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A Reflection on the Teaching and Learning of Mathematics

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Abstract:

In this paper, we approach the idea of meaning in mathematics, by reflecting on its teaching and let the students learn it freely and passionately, the list is long and if the questions are precise, the answers nonetheless remain complex. What is the age from which a student can assimilate certain concepts: abstraction, literal calculus, demonstrations? By the learning objectives of mathematics proper is to try to redefine the roles of the teacher. This "role" should be facilitated by the basic thinking options dealt with and preliminary and effective questions. In short, theorize professional practices of a different kind. We are looking for methods of teaching mathematics. According to the two points of view horizontal, vertical - and the horizontal view - it is based on reality, which searches for mathematics in different contexts (daily, physical, geographical, economic, etc.), where one uses the drawing, constructions, manipulation, perceptions and intuition. The second - a vertical perspective - is one that presents theory, structure, logic, conclusion, clarifications, and correctness. We will focus primarily on two dimensions related to mathematics education, one of which is the problem-solving approach, and the second is the importance of using the history of mathematics in thinking to design good ways to learn the material.

Keywords, Mathematics, Treffers model, problem, Situation, Didactics, Meaning in mathematics.

Introduction

One of the most remarkable things of late is the persistence of failure rates in mathematics despite the constant change in curricula. Mathematics has become a difficult and dry subject for our students.

Levels of difficulty in learning mathematics generally vary. There are comprehension difficulties related to symbols or expression, difficulties in understanding a problem, the inability to infer, the inability to analyze the elements of a problem, or other difficulties. Does the problem lie with the subject, the teacher, the curriculum, or the students' negative attitudes?

It is therefore not unlikely that students view mathematics as a mysterious subject and a static part of knowledge. Not presenting the motor development nature of mathematics deprives them of the experience of experimentation, discovery, creativity, and appreciation.

What's sometimes missing is a connection with intuition and imagination, completing meaning. As E. Kant said: "*A concept without intuition remains empty*."[9] The completion of meaning can be found in many places: practical problems, games, etc.; but also, in the history of matter.

Is repetition necessary? Isn't too much repetition proof that the content hasn't been understood?

How can we accustom students to using rules? Should we be patient and go through a long process of assimilating concepts, or should we, on the contrary, move as quickly as possible toward the use of rules? What are the pedagogical dangers of these different approaches?

At what age can a student assimilate certain concepts: abstraction, literal calculation, demonstrations? Is it true that if we wait too long (for example, before doing demonstrations), students are no longer "open" enough to be interested in more abstract reasoning?

Should we be strict with grading? Does rigor go further than complacency?

What are the origins and nature of certain mathematical errors?

How can mathematics curricula be formulated so as to be independent of the chosen textbooks? Is a competency-based formulation a solution?

The list is long, and while the questions are specific, the answers remain complex. Rather than tackling these questions head-on, let's (re) focus the objectives of the mathematics course and thus (re) specify the teacher's role. This "detour" through fundamental concepts and options should facilitate the effective handling of the initial questions. Indeed, examining each person's representations regarding the teaching and learning of mathematics and putting them into words allows us to go beyond the exchange of individual recipes, to place discussions on a higher level of reflection, to distance ourselves from our own routines in order to better understand their scope. In short, theorize our professional practice in order to increase our mastery of it.

This article is therefore presented as a tool to help analyze practices and their evaluation. If “to evaluate is to compare,” it is important to have a reference point, allowing us to compare “what is done” with the “ideal principles of what should be done.”

What mathematics do we want for our students?

There is not one conception of mathematics, but several. Indeed, for some people, mathematics is a purely gratuitous mind game whose usefulness remains to be verified; for others, it proves to be a powerful language and an instrument of implacable logic; for still others, it is reduced to a multitude of symbols whose learning is more akin to a Chinese puzzle than to any kind of logic of thought.

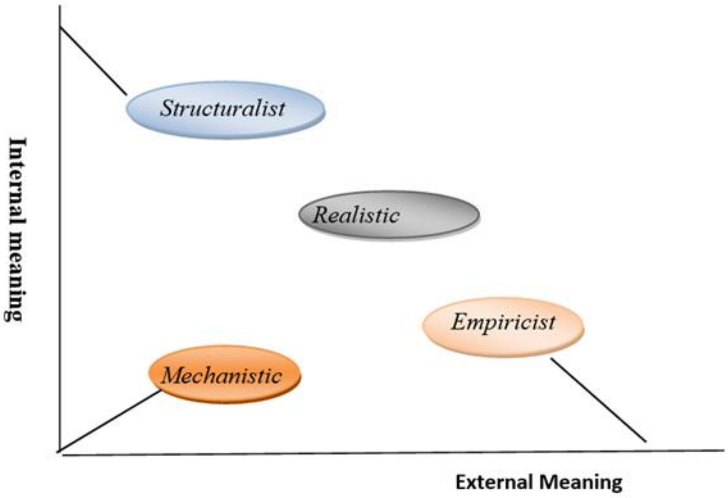
Even if it seems oversimplified, even caricatured, the Treffers model[17]has the advantage of Fallowing[17] for a fairly easy "positioning" in relation to the conceptions of mathematics.

This model proposes to position oneself in relation to two axes:

- the horizontal axis is that of context, of the familiar sources of mathematics, of reality, of the meaning external to mathematics that encourages observation and manipulation (material or mental),

- the vertical axis is that of deductive architecture, of the sequence of definitions, of properties, of the meaning internal to mathematics.

Schedule 1: Mathematical concepts (Treffers[17]Model)



In relation to their positions on these two axes, three conceptions of mathematics emerge:

- *A mechanistic* concept if it is not concerned with either the vertical or horizontal perspective. Doing mathematics amounts to performing routine calculations, applying rules and techniques without understanding where these rules come from (no vertical perspective), or what problems they are likely to explain (no horizontal perspective).

- The *empiricist* conception when the emphasis is on manipulation and observation without organization, demonstration, or justification of "discoveries." People imbued with this representation of mathematics are often attracted to solving challenges, puzzles, and problems,

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[1] - TREFFERS, A. (1986). Op. Cit,

but not by justifying the method used to achieve this resolution. This conception of mathematics is located at the extreme of the horizontal axis.

- Finally, a conception that overly favors the vertical axis is called *structuralist* because it emphasizes the structure of mathematics. The structuralist views mathematics as a flawless construction, where everything fits together logically. The teaching of "modern mathematics" contributed to the development of this view, where clear and elegant theoretical connections were the primary concern.

- *A realistic* conception of mathematics integrates the three previous dimensions. This gives **MEANING** to the mathematical activities offered to students.

Indeed, when faced with a mathematical tool to use (mechanistic logic),

The student has the right to ask themselves

On the one hand, where they fit into the mathematical construction (structuralist logic),

On the other hand, what context they fit into (empiricist logic).

Schedule 2: "The MEANING"

Access to MEANING ←		**Access to MEANING** →
Inside mathematical deductive logic	**Mechanistic Concept**	Within the mathematical context
Structuralist Concept		**Empiricist Concept**
"I know structurally why I do it"	"I do"	"I know contextually why I am doing it"

Meaning according to Vergnaud [19].

The acquisition of the meaning or significance of a concept (or knowledge) occurs through confrontation with problematic situations that involve the concept (or knowledge).

Meaning: This is a relationship between the subject and the situations and symbols that indicate the concept. These are the schemas we evoke when situations are presented to us.

Schema: The invariant organization of behavior for a given class of problems.

Theorems in action: These are "propositional" invariants: they are held to be true in the functioning of the activity. Example: $10 \times 4.7 = 4.70$ ("**When we multiply a number by 10, we add 0**.")

What is the role of the mathematics teacher?

1. **Teaching**

This role focuses on the mathematical content to be taught. This constitutes the basic material for fully fulfilling this role. The objective is the student's mastery of the curriculum content. Its assessment aims to monitor the level of mastery achieved by the student.

2. Trainer

This second role is just as fundamental as the first. It focuses more on the student as a learner of mathematics. Mathematics is no longer experienced as the goal of learning but as a support for a deeper learning process, that of "structuring one's thinking"[14] The objective this time is the development of qualities that promote learning. The assessment implemented to support this development is formative in the sense that it is the progress made by the student that is important.

These two roles are not juxtaposed, nor does one exclude the other; on the contrary, they stem from the same goal: "the training of the student in mathematics." The teacher-teacher and the teacher-trainer are not independent. One has an impact on the other. Thus, the following hypothesis is strongly suggested: *the development of qualities specific to learning mathematics will influence the results obtained during this learning.* In other words, it seems beneficial *to pursue training objectives to better achieve teaching objectives.*

The following table summarizes these two roles and their main characteristics.

Schedule 3: “Teaching-training”

Objective…	**Teaching**	**Training**
Direct Purpose:	Teaching someone something	Training someone to do something
Focused on...	Content mastery	Developing skills
Logic of...	Results	Process
Role	Teacher-monitor	Trainer-observer
of Assessment:	Summative and certification	Formative
Assessment Situations:	Tests, homework, essays	Classroom activities, resolving problem or open-ended situations,
Summary of Assessments:	Grades	Educational interviews, remarks, comments, monitoring sheets, etc.
Assessment Referent:	Program	Skills framework [12]
Purpose of Assessment:	Level control	State of progress

- **How to “learn by problems” in mathematics?**

Before addressing the issue of problem-based learning in mathematics in more detail, it is important to introduce the different types of problems encountered in mathematics. Let's distinguish three types of problems:

1. **Application problems;**
2. **Problem situations;**
3. **Open problems**.

- The **application problem** is the "classic" mathematics problem. It consists of a statement whose purpose is to stimulate the application of techniques previously seen (very often seen just before). It is rarely isolated but rather is part of a series of problems of increasing difficulty. It is traditionally proposed at the end of a learning period. Old mathematics textbooks were generally very fond of this type of problems.

Solving this type of problem is often based on "model practice," meaning that a model problem is solved in front of the class and then, through imitation, the student is expected to solve the following problems. Initially, the numbers in the statement are varied without departing from the context. The student's task is to identify them and substitute them for those in the proposed model. Then, more significant modifications are introduced: changes in context, introduction of intermediate steps, variations in the chosen units, etc.

While these problems rightly continue to occupy a prominent place in mathematics teaching, it is also important to control the limits of their scope.

"When using this type of problem, we do not always pay sufficient attention to the fact that it is not enough for a student to have studied a concept (that of division, for example) and to have understood its use in certain situations, for them to be able to reuse it in other situations which, for us, seem similar. We will show, (...), that the understanding of a concept takes time, that it takes time, a lot of time, for the different aspects of the same concept to be appropriated by the students, even when, for the experts that we are, these aspects seem very similar.[5]"

In addition to this drawback due to the lack of time-based approach, there is another criticism often leveled at this type of problem. This problem-solving approach is often based on excessive mechanization, which risks leading to "automatic" phenomena [2,3,4].

- **The situation problem** has been appearing for several years now in mathematics textbooks and curricula in the various countries where mathematics teaching has taken root. It is a problem whose objective is the opposite of that of the application problem, since it is no longer a matter of exercising and reinforcing existing knowledge, but rather of discovering knowledge from the problem, of giving it meaning. The problem situation must therefore "create the gap," open a gap that knowledge will then fill. A. Mercier summarized this process very well by entitling an article [15]:

"The Creation of Ignorance, a Condition for Learning."

By its very nature, the problem situation is at the beginning of the learning sequence. We sometimes refer to it as a "questioning situation" rather than a problem situation to emphasize the questioning role played by the problem. It is important to "put the student in question" before introducing the desired knowledge. Much like in a television commercial, where the first phase serves to engage the viewer, to put them in a situation of "astonishment" before informing them about the product in question, in class, it is therefore important to place the student in a situation of "astonishment" to facilitate the assimilation of the information.

"Learning mathematics, in our opinion, is first learning to be amazed, then learning to ask questions." For if there are no answers where there are no questions, there can be no questions

where there is no astonishment! In which case, didactics of mathematics is first and foremost didactics of astonishment." [10]

➢ **The open problem [8]** differs from the application problem and the situation problem in that it does not aim at the application of knowledge or the construction of knowledge. Its objective is to introduce the student to mathematical research and its various strategies. It is obvious that it is impossible to completely isolate a problem from the field of knowledge, and therefore no one will deny that to successfully complete an open problem, a certain amount of knowledge is involved, but this knowledge should not hinder the progress of the task in an open problem.

This type of problem [18] does not intervene directly within a learning sequence but rather alongside these sequences. Moreover, in the textbooks used in French-speaking Switzerland, these open problems are offered in the form of mathematical workshops alongside "normal lessons," even though the skills developed during these activities are obviously injected into the overall mathematical activity.

"The goal is to strengthen and promote activities in which the objectives of acquiring concepts give priority to behavioral objectives, such as:

- teaching students to search for and interpret data, extract relevant information, and ask questions;

- accustoming students to reacting positively to open-ended or momentarily difficult situations;

- valuing the procedures students find to solve a problem;

- encouraging students to increasingly refer to the results of their actions to judge the value of the work accomplished;

- promote all forms of intelligence [7]"

The open-ended problem emphasizes the processes involved more than the results; it encourages the adoption of a "research attitude." R. Charnay makes a genuine case for the open-ended problem and the "pleasure of research" it is supposed to foster [5] .

"A large part of school time is devoted to learning new knowledge and practicing its use. Is there time left to develop the pleasure of research, to challenge students with intellectual challenges whose objective lies in the activity rather than its results? Time, too, to develop the attitudes and skills necessary for this activity, time to try, to make mistakes, to discuss a solution with others, to try to convince others, to question a method or an answer? And all this, without the concern for learning concepts and without the pressure of assessment (...), there must be room in school for this kind of activity."

The open problem [16], the material for mathematical research, is a problem with the following characteristics:

- the statement does not imply either the method or the solution. Under no circumstances should this solution be reduced to the immediate use or application of a strategy presented in class. In this sense, an open problem is always original; it always requires a "design" phase.

- the "paths" leading to the solution are multiple. Thus, there is no single way to handle the situation favorably. **Multiple approaches** are thus discussed and emphasized; a single approach will never be institutionalized.

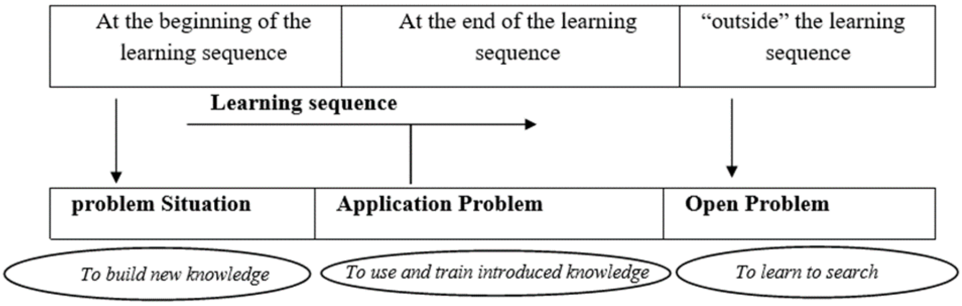
- the problem is located in a **conceptual field** with which the students are **sufficiently familiar**. This allows them to easily take "possession" of the situation and engage in testing and solution projects.

“The **entrance** is wide and welcoming enough to stimulate investigation”

- The situation must be complex enough to encourage a real research process, where exchanges between students are necessary and fruitful.

“The **exit** is far enough away for the stay in the research space to be fruitful.”

Schedule 4: “**Different types of mathematical problems”**



The implementation of these different types of problems in student activities contributes to what some have called "problem-based learning."[3] This concept of learning finds its place in the mathematics classroom for two major reasons.

The first is the fact that the fundamental importance of the "problem" in learning mathematics is well established: every mathematical concept starts with a problem and returns to it.

The second reason is that the objectives of the mathematics course, as we have developed them in the previous pages, coincide with the goals sought by “problem-based learning”, where the aim is on the one hand to master content and on the other hand to develop qualities. This duality is similar to that mentioned in the table.

- **Comparison between open situation and problem situation.**

	Open Problem	**Situation-problem**
Activity Type	• The student is placed in a research situation, • The statement is chosen so that everyone can engage in the resolution.	

Objectify	Methodological *The student does not have a problem-solving method that has been taught to them.* They must develop their own solutions.	Acquisition of new knowledge *The student can engage in the solution by drawing on prior knowledge.* *But this knowledge proves to be either wasteful or inappropriate.*
Taking the student into account	Taking into account student differences: Each piece of work is taken into account, the diversity of approaches is recognized, and originality is valued. No single procedure is favored. Context-based validation is not always possible.	Considering students' conceptions: Students must be able to verify for themselves whether their knowledge is uneconomical or inadequate (an obstacle) for solving problems. The targeted knowledge is the most effective solution tool. Contextual validation is necessary; the importance of control methods.
Conclusion	Teacher's choice: • Research methods • Highlighting the diversity of approaches	Institutionalization: Identification of new knowledge or know-how.
Contract	The student should not be able to be guided by the teacher's expectations.	

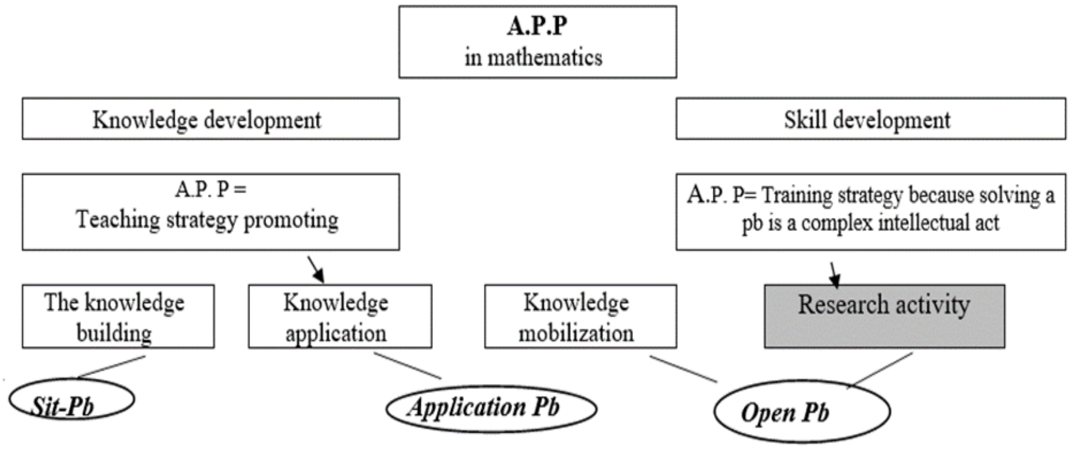
The following table schematically shows how "problem-based learning," or PBL, can be applied in mathematics and how the three types of problems mentioned [1] above fit into it.

According to the learning objectives.

- Problem situations lead students to self-construct new knowledge. Students become aware of the limitations of their current knowledge in order to construct new knowledge.
- Reinvestment problems allow students to reinvest previously acquired knowledge.
- Synthesis problems, often more complex, allow the implementation of several types of knowledge.
- Assessment problems, fairly standard, allow the teacher and students to take stock of how knowledge is being mastered.
- Open problems are designed to place students in a research situation.

This typology highlights the unique nature of the open-ended problem. The other types of problems focus on the acquisition or mastery of mathematical concepts. The open problem is intended to develop research behavior and methodological skills.

Schedule 5:" **The A.P. P in mathematics"**



Application 1. (The Greatest Product)

The number 23 can be written in several ways as the sum of integers:

For example: 23 = 11 + 5 + 7.

Find among these sums the one whose product of the terms is maximum.

And with other numbers?

The Mathematical Situation

Study of the product of integers with a fixed sum. The solution to the problem can be expressed as follows:

- If the number is a multiple of 3, the largest product is obtained by calculating 3 × 3 × ... × 3 (decomposition into 3 + 3 +...+ 3; for example, for 12, the largest product is 3 × 3 × 3 × 3 = 81)
- If the remainder of the number in division by 3 is 1 ("if the number is equal to a multiple of 3 plus one," to use a common formulation among students), the largest product is obtained by calculating 3 × 3 × ... × 3 × 4; (decomposition 3 + 3 +...+ 3 + 4, the 4 being obtained by adding the last 3 and 1; for example, for 10 the largest product is 36; 3 × 3 × 4 or 3 × 3 × 2 × 2)
- If the remainder of the number in division by 3 is 2 ("if the number is equal to a multiple of 3 plus 2"), the largest product is obtained by doing 3 × 3 × ...× 3 × 2 (for example, for 14 the largest product is 3 × 3 × 3 × 3 × 2 = 162).

The proof of this solution is based on the following properties:

a. If 0 appears in the additive decomposition, the product of the terms is zero.

b. If 1 appears in the additive decomposition, the product of the terms is improved by adding 1 to one of the terms of the product (e.g., 3 × 3 × 4 instead of 3 × 3 × 3 × 1).

c. If, in an additive decomposition, any number greater than or equal to 5 is decomposed into two terms greater than 1, the product of these two terms will be greater than the original number.

Indeed, if n is one of the numbers in the decomposition, replacing it with [(n - 2) + 2] does not change the sum, and the product becomes 2 × (n - 2) = 2n - 4 = n + (n - 4). Now (n - 4) is positive if n is greater than 4, so n + (n - 4) is greater than n, if n is greater than 4. Any number n greater than 4 (greater than or equal to 5) allows us to obtain a larger product if we replace it with 2 × (n - 2). By applying this property, the only numbers kept are 3s or 2s (since 4 = 2 × 2).

d. if in a product we replace 2 × 2 × 2 = 8 with 3 × 3 = 9, the product will be larger; so as soon as there are three 2s in the decomposition, we replace 2 × 2 × 2 with 3 × 3; Therefore, only one or two 2s are retained among the terms of the product.

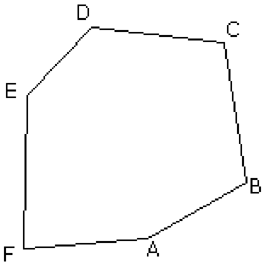
Mathematical Objects That Can Be Worked On

Regarding the mathematical objects worked on, several are objects that can be considered acquired by the fourth grade, but certain types of reasoning make it possible to consider implementing this situation at all levels of high school, and even beyond.

Primary College	**High school**
- 0 absorbing elements of multiplication - 1 neutral element of multiplication - additive decompositions of an integer - multiplication tables - associativity and commutativity of multiplication. - understanding of the terms "sum," "product," "terms," "product of the terms of the sum" - elementary reasoning about numbers: $1 \times 1 < 2$; $1 \times 1 \times 1 < 3$ and $1 \times 2 < 3$; $2 \times 2 > 1 \times 3$ Return to	Additional methodological skills, particularly: - Reasoning by disjunction of cases - Reasoning by recurrence - Writing the solution to the problem posed - Interpreting elementary reasoning about numbers? ($1 \times 1 < 2$; $1 \times 1 \times 1 < 3$ and $1 \times 2 < 3$; $2 \times 2 > 1 \times 3$) In terms of the form of the additive decomposition obtained for the initial integer. - Euclidean division by three, more precisely, remainders in this division - Algebraic calculus, more precisely, solving a first-degree inequality with one unknown, and interpreting the solutions by returning to the problem posed

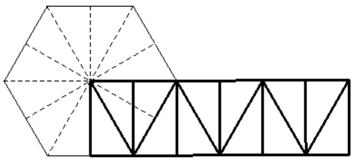
Application 2. (Areas without calculation [6])

Without calculation, use the straightedge and compass to transform a hexagon into a rectangle with the same area.

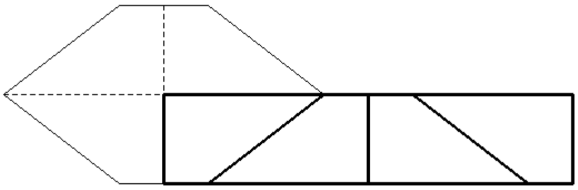


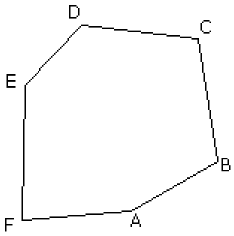
Solutions (nondetailed)

If the hexagon is regular, we can consider the following transformation:

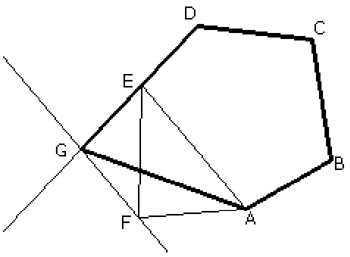


If the hexagon has two axes of symmetry, we can consider the following transformation:

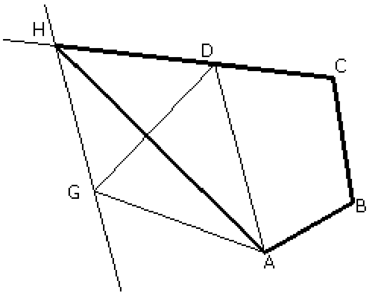




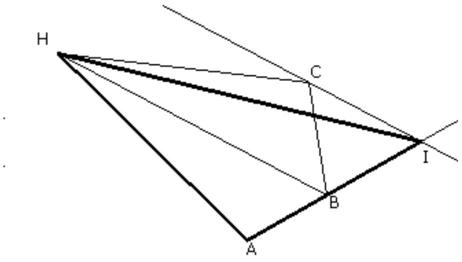
I Let ABCDEF be any hexagon.



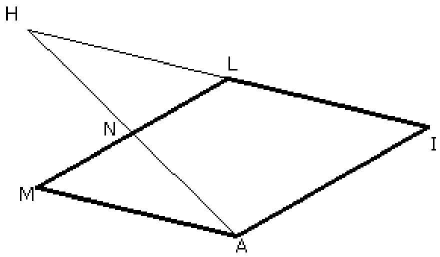
II We draw the segment [EA] (we join two non-consecutive vertices of the hexagon), the half-line [DE). We then draw the parallel to [EA] passing through F: it intersects [DE) at G. We thus obtain the pentagon ABCDG.



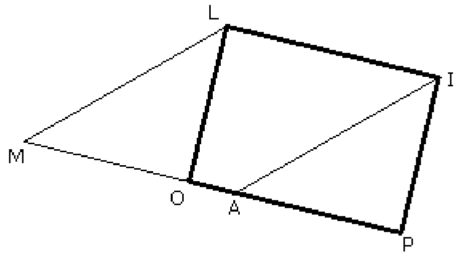
III We draw the segment [AD], the half-line [CD). We then draw the parallel to [AD] passing through G: it intersects [CD) at H. We thus obtain the quadrilateral ABCH.



IV We draw the segment [BH], the half-line [AB). We then draw the parallel to [BH] passing through C: it intersects [AB) at I. We thus obtain the triangle AIH.



V We draw L, the middle of [IH]. We then draw the parallel to [AI] passing through L and the parallel to [IH] passing through A. We obtain the parallelogram AILM.



VI We draw the perpendicular to [AM] passing through L: it intersects [AM] at L. We draw the perpendicular to (LI) passing through I: it intersects (AM) at P. We obtain the rectangle OPIL.

Changing one's practices? Under what conditions?

At this point in the reflection, it seems interesting to question the necessity, the interest, or the need for teachers to change their ways of doing things. This question is central to didactic thinking. Does this mean we must question everything? That we must change our practices from top to bottom? That what is currently being done in our classrooms is derisory or even outdated?

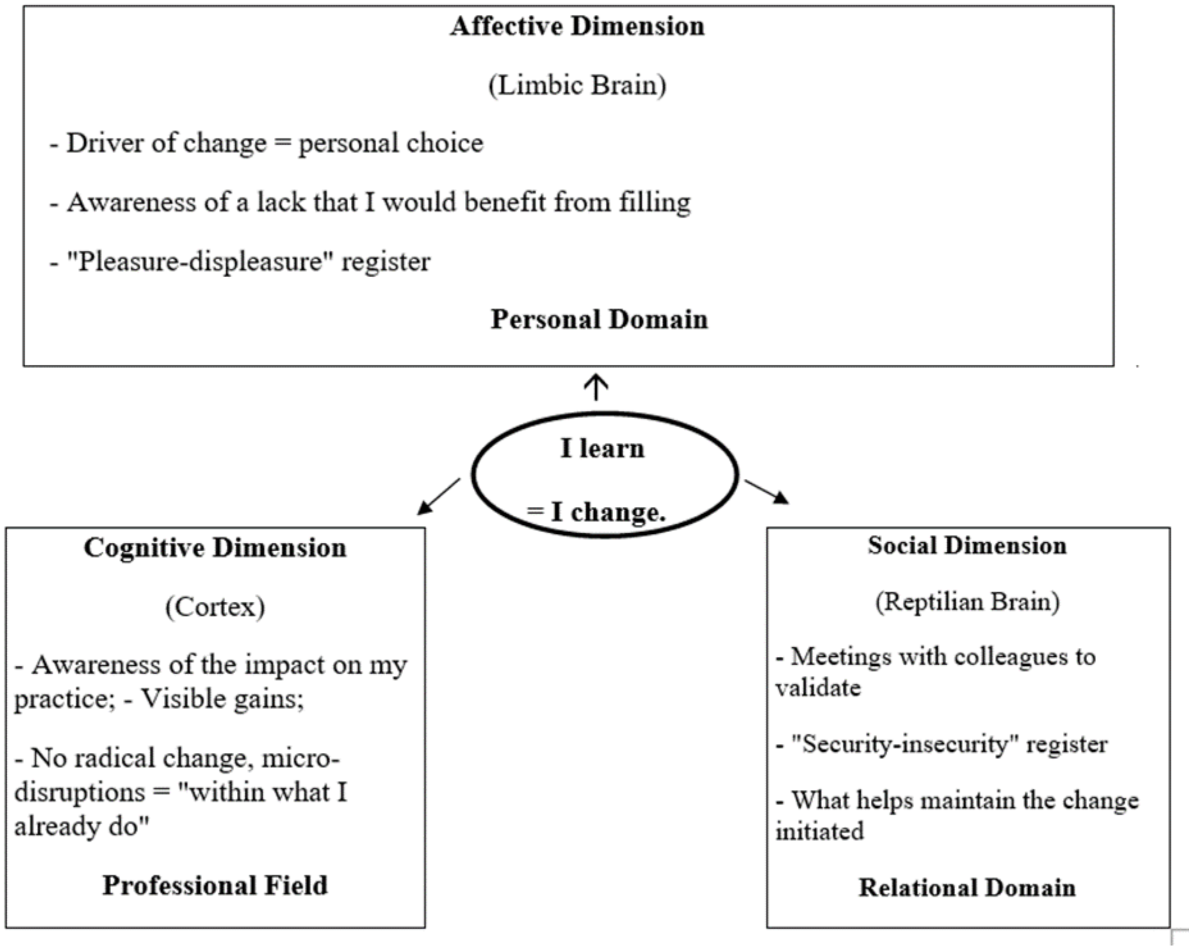
These reflections are not part of a logic of radical change but rather a perspective of evolution. It is about progressing in our professionalization rather than "wanting to do things differently tomorrow and denying what was done yesterday."

According to this model, any change in an individual's behavior (student, teacher, or other) requires the integration of numerous learning processes, while the achievement of learning requires a change in cognitive structure. To summarize, we will say that to change is to learn, and to learn is to change. This statement is put into perspective with neuroscience and more specifically the fact that following the vertical axis, the human brain is subdivided into three distinct but complementary structures: the reptilian brain, the limbic brain and the gray matter, the cortex. Each structure has a different function.

“These data from neuroscience now allow us to know that our cognitive activity begins as soon as sensory stimuli enter the reptilian complex, which processes them according to a register of security or insecurity, that is, by assessing whether they constitute a threat to our physical or psychological integrity. The limbic system then takes over and apprehends the stimuli that reach it from a register of pleasure or displeasure, searching its memory to give it meaning. The information finally reaches the cortex, which processes it based on a register of adaptability to understand its meaning. In summary, to function optimally, our reptilian brain needs to feel safe, and our limbic system must experience or anticipate a minimum of pleasure so that the cortex can understand the information provided to it.”

Thus, we can summarize in the following table the three dimensions that any change must include if it is to be efficient, each corresponding to a structure cerebral.

Schedule 6:"**The three dimensions of change-learning**"



Affective Dimension

(Limbic Brain)

- Driver of change = personal choice
- Awareness of a lack that I would benefit from filling
- "Pleasure-displeasure" register

Personal Domain

I learn

= I change.

Cognitive Dimension

(Cortex)

- Awareness of the impact on my practice; - Visible gains;
- No radical change, micro-disruptions = "within what I already do"

Professional Field

Social Dimension

(Reptilian Brain)

- Meetings with colleagues to validate
- "Security-insecurity" register
- What helps maintain the change initiated

Relational Domain

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