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The work on the conceptions of the learners goes however much further when it comes to the mechanisms in play in the act of learning. It renews the question of cognitive learning. It refutes certain well-established ideas of contemporary psychology, notably showing certain limits of constructivism. Since then, scientific education could no longer target the acquisition of knowledge (contents and modes of reasoning) without concerning itself with the field of significance of that knowledge to the learner. By the same token, it could no longer evade the frameworks and the referential practices which conditioned these acquisitions and their ulterior mobilization.

In this context, new models have been produced, for example the allosteric learning model, which we have corroborated in classrooms. As well as providing some insights into the functioning of thought, it puts the accent particularly on a environment which facilitates the learning.

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Different uses of learners conceptions
From constructivist models to the allosteric model.

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The idea that the student participates actively in the development of his knowledge is certainly not new. In the past fifty years, Piaget, Bruner, Wallon, Kelly, Gagné, Ausubel, Novak have in turn developed this theme. It is true that this idea was already found with a certain constancy in the pedagogical literature since the Renaissance. Montaigne, Rabelais, Rousseau, Fénelon, Kant, and then Cramaussel, Claparède, Montessori, Decroly, Ferrière, Dewey, Freinet had already emphasized the importance of the child and of its methods of learning, without however giving themselves the actual means to know these methods better.

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In this context, new models have been produced, for example the allosteric learning model, which we have corroborated in classrooms. As well as providing some insights into the functioning of thought, it puts the accent particularly on a environment which facilitates the learning.

1. SUMMARY OF THE STADE OF RESEARCH ON CONCEPTION

The science education rechearchers first defined “conceptions” (misconceptions)[1], as the distance between the thought of the learner and scientific thought. The term “misconception”, widely used in anglosaxon works (Novak et all. 1984, 1985), is significant in this school of thought. Bélisle and Schiele (1984) so designate the conceptions as “knowledge

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[1] We prefer the term "conception" (Giordan 1987) to "misconception" or to "representation" to avoid the numerous confusions of meaning. “Misconception" pertains to error, an idea which we wish to eradicate from our approach. "Representation" has taken on multiple connotations in the different branches of psychology. Further more, the word "representation" can also designate what is represented in the Mathematics. Thus, a triangle drawn on the blackboard is a representation of the concept of a triangle.

acquired outside of science". In parallel, a series of works primarily in French, had listed references for the students of their conceptions prior to teaching, in order to better understand what can get in the way of the acquisition of scientific knowledge in a specific domain (see databank in Duit, 1988 or in Biodic, 1993).

The conceptions are thus mainly considered as an "already ready concept", an accumulation of information, theoretical and practical, structured and stored in memory, to be gathered before teaching in order to better adapt the lesson to the students" current state. Since then, the studies on this theme have been broadly developed. The idea emerges, from the recent works taken as a whole, that the conceptions are neither simple memories nor reflections of context. They appear rather as original productions, or better, as a universe constructed from meanings, putting into play the accumulated knowledge which is more or less structured, near to or far from the scientific knowledge which serves as a reference. In each particular situation, this ensemble is only in part activated and mobilized as a function of the stakes in the situation.

The conceptions intervene in the identification of the situation, in the selection of pertinent information, in their treatment, and in the production of meaning. They are, according to the authors, "tools", "compendiums of operation", "thought strategies", the only ones the student has to apprehend reality, the objects being taught or the informational contents (Novak et all. 1984, 1985 ; Pope et all. 1983 ; Host 1977 ; Kinnear 1983 ; Lucas 1986).

Since then, the conceptions are interpreted less as elements of an informational inventory destined to ulterior consultations than as "a sort of decoder" permitting the learner to comprehend the world which surrounds him (Simpson et all. 1982 ; Osborne et all. 1980, 1983,1985). It is from these conceptions that new questions are approached, that situations are interpreted, that problems are resolved, that explanatory responses are given, that predictions are made. It is through them that the learner will select information, give it a meaning (which possibly conforms to known scientific references), will understand it, will integrate it and thus... "learn" (Giordan et de Vecchi 1987; Driver et all. 1989). This shows the importance of these conceptions in the mechanisms of the appropriation of knowledge. To acquire a piece of knowledge, is to pass from one conception to another more pertinent one with respect to a given situation.

Meanwhile at this stage of reflection, the science education question remains unanswered. Can one facilitate the acquisition of knowledge ? If so, how ? Is it a matter of “associations”, of enrichment by building in relationships, of “cognitive bridges” or of transformation of conceptions[1] ? In the vast majority of studies, the analysis of the conceptions of the learners appears as a stage in the path of a greater mastering of educational practices. Yet this position, if it seems necessary and even indispensable, quickly shows its limits, and an attentive reading of a number of works reveals that it could be the source of naivete and of illusions.

Where these preoccupations intersect is the focus of the research on scientific education with stakes both theoretical and practical. Practical because a better mastery of the collection and of the use of the learners' conceptions will contribute effectively to choices in regard to learning (Giordan 1978; Giordan et all. 1978; Giordan et Souchon 1991; Clément et Mein 1988; Clément 1984, 1988, 1991; Kinnear 1983; Bernardini Mosconi et all. 1989; Borum 1988, 1988; Girault 1987, 1990; Guichard 1990). New innovations and research are to be developed based less on the conceptions per se than on the effectiveness of their use on a practical level (Bednarz and Gamier 1989; Giordan et all. 1989; Giordan et all. 1993).

Theoretical because the precise mechanisms of acquisition of specific scientific knowledge, as well as the interaction between these mechanisms and the context of the learning, remain to be elucidated (Ausubel 1968, Novak 1976, Giordan et all. 1983, Clément 1993). At the moment when certain grand dogmas which founded certain current pedagogical choices are crumbling, and when cognitive sciences are beginning to interest themselves in these questions, the research on science education must accept decisive challenges. Is it presumptuous to predict that this research might furnish elements to reopen classical questions of epistemology and of psychology, for example on the articulation between cognitive, affective and procedural aspects in the acquisition of knowledge, or on the nature of reasoning, the role of images...?

2. UTILIZATION OF CONCEPTIONS IN TEACHING

2.1 First works

Research in science education finds itself confronted by a major problem which it raised but hasn't worked on very much. How can a teacher, or any other mediator, use the conceptions of the learner when he wishes to transmit a piece of knowledge? Should he help

[1] Classical psychologists have tried to respond to this, but until now, they have not examined neither the content of the knowledge to be transmitted, nor the context and strategies of intervention.

the learner to enrich his conceptions, and/or to shift them ? Should he refute them, transform them ? By what practice in class or of mediation ? Playing what role(s) with what didactic aide(s) ?

To this end, it seemed to us to be important to survey the different uses of conceptions in the classroom. The work has not been easy, current authors in the domain are not very explicit. Specific research on the use of conceptions in leaming situations are to be promoted. Precise studies in this domain, such as Giordan and De Vecchi (1987), De Vecchi et Giordan (1989), Paccaud (1991) are too few. But this research is necessary, without which the didactic concept of "conception" may not be operative.

From different writings, it has been possible to infer three broad positions :

- 1. "ignore conceptions",
- 2. "avoid them" or
- 3. "know them"'.

The first two, which we mention as a reminder, reflect the foundations of traditional teaching. The third one, with which current debates are concerned, may, in turn, be divided into several hypotheses.

The chart below groups the main positions advanced:

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1. **"ignore conceptions"**
2. **"avoid them"**
3. **"know them"**
3.1. it supplies "information on the public"
"... to specify objectives"
"... to prepare one's courses"
to facilitate a "continual matching of the course"
3.2. it might or should be used **as elements of the course** as ...
3.2.1. a "source of motivation"
3.2.2. a "material for didactic processing"
3.2.2.1. work with
"make them emerge" "expand on them", "oppose the "reorganise them"
3.2.2.2. work **against**
"purge them"
"evacuate them", "refute them", "eradicate them", "shake them",
"contradict them", "go round them,
"bring them into opposition"
3.2.2.3.: "one can work **through** them", "transform them by interfering with them".

Chart of Pedagogical positions on the use of conceptions

Some researchers advance the idea that the knowledge of conceptions is important be cause it supplies information about the public. Misconceptions enable one to «specify objectives» to «prepare one's courses» or yet again to facilitate a «continual matching of the course». Other researchers think one must go further : the knowledge of conceptions is certainly useful in making pedagogical inferences, but they also may or should be used as elements of the course. This point of view leads once again to sub-positions (see chart behind).

2.2 Presuppositions, value and limitations of each position

It is currently believed that a learner is not a blank sheet of paper on which knowledge can be printed.

Each learner has conceptions through which the various received information is interpreted, or, more often, distorted or evaded. This entails educational or cultural actions which take into account conceptions, in order to produce knowledge which helps solve problems more effectively.

Unfortunately, this is not the situation in most educational systems throughout the world. The most widespread position relies on ideas popularized by Condillac. It is thought that "saying" or "showing" is enough for the learner to be able to record scientific knowledge spontaneously. Hence the daily importance given to magisterial lessons, or to seemingly more open practices such as reports illustrated by slides or experiments, or again to some dialogued pedagogies which are quite as dogmatic and direct.

Some educators, particularly experts in adult training are awakening to the existence of conceptions. They realize that the latter interferes with significant learning, but that does not necessarily bring a change to their practices. Various parameters lead them to this contradictory choice, when, for example, they consider that conceptions may exist, but only as an anecdotal phenomenon. In their opinion, the learner expresses a kind of anarchic knowledge or "parallel knowledge" and what he says merely translates his thoughts very imperfectly, that is, it is "sheer word production". Anyway these notions need not be taken into account, since they are "outside knowledge" and since "the adult logic will naturally substitute itself for this chaos".

Other more pragmatic teachers say it is extremely difficult to take these conceptions into account, for they are too diverse and might lead the class into divergent directions. Besides, this entails more individualized teaching, which seems difficult for some of them to harmonize with overcrowded and badly equipped classrooms. In that case it is better to overlook these simplistic conceptions and to present safe new knowledge, with no relation to "all those approximations". Besides, the new knowledge always prevails.

Still others argue that one can do nothing faced with insane curricula. Furthermore, "he exam is the the leading concept and what will be expected of the candidate is precise knowledge or exercises for which he will have been drilled.

Coming into gradual opposition to such ideas, suggested by the champions of a so-called classical pedagogy, has been the hypothesis that conceptions must be taken into account. The arguments put forward to corroborate this hypothesis portray conceptions as the first and only link that the learner can have with the new knowledge. Ausubel calls it "the only factor significantly influencing learning, what the pupil already knows", because it is this personal model of thought that enables the learner to decode his environment and the received information.

Among those who favour recognition of conceptions, several options have emerged. As a rough approximation, one can distinguish two main streams. The first uses conceptions as a "way of knowing" : work with them. In this context, the teacher introduces a more or less enticing starting situation, in order to let the students express their ideas. Then, either in working groups or with the whole class, the teacher allows the various conceptions to face or oppose one another. The ensuing debates cause pupils to adopt a detached attitude to their own conceptions, to develop and sometimes to reorganize them. These developments may be completed by direct investigations of reality (observations, experiments, inquiries) or by work on documents.

We are dealing with a multi-faceted point of view which we have championed and which remains attractive to some extent, particularly to the humanist and non-interventionist currents (specially Rogers and followers). Indeed it differs sharply from traditional practices, mainly because the teacher only focuses on the learner and plays the part of "genuine congruent" facilitator (problem-solving activities, confident atmosphere, etc.).

This position also puts the emphasis on the interaction likely to exist between the learner's development and some necessary conditions introduced by the teacher. It avoids any conditioning, particularly by letting the pupil tend, in the fullness of his "organismic capacities" to "significant knowledge".

Such a pedagogy, which clearly goes beyond the strictly therapeutic aspect, has its virtues. It is particularly valuable at the level of scientific initiation, with young children as well as with adults. It even forms an indispensable stage for fighting off some inhibitions. It restores and stimulates inquisitiveness, fosters self-confidence, develops communication and encourages the learner to choose a number of objectives to be achieved, according to his own interests. All these being goals left untouched by traditional pedagogies.

Yet, in so far as the construction of knowledge is concerned, this approach quickly reveals its limitations. It does not result in a real transcendence of prior conceptions. This is particularly obvious at the level of basic concepts. One reason may be that such a pedagogy presupposes a continuity between immediate understanding of familiar reality and of scientific knowledge, which means one can go from one to the other with neither break nor gap. For such a conception there would exist a term for term correspondence between a representation and a concept, or more generally between more or less systematically organized conceptions and a conceptual network: it would thus be possible to express a scientific concept in a non scientific language, without transforming it or lessening its specificity.

To sum up, one can add that though this pedagogy can supply a few initiatory elements, particularly when acquiring scientific proceedings or attitudes, it remains limited because it is built on an erroneous conception of scientific knowledge. To consider conceptions as a step towards concepts or to assert that «learning is enriching one's conceptions» shows a lack of understanding which would be dangerous if spread.

Another widely asserted position comes from Bachelard's writings and in particular his notion of "epistemological obstacle" (Bachelard, 1934, 1938). For him, conceptions have a significant status from which some pedagogical consequences can be inferred : conceptions are valuable because of the mistakes[1] they bring to light. Thus to Bachelard and to his followers, when conceptions are ignored in educational action, they are not really removed but are merely driven back. The subject only acquires an illusion of knowledge. This appears particularly when stereotyped recipes are applied or when phrases or words devoid of meaning are used. This conception led to refutation pedagogies, going beyond Bachelard's thought which only advocated rectification teaching.

In their more significant applications, methods start, as stated earlier, with the learner expressing and releasing his own conceptions ; from there, several alternatives have been advocated in turn. For some, the teacher will act alone to challenge initial conceptions; for

[1] These are no mere mishaps, they are only due to what is external to knowledge, but they are revealed by "knowledge in action", in Canguilhem's works (Canguilhem, 1965).

others, the group itself will assume this role, through the conflicting exchanges for which it allows; for others again, after the stage of expression of representation, the teacher provides the intended knowledge, then calls for a confrontation of prior conceptions, in order to show the students the discrepancy between what they know and reality.

Lastly, others advocate first putting the learners in a situation where they can express and explore their conceptions. The group, with the teacher's aid, and through work on these conceptions, tries to reach a conceptual formulation in a mutual language. Through a series of successive rectifications, as well as the practical and professional experiences of the group member and, the use of documentary resources, the formulation gradually evolves into a scientific concept.

Such practices are efficient to a certain extent, at certain moments and for some types of learning. Yet they cannot be generalized to the acquisition of scientific knowledge, for several reasons this is related either to their use, or, at a deeper level, to some unfounded presupposition. The knowledge transmitter often tends, after allowing for the expression of conceptions, to introduce the intended notion casually, eluding the student's learning mechanisms. In practice one notices fairly often that the teachers attempt to let conceptions emerge collectively and then discard them except as illustrations. In that case they put forward their picturesque aspects without attempting to take them into account or to work on their underlying logic. Besides, they underestimate the resilience of conceptions or think it sufficient to present a single argument or "crucial experiment" to transcend the obstacles.

This type of practice, like some traditional pedagogy, only uses conceptions as a pretext to begin a lesson. Moreover, they are prone to introducing the learners too soon to poorly delineated concepts, with the major outcome being the suppression of the searching spirit. This type of pedagogy then misplaces the moment when conceptions are able to play a leading role in the learner's process of elaborating knowledge. These practices promote the role of initial conceptions, which are treated as an end in itself, rather than as the expression of a type of intuitive apprehension that, hinders the building of knowledge. In addition, the aim is not to put the learner in a position to become aware of the "mistakes" ingrained in his conceptions before building an acquisition. This activity should preferably intervene before or after the building of knowledge so as not to foster the existing obstacles. One can evaluate the difference between these, two explanations only insofar as one really knows both of them. Asking someone who has never caught sight of the sea to compare it to a large lake is as illusory as asking a learner to become aware of his conceptions when he knows nothing else and when they are selfevident to him. It is when the scientific explanation has been at least partially assimilated that it is possible to return to prior rectifications and to really transcend them through gradual rectification.

Besides, it is no obvious thing to refute straightforwardly a prior notion. It most often withstands even the most elaborate arguments because it is a part of the coherent structure of a broader thinking process, which has its network of established relationships, its context and its environment.

Last of all, we must add that initial conceptions are not always an obstacle for the learner. Indeed they show the teacher the ground that remains to be covered as well as the difficulties the pupils are liable to meet. The student, however, is rarely aware of this and it is sometimes useless to expose him to extra difficulty, even more so since this «erroneous» knowledge may turn out to be useful, especially in a phase of knowledge building[1] .

3. A NEW MODEL OF LEARNING

To mitigate these insufficiencies in the matter of learning, it thus seemed useful to us to promote another model. This new model[2] tries to answer directly and in first priority questions related to learning. Furthermore, it has not been transposed from another approach like the majority of the above theories have been, even if it contains some elements which issue from them. Furthermore, it allows one to infer forecasts: an ensemble of conditions likely to generate learning. In this text, we will only partially describe it. To know more about its structure, we refer the reader to other texts (Giordan 1987, Giordan 1989).

3.1 The functioning of the model

The appropriation of any knowledge depends on the learner as principal 'manager" of his learning. The appropriation is an extension of previously accumulated experiences and yet at the same time is in opposition to them. In effect to begin to understand, the student does not start from scratch, he already has his own tools : the conceptions. They provide him with his framework for questioning, his manner of reasoning and his references. It is through this

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[1] The story of ideas is quite revealing in this respect. Views diametrically opposed to the ones which prevailed in the end have been known to play a positive role at some stage of the ideas' evolution. This hypothesis is to be corroborated in a as much as possible. As far as the student's learning is concerned : a «mistaken» conception -say that of heat considered as a fluid- may be a sufficient approximation to deal with daily problems relating to energy for instance, whereas the actual scientific concepts, delivered too early, will very likely be discarded.

[2] It is better to see it as a set of micromodels (or partial models) both on learning and teaching.

analytic grid that he interprets situations with which he is confronted, or seeks and decodes the different pieces of information which challenge him.

Any significant learning, however, should occur through the rupturing of the learner's initial conceptions. During the acquisition of a concept, the ensemble of the mental structure is profoundly transformed, the frame of questioning is completely reformulated, the grid of references broadly elaborated. The student learns at the same time “owing to” (Gagné), “from” (Ausubel), “with” (Piaget) the functional knowledge in his head, but at the same time, he must comprehend “against” (Bachelard) these last ones. Indeed, to learn, the student must go more often than not against his original conception, but he can only do so by working with it, and this until it “breaks” when it seems to him limited or less fruitful than another already formulated conception.

CONCEPTION = f (P,F,O,N,S)

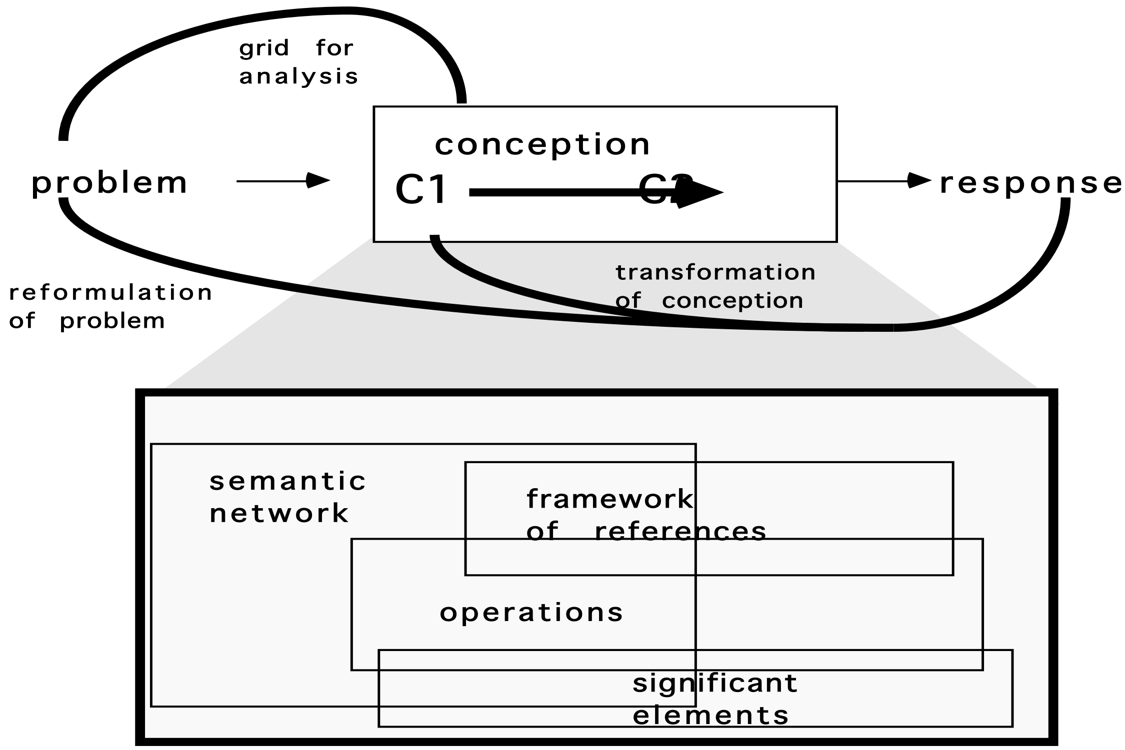
where

P (or problem) is the ensemble of more or less explicit questions which induce or provoke the putting in place of a conception. In short, it constitutes the «engine» of intellectual activity.
F (or frame of reference) is the ensemble of peripheral knowledge activated by the subject to formulate his conception. In other words, they are the other conceptions already mastered on which the learner relies in order to produce his new conception.
O (or mental operations) is the ensemble of intellectual operations or transformations that the learner masters. They allow him to put in perspective the elements of the frame of reference, to make inferences and so to produce and to use the conception. Specialists call this operational invariants.
N (or semantic network) is the interactive organization put in place from the frame of reference and from mental operations. It allows one to give a semantic coherence to the whole. In other words, it is the emergence, originating from the interplay between established links connecting all the principal or peripheral elements, which compose the conception. This process produces a network of meanings and gives a specific sense to the conception.
S (or significans) is the ensemble of signs, traces, and symbols necessary to the production and the explication of the conception.

Components of a conception

But, one still needs the opportunity to put the above approach into action. This process does not come about haphazardly, it establishes itself only in based on the structures of thoughts in place (questions, frame of reference, mastered operations) and of the stakes the individual perceives in the situation.The conceptions are thus not merely the point of departure, nor the result of the activity. They are the very instruments of the mental activity. Apprehending a new piece of knowledge consists thus in integrating it in a conceptual structure already functional. The new conception substitutes itself for the old by replacing the prior conceptual structures.

That which changes, however, is principally in the head of the student, and here the allosteric model shows clearly that it is not the information, but the network which connects the information, that produces a meaning in response to a question. The student is thus at the heart of the process of knowledge. Knowledge is not transmitted, it proceeds from an activity of elaboration during which the conceptual system is mobilized by the learner, confronting new information and his mobilized conceptions produce new meanings more likely to respond to the questions posed.



Mobilization of the conceptions in a conceptual learning

3.2 Obstacles to learning

Besides its explanatory value, the allosteric model allows one to predict a series of obstacles to learning. They are situated at different levels, so that different specific treatments are induced necessarily. First of all, the simplest case, he may be missing essential information. In other cases, the needed information is accessible to him, but the learner is not motivated with respect to that information or he is preoccupied by a different question. Third, the student is incapable of accessing the information for reasons of methodology, of operations, or of referentials. Finally and most often, he is missing elements needed for the effective management of comprehension.

It is over the last two points that the allosteric model is the most pertinent. In the case of fundamental leaming, the model shows clearly that the knowledge to be acquired never automatically follows from anterior knowledge; the latter constitute, most often, an obstacle to the integration. One must therefore foresee a radical transformation of the conceptual network. This implies a certain number of supplementary conditions.

First, the student must be in a condition to go beyond the edifice constituted by familiar knowledge. But this is far from easy because the conceptions which he activates correspond to the only instruments at his disposition: it is through these that he decodes reality. He must therefore constantly re-examine these conceptions because they lead inevitably to the obvious and constitute a filter on reality. Second, the initial conception only transforms itself if the student finds himself confronted by an ensemble of converging and redundant elements which make the conception difficult to manage. Third, the student cannot elaborate a new conceptual network except by connecting differently the information gathered, notably by relying on models that serve to organize which permit one to structure the knowledge differently. Fourth, the concepts being elaborated require that they be-to become operational- progressively differentiated and delimited in their field of application during the leaming, then consolidated by a mobilization of knowledge in other situations where they can be applied.

Last of all, the learning process assumes that the learner exercises deliberate control on his studying and on the process which governs this activity, and this at different levels. First, the learner must reorganize the information presented to him (or which he himself gathers) as a function of the appraisals he makes of the situations, of the meanings he elaborates about them, and of the knowledge conceptions he establishes. Next, the learner must reconcile the ensemble of the preceding parameters to constitute a new knowledge, in case it can be reused. Finally, he must locate the similarities and the differences between his old knowledge and the new and, more often than not. solve contradictions.

3.3. Conditions for a transformation

If one of the preceding conditions is not met, the learning process might be compromised. The thought of a learner does behave like a passive recorder system which would engrave new knowledgeon virgin (or brand-new) ground. The learner' thought possesses its own way of explaining which orients the ways in which orients the way in which new information is apprehended. This conceptual network, involuntarily and unconsciously built from the first experiences, and from personal interpretations of former teaching situations and former mediations, form a veritable filter for any new acquisition.

Thus is the student who, for one reason or another, must find himself in such a situation as to change his conceptions. If teaching does not take into account these conceptions, they strongly resist any change or remodelling. But the learner does not just put into place a process of assimilation-accommodation. True, a self-regulating process must be established, but it cannot function only as a "cognitive bridge" (Ausubel 1968) or as a "reflecting abstraction" (Piaget 1950, 1968).

The image which best describes the mechanics of leaming is that of an *elaboration*. Indeed, the learning process simultaneously presents mostly conflicting and integrating modes. Moreover, its principal characteristic is to be, at the outset, interfering. These interferences are the consequence of multiple interactions, necessary between conceptions and the learning context, between conceptions and concepts, and above all between multiple elements which constitute the conceptions (framework of questioning, frame of reference, conceptual processes put into play, and even signs used).

Teaching blood circulation at school

The teaching of the concept of circulation at primary school or during the equivalent of junior high school does not take care of itself. To transmit the idea that blood circulates has no meaning in itself, even more so because we do not know the exact meaning of to circulate. In any case, one can see that the message does not reach its destination as long as there is not a question behind it.

1. One possible motivation to approach this concept might be the question of nutrition. The organs or the cells (to be discussed depending on the chosen audience) need to be nourished [or «fed»]. How can they do so? The students easily realize that the organs or cells do not have direct access to the exterior. A procedure had to be put into place by the living person. At this moment, the blood, already well known, takes its place: it becomes the liquid of transportation. This conceptual imbalance allows, from the outset, concern by the students. All the obstacles, however, are far from being cleared. It is still necessary that the children be convinced that nutrition is the concern of all the cells or of all the organs and not a global function of the organism in general: «one eats to live». A time to discuss this system must be made available at this very level.

2. The excretion of cells can mobilize this first message and reinforce the role of the blood. However, the idea of bringing of food and of recuperation of waste does not automatically imply the idea of circulation. (as in the first meaning of circle). Historically one always envisaged a typical mecha nism: the watering of fields. This other difficulty may be overcome if the students are confronted with another question: "is blood incessantly renewed as is the water in the fields ? If not is it the same?"

A little calculation can help:
"about 5 liters of blood pass per minute through the heart", "one cannot make as much blood per minute, especially considering that one has about that much blood altogether". This argument unsettles the model of watering but it is not in itself sufficient to induce the idea of a circular transportation. At this level, it is preferable to introduce the model of a circuit. Circulation alone can refer the idea of automobiles circulating with coming and going on the same street.
The teacher directly or indirectly by the situations he creates, must induce the idea of a circuit. The usual diagrams are illegible or block this idea, notably because of the dual circulation where nutrition and respiration are superimposed.

Some possible confrontational situations :
- film on a transparent young fish where one can see, thank to red corpuscles, the simplified blood circulation of fish ;
- envisage the continuity of arteries and veins and then reflecting on that which happens in the organs (works on capillaries) ;
- making of dynamic mock-ups to visualize the passage of blood, with pump, organs and king of tubing, actualizing the function of the parts of the system. In exposition, the possibility of visualizing using moving spheres with different lightings of blood in the organs or in the lungs. in the classroom, this modelling can be accomplished using recycled materials.
This last point constitutes a first practical approach to modelling. Paper and pencils models can be also made successfully by students.

3. The idea of nourishment can be used again and mobilized in regard to the subject of respiration, which is yet another preoccupation that is easy to induce to the pupils. "Oxygen has to be brought" to the organs or to the cells.
In this case, however, a very strong obstacle has to be overcome for some of the pupils, respiration concerns more than just lungs. Moreover, multiple connections have to be made by the pupils :
- food + oxygen ---> energy
- the organs need energy,
- the organs makes the energy (metaphor of the car);
Each point requires clarification and confrontation between pupils and between pupil and documentation. Conceptograms (concept maps) may help the student achieve this.
Other related problem to be resolved : what can one say about oxygen without remaining at the common idea of vitamin. If all these elements are necessary, one obtains in this case another reinforcement by mobilization of knowledge on another situation.

The very action of production of meaning by the learner is at the heart of the process of knowledge. It is the latter which sorts, analyses and organizes the data in order to elaborate a personal response to a question. And nobody can do it for him. It is still necessary his having in mind a question which intrigues him. Only the learner can work to integrate this new information which comes to him or which he encounters in order to give it a meaning which remains compatible with the overall organization of the mental structure previously established. It is there, by the way, that the notion of interference takes on its importance, which takes time and necessarily passes through a series of consecutive stages.

However, the engine for this process is not a simple "maturation". It is rather an emergence dependent on internal conditions which regulate the thought of the learner, on the one hand. On the other hand, external conditions into which the student is immersed, interfere greatly for their part. Besides, it is the network of relations mobilized between the conceptual system of the student and information gleaned at school or outside of school which is pertinent, and not the result of registered data.

One thus sees to what extent the learning process cannot be a mechanism of accumulation either. Yet this idea still underlies all school programmes. One breaks down the knowledge into a series of disciplines, the disciplines in chapters, sub-chapters, etc. One approaches them in stages, their juxtaposition spontaneously composing the entirety.

The appropriation of knowledge should be contemplated first as a series of systematic and progressive transformation operations, where what counts is that the student be involved, that he be challenged in his way of thinking. Yet usually the knowledge is proposed to him "cold", without questioning.

3.4. A environment

This process cannot be the product of chance. It must be greatly supported by what we call a *science education environment*, put at the student's disposal by the teacher, and in a more general manner, by the whole educational and cultural context. The probability that a student could «discover» on his own, the ensemble of elements which can transform the questioning, or which can facilitate installation of multiple connections and the reformulations, is practically null in a limited amount of time. Even autodidacts recognize that their acquisitions were facilitated.

Among the significant parameters, a certain number can already be listed owing to the allosteric model. First, the educational context must necessarily induce a series of pertinent conceptual imbalances. The purpose is to generate in the student the desire to learn, and then an elaborating activity. For this one must motivate the learner with respect to the question or the situation being dealt with or at least make him enter in the situation.

In particular, a certain number of *authentic confrontations* is indispensable. These may be the student reality confrontations via investigations (observations, experimentations, inquiries if appropriate). These might be student-student confrontations via tasks done in groups or confrontation with information. All these activities must convince the learner that his conceptions are not suffiently adequate with the respect to the problem at hand. These confrontations help the learner clarify his thought and lead him to step back and re-examine the once obvious, more often then not, reformulating the problem and/or considering other links. In addition, they can induce him to glean a set of new data to enrich his experience.

Second, it is important that the student has access to a certain formalism. This formulation can take widely divergent mode of expression : symbolism, diagramming, modelling is an aid to thought. Think how much Arabic numbers and multiplication can ease the acquisition, unlike the Roman numeral or the abacus of the Middle Ages. Of course the symbolism chosen must be accessible to and manipulable by the learner. It must correspond to a reality, must allow him ton organize the various data or serve an anchoring point to produce a new structuring of knowledge. On this last level, the introduction of models always allows renewed vision of reality. It can serve as "solid core" to federate the information and to produce a knew knowledge.

On this point, a certain number of rechearches are underway. a certain number of different procedure appear successfully usable from depending on the moment. as first step, it appears that for a given content, it is more economical for the teacher to provide a rough outline. The teacher must however be cautious. It is useful that this "premodel" be legible, comprehensible, adapted to the perception of the problem which the student holds. Beforehand, it is desirable that the student have had the possibility of producing some and even of putting some to work. It is most of all important that the student has become aware of the fact that there are no good models. Any model is a temporary approximation. It is thus useful that the student play with several of them to test their operationality and their respective limits.

Third, it is desirable to provide the learner with situations in which, once elaborated, the knowledge will be able to be mobilized. These activities are indispensable in showing the student that new data are more easily learned when they are integrated in introductory *apprehending structures* or when they have a use. Don't we learn most often when called upon to teach or when one has to reintroduce knowledge into practices? Likewise, these situations get the learner used to 'grafting' the new onto the old. The methods draw with them a “coming and going” between that which he knows and that which he is appropriating for himself. Anterior adherences are more easily surmounted.

Last of all, it is desirable that the student put into operation what we call *knowledge on knowledge*. Numerous difficulties have been seen which show that often the obstacle to leaming is not directly tied to the knowledge itself but is the indirect result of the image or the intuitive epistemology the learner has about the process involved or about the mechanisms of production of knowledge.

-Elaboration of concept of plant nutrition through allosteric model

Between the learner and the object of the knowledge, a complex system of interactions must be established. What is necessary is a dissonance which hits the “delicate” core of the conception. This dissonance alone causes progress, it creates a tension which ruptures the fragile equilibrium that the brain had previously realized. But dissonances are less and less acceptable when the experience is important and notoriety assured. One sees how the change of conceptions is not a simple or direct process. It is never neutral, either. One can even say that at times it is a disagreeable process. Indeed, our conceptions of the world, of beings or of things give a significance to these. Each change of conception becomes a menace. It changes the meaning of our past experiences. In doing so, it menaces the technique which the individual had formerly had to interpret reality.

Moreover, this change can only happen in a discontinuous fashion. So great is an individual's investment in his ideas, produced from a certain conception of the world and/or support for his action, that a sort of crisis, which can sometimes be an identity crisis, can result. The change is easier when another equilibrium emerges on the horizon. One can add that another level of knowledge only substitutes for the old when the student finds an interest and learns to make it function successfully. At this level also, he must be able to confront himself with a certain number of adapted situations, of selected information.

To generate, within the student, an elaborating activity on such a subject is not easy. The students have the impression that they know “the plant nourishes itself in the earth” and they are little motivated to know more.

Various situations can challenge him with success: plants without soil, hydroponic cultivation, air plants of tropical forests, lentils, “miseres” in a glass**.** One must point out the importance of either prior or concurrent mastery, for the student, of a certain level of attitude and of thought processes. This facilitates a questioning of and a stepping back to re-examine the phenomena. Each time a real confrontation is indispensable (confrontations student-reality, confrontations student-student), so that he can make explicit his thoughts in the framework of group work. Moreover, several tasks should bring him to glean an ensemble of new data to enrich his experience with respect to the question in play. They must bring him to test his thought through observations or experiments (variation of the diverse experimental factors: light, temperature, concentration of C02, mineral salts, etc.). They should bring him to step back from what he takes for granted, most often to reformulate the problem (what does it mean to nourish oneself?) and/ or to envisage other relationships (relation of food to energy). The necessity of diverse arguments is primordial in this regard, the teacher must never be satisfied by just one, quickly presented. Moreover, all these elements must be adequate with respect to the frame of reference of the student, otherwise, he eludes them. For students who master the scientific method, the approach might be facilitated by student-informa tion confrontations within the framework of a documentary task (cultivations on various soils, interaction of factors, role of fertilizer, of humus, of manure). All these confrontational activities should convince the learner that his conceptions are not adequate or are incomplete with respect to the problem at hand, and possibly that other conceptions are more operational. Then, the learner must have access to a certain formalism as an aid to thought. This formalism may take on several forms (diagramming, modelling). It should also be easily manipulable to organize the new data or to produce a new structuring of the knowledge (in the form of an anchoring point).The introduction of a global model can serve as "solid core" to federate the information as it is supplied.

This model may be made up of compartments. Certain partial models must be envisaged in a complementary way to pin down each point (role of light, of chloroplasts, of respiration with respect to photosynthesis, transduction of energy). Each time, the partial models must be adapted to the student's frame of comprehension. Last of all, one must add that, for the concept of photosynthesis to be really operational, it is necessary to provide the learner with situations in which he can mobilize his new knowledge and test its operationality and the limits (cultivation activities, trophic chains).Concretely, one must put in place a reflection on conceptual practices, and this to be done at the earliest possible age. What are their extents, their interests? What steps are put into play in class ? What are their underlying logics ? Why shouldn't knowledge and even the leaming process be a object of knowledge... at school !---

4. THE DIDACTIC COCKTAIL

In order that all these parameters be simultaneously operational, it follows that the role of the instructor teacher is primordial and irreplaceable.The sum of the contributions, their interactions, their progressiveness in implementation, cannot be the object of a preestablished programme. Due to this, the teacher will have to modify their pedagogical conceptions: their job, while fundamental, is secondary. The teacher becomes the organizer of the conditions of the leaming process, a sort of interface, so to speak, to take a term now fashionable, between the knowledge, reality, and the learner.

His role is no longer expository, it is not only to present information. When information is to be presented, there are more profitable means for doing so. His role is first and foremost to involve the learner, to concern, to suggest, to counsel, to convince him to pass from one level of thought to another of higher performance.

That does not mean that he must deprive himself from interfering or furnishing landmarks. To the contrary, if the leaming process is started by the learner, the teacher must not fear the treating the student tactfully. To succeed in his daily challenge, however, the teacher must have "in mind" the fact that his action will have valid results only if he puts in place the surprising *cocktail* constituted from the pertinent parameters that we have briefly described above.

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