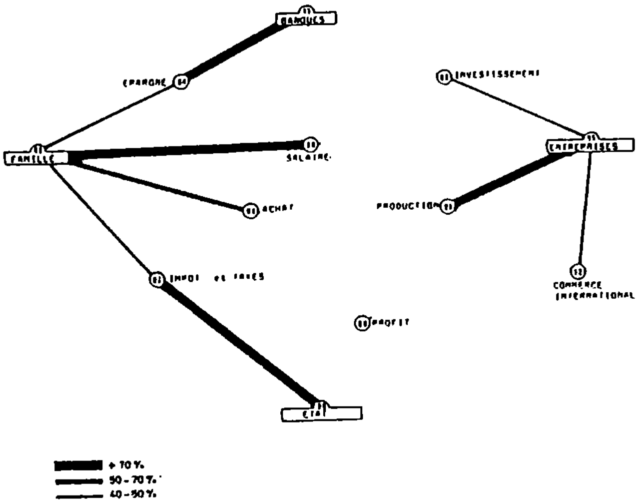
This conclusion stresses the fact that researches on "natural" intelligence could be very effective to improve A.I. as well as the reverse, and that a huge amount of researches is still to be accomplished.

Such "models of understanding" are specially important when the A.I. researchers want to deal with "a student's partial understanding" (BROWN *et al.*, 1982, p. 252). It is not an easy job since, as MC MILLAN et al. (1988, p. 231) note "The teaching agent cannot directly observe or manipulate the knowledge structures of the student ... [nor] measure the state of [this] knowledge without error [... so he] is never certain".

Converging work have been undertaken by specialists coming from distant origins : representations analysis and A.I. For instance, NORMAN (1982), NOWAK and GOWIN (1984), LECLERCQ (1990), and others have developed techniques (known as **"concept mapping"** or "mental networks" or "burr diagram") to collect and represent the structure of a given person's concepts in a given area. ALBERTINI (Ed., 1985) has described **the evolution** of the conceptual network from 12 years old students to 16 years old ones, in 4 regions of Europe (Lyon, Berlin, Manchester and Liège). The concept space has to be defined not only concerning the four economic agents (i.e. Companies, Families, Banks and State). It also implies the words Savings, International Trades, Salaries, Investment, Profit, etc. The Liège graphs (hereafter) are similar to the other ones. It appears that, when 12, students hardly link to each other the four economic actors : companies, banks, state and families.



When 16, the area of "consumption" is structurating, in the same way as the area of "production", but they remain rather remote from (i.e. unconnected to) each other.



The fact that the big links at 16 are the ones that were already big at 12, strengthens the hypothesis that **mental structures evolve by complexifying from what already exists** and that the most crucial factor of learning is what the learner already knows (AUSUBEL, 1968), that will enable him to "subsume" the new information.

Converging with those consideration is GOLDSTEIN's concept (1982, p. 74) of Genetic graph, the topology of which provides **a learning complexity measure** : when a given rule has many links, the (tutor's) expectation is that the student will have difficulty in acquiring that rule himself ... elsewhere there is a need for "tutoring advice".

This last trend of researches shows that an efficient **tutoring** can only be based on informations coming from **monitoring,** i.e. picking up raw data and interpreting them into meaningful indices.

These considerations led a European consortium to define and attack the problem of Tutoring and Monitoring Industrial Environment (TMIE) in the DELTA program.

E. A SYSTEMIC APPROACH

There is **not one optimal way to tutoring** that is independent of general objectives. The tutor, or better, the learner himself has to decide of priorities and research has to go on developing measurement principles, concepts and procedures adapted to each of the four levels of learning.

In addition to that first level of complexity (the individual), **other levels of design issues** such as the tutor's own regulation, the local training system, more global ones, etc. (PIROLLI and GREENO, 1988, 183).

1. The TMIE project

For these reasons, it is of paramount importance to make available "**Tools for rapid prototyping** [...] to avoid the familiar line [...] 'that will be too expensive to change now'. The development and field use of authoring tools should be a high priority for the ITS R & D community" (JOHNSON, 1988, 30).

A european consortium named TMIE (Tutoring and Monitoring Industrial Environment) has been constituted (contract D1020) to work on this kind of problems, in the framework of the DELTA program set up by the European Community (DG XIII).

DELTA stands for 'Developing European Learning through Technological Advance'. Partners of the TMIE consortium have **already developed tools to** adress the **rapid prototyping** challenge. For instance, CNRS-IRPEACS has developed ORGUE, a powerful system for designing multimedia courseware without computer programming competency and SHIVA, a knowledge representation tool (BAKER & BESSIERE, 1990). BULL has developped STARGUIDE (CLAES, 1989), a tutor expert conceived to be **easily superimposed on existing** software (e.g. text processing, DBase manager, spreadsheet or any courseware). SOFTIA has developed HYPERINFO (WEIDENFELD, 1988), a hypertext facility also conceived to be just an additional layer to any existing software.

2. The TMIE key concepts

A first concept put forward by TMIE is **the regulation process,** that can be decomposed into five major steps : conception (of a project), planification, execution (or action), observation (or measurement) and decision (regulation loop). This is reflected in dimension 1 of the TMIE cube.

A second concept is the **multilevel** aspect of this regulation processes, that are embedded in each other . At a microlevel, the learner has his own goals, plans, acts, observations, decisions. But, at other levels (mini, meso, macro), other actors (tutor, training system, company) have their own goals, plans, acts, etc. This is reflected in dimension 2 of the TMIE cube.

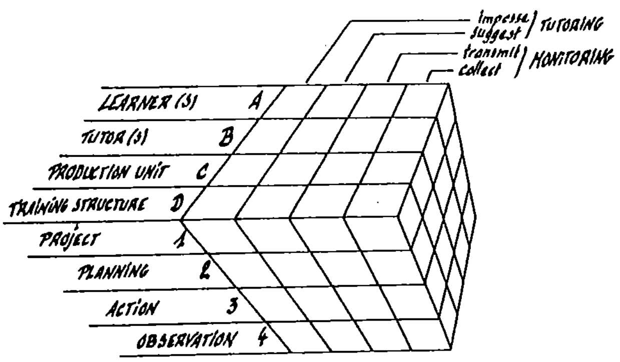
A third concept is the **multiplicity of** the possible **exploitation of raw data,** i.e., they may be combined in various ways to be transmitted (fed back) to various destinators at various "levels". Actually, four levels of actions are considered :

- Monitoring : picking-up (recording) of raw data.
- Monitoring : transmitting.
- Tutoring : Offering possibilities, proponing, suggesting.
- Tutoring : Informing.

This is represented as the third dimension of the TMIE "cube".

3. The TMIE cube

The cube (DELTA, D1020, TMIE, WP5, DEO3, mars 90) looks as follows :



It is used to conceive the kind of informations to obtain and to communicate (MONITORING) as well as the kind of decisions to make (TUTORING). Each cell is systematically explored.

The TMIE team is preparing a mock-up of an AI system conceived in this way, in the domain of museum security training.

F. CONCLUSIONS ON INTELLIGENT TUTORING SYSTEMS.

In order to encapsulate the idea of reciprocal benefits from ITS and classical research, let us refer back to the four components often found in an Intelligent Tutoring System.

Monitoring functions are often implicitly situated in the interface. According to TMIE work, we will suggest to **make Monitoring an explicit component** and to place the interface at the centre of the picture, with its facilitating each of the four main functions.

A second change is the **representation of the theoretical frames** in which each of those four models are embedded.

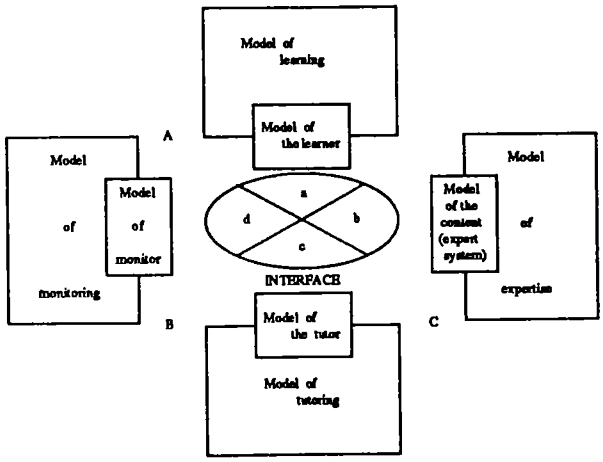
Finally, we suggest to add **circumstantial parameters** such as

A - the objectives the learner determines for this run;

B - the degree of adaptation to individual differences and needs the system can afford this run;

C - the severity or level of requirements by the potential user (employer, teacher) in these circumstances;

... and this is not an exhaustive list !



with

a = enabling student's expression, action, exploration, questionning.

b = enabling the expert to reveal, unfold its reasoning.

c = enabling the tutor to manifest itself, to justify its decisions, etc.

d = enabling the monitor to take samples, to observe and record information.

We hope it is obvious how a series of points discussed through out this paper could be classified in one of those boxes. The purpose of the schematic representation is to contribute in mapping where lies what has already been done ... and what has yet to be developed.

* *

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The present paper was a tentative contribution from an educationist towards ITS, ICAI and AI developers, but it is an "interested" one, since we believe the benefit from AI to education is potentially crucial, sharing HAJOVY and CHRISTENSEN's (1987, p. 14) views :

"Much like educators have for decades used the research tools from the field of statistics for help in experimentation, we can use the tools offered by computer science in the design of learning environment.

In both situations, however, the educator must control the tools as a means to the end, not as the end in themselves ...".

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