THE STUDY OF THE OBSTACLES AND ERRORS IN THE MODERN DIDACTICS. PARTICULARIZATIONS FOR MIDDLE SCHOOL MATHEMATICS

(METHODOLOGICAL ASPECTS OF EMPIRICAL RESEARCH)

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Abstract

The learning approach in a constructivist manner implies, among other things, considering the obstacles that arise in carrying out this *process* and are manifest, if they are not overcome, at the level of the learning outcome, by *errors*. In mathematics learning, some of these obstacles are isolated and more difficult to control didactically. However, most of them have a phenomenological character and, consequently, the identification of their nature (*epistemological, psychological or didactic* (Astolfi, 1997)) is required. This co-ordinate sets new dimensions to the didactic field, generating a new paradigm concerning the role of errors in mathematics study.

Key words: *didactics, learning process, obstacle, error, research methodology.*

1. The theoretical frame of the obstacle and error problems in the learning process. A synthetic presentation

Out of the multiple perspectives from which the problem of the difficulties that pupils (and not only they) are confronted to in the study of school mathematics, we have focused our attention on one that we consider to be central: *the mathematics teaching and learning in the middle school.*

The research carried through so far has demonstrated the fact that, in the learning process, there is a two-way interdependence relationship and determination between obstacles and errors: an obstacle that the subject involved in a learning *process* may determine an error in the learning *outcome*, and at the same time, an unidentified error that was not unsolved in due time may constitute an obstacle in the further evolution of knowledge.

The relation between obstacles and errors is of interest for the *error didactic* field. *The learning error*, far from being avoided or blamed, can be revaluated as a *didactic instrument*, as a *symptom* of an inadequate cognitive step in which the pupil is engaged, with repercussions on the knowledge

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building manner. In these conditions, the identification of the various types of obstacles determining error arising is called for, so that they may be either prevented or removed, the specific errors especially, by their provocation-anticipation. However, this supposes from a didactic point of view, the knowledge of the specific obstacles of the learning situation, as well as of the errors they can determine. Hence, the expected results should be obtained by their appropriate diagnosis and treatment.

In didactics, it is important to differentiate between *error* and *mistake*, notions that are synonymous up to a certain point: the obtained result of a didactic (learning) activity is not equal to the expected result. This meaning superposition regards only the learning outcome, the process aspects being, however, different. Thus, if the pupil knows the correct way to the result but the obtained result is not the expected one, he has committed a *mistake*. But, on the other hand, if the pupil does not know the correct way to the correct result, and the obtained result is not the expected one, this is an error. Therefore, mistakes are accidental, superficial, determined by mostly subjective factors (carelessness, fatigue, emotions, etc.), and they must be avoided, not having any didactic value. But errors are more profound, of a randomly or systematic nature, being the proof of a certain manner of thinking, of reasoning, a very important conduct element in the pupil's engaging in a learning activity. Every error, as irrational as it may seem, has its own logic.

From a didactic point of view, the knowledge of the errors and of their ground causes is very important, because they can be diagnosed in an extremely correct way in this manner.

2. The methodology of the empirical research

Our research belongs to the psychological and pedagogical kind of research concerning the education subjects' interaction with the educational reality. The main **purpose** of the undertaken research has been on the one hand, the *identification of some of the obstacles that the middle school pupils and, implicitly, the teachers are confronted with, in the process of mathematics teaching*. On the other hand, we have had in view the *gathering of the frequently encountered errors in mathematics* learning at this level. The investigation field has been focused on the structural elements of the didactic system and especially on the curricular offer presented to the middle school pupil at the mathematics classes.

2.1. The research objectives

The complexity of the studied phenomenon, derived from the complexity of the teaching process and correlated to it, calls for a complex investigating approach, with an aim to finding out as many relevant aspects of the phenomenon as possible.

Being adapted to the problems of the obstacles and errors in mathematics teaching in middle school, this purpose is particularized by the following general objectives:

O1: ***The psychological and pedagogical analysis of the mathematics contents presented in the main curricular documents for middle school.***

O2: ***The analysis of the didactic strategies (of teaching-learning-assessing) used in mathematics teaching at the middle school level, from the perspective of the studied problems.***

O3: ***The study of the middle school pupils' motivational level for mathematics learning and the identification of the factors with an affective-motivational impact on their result/performances.***

O4: ***The analysis of the results obtained by the pupils in mathematics learning.***

O5: ***The identification, recording and specific analysis of the obstacles and specific errors in mathematics learning in middle school.***

These general objectives have constituted the reference frame for working out the **specific objectives** of the research. Their analysis can be examined as follows:

O_1. *The analysis of the presentation of the mathematical concepts in the basic curricular documents, from the perspective of their practical application.*

O_2. *The study of the impact of the applications with a practical content on the results in learning mathematics at middle school level.*

O_3. *The study of the didactic treatment of the mathematical concepts from the perspective of the transversal (intra- and inter- disciplinary) correlations and of their spiral evolution.*

O_4. *The knowledge of the pupils' degree of implication in the achievement of their learning tasks.*

O_5. *The study of the impact that mathematics has on the middle school pupil's self-image and on his outlook on mathematics as a school subject.*

O_6. *The identification and the analysis of the determining factors of motivation for learning mathematics – the perspective of the teachers' outlook and of the pupils' strategy.*

O_7. *The examining of the degree to which the obstacles appearing in mathematics learning at middle school level are taken into consideration in the projecting, carrying out and assessment of a didactic sequence.*

O_8. *The recording and the interpretation of the specific errors of the studied mathematics contents in middle school and the analysis of the way in which they have been perceived by the pupils and by the teachers.*

O_9. *The investigation of the assessment strategies used in the middle school mathematics teaching.*

O_{10}. *The analysis of the shaping and developing of the pupils' meta-cognitive behaviours (self-observation, self-analysis and self-assessment) specific didactic contexts of mathematics learning (a concept learning, a problem solving, the practical application of a mathematics piece of knowledge).*

2.2. The hypotheses of the research – the axis around which the components of the investigating steps are articulated

The carried out research focused on the checking of the **general hypothesis**, according to which ***middle school pupils are facing a series of obstacles in mathematics learning, which they, as well as the teachers, are more or less aware of; the knowledge and going beyond these obstacles, as well as the appropriate dealing with the specific errors determined by them will ameliorate the mathematics teaching-learning activity.***

In order to check the general hypothesis we have elaborated a set of **secondary hypotheses** naturally deriving from these. The first four ones have a descriptive character:

I_1: *To what extent mathematics curriculum at the middle school level evinces explicitly enough the finalities of mathematics study in school, especially from the perspective of its practical applications and how these influence the pupils' perceptions on the usefulness of mathematics learning.*

I_2: *To what extent the mathematics curriculum at the middle school level has continuity with the one at the elementary school level, with the one at the high school level respectively, in the sense of forming mathematics concepts and applicative representations corresponding to the gradient levels of complexity, to the ensuring of the connections between knowledge and the achievement of the intra- and inter-disciplinary transfer.*

I_3: *To what extent the middle school level pupils are adequately motivated for mathematics study, sustain the mathematics teaching process and aim at achieving purposes of pragmatic and autonomous learning.*

I_4: *To what extent the employed didactic strategies and the particularities of the learning environment created by the teacher in doing his classes facilitate the achievement of efficient didactic activities, which sustain the constructive mathematics learning, based on the optimal revaluation of the pupils' mental potential (fine and systematic actions of self-observation, self-analysis and self-assessment of the involved mental processes).*

I_5: *If the system of assessment of the middle school mathematics study outcome is correctly projected and achieved, positively influencing the carrying out of the learning process, then we will have a constructive and formative process of mathematics study.*

I_6: *If the middle school pupils, together with the teachers, focus their attention and concentrate their study potential on the identification and revaluation approach of errors that are produced in the mathematics study, then they will identify and differentiate the "errors" from the "mistakes", they will have a positive self-image, and a "pro-mathematics" motivational and attitudinal conduct*

The research variables of the educational field subject to the investigation and the worked out hypotheses concerning them constituted the selection criteria regarding the research methods, whose system we are presenting synthetically as follows.

2.3. The research variables- the status and the operational-rendering

The approach to the educational act in a systemic perspective increases its level of complexity and, consequently, it enhances the difficulty of the identification and of the selection of the research variables. Owing to the fundamental role of the variables in the carrying out of the investigating steps, i.e. the operational-rendering of the studied problems, we have taken into account two criteria in their selection: on the one hand, their high relevance from the point of view of the problems of the obstacles and errors in mathematics learning in middle school and, on the other hand, the implication of the three components of the triangular model of the didactic act (teacher-pupil-knowledge). Therefore, our research has been sustained and directed by the study of the following variables:

V_1. *The curricular analysis*: the degree of representative being of the mathematics applications in practice, at middle school level.

V_2. *The continuity and discontinuity at the level of the mathematics curriculum for middle school.*

V_3. *The pupils' motivation for learning mathematics in middle school*: the middle school pupil's affective-emotional state and self-esteem as reported mathematics, but also his outlooks (favourable or unfavourable attitudes and prejudices) concerning mathematics as a school subject;

V_4. *Middle school mathematics learning strategies*: the didactical dealing with learning, with forming mathematics concepts and with features of the middle school mathematics learning environment;

V_5. *Middle school mathematics learning strategies.* The knowledge, forming and modeling of the meta-cognitive capacities: self-observation, self-analysis, self-control, and self-assessment of the mental activity;

V_6. *Middle school mathematics assessment strategies.* Specific polarizing in the educational field: formativeness-formalism, process assessment- outcome assessment, and others.

V_7. *Pupils' performances in mathematics learning*: the knowledge level of school mathematics basics and the level of the mental training of the pupils being in the learning situation (generative or algorithmic structures).

V_8. *The status of the learning errors, in the pupils' outlook:* behavioural–attitudinal schemes of the middle school pupil confronted to obstacles and errors;

V_9. *The status of the learning errors, in the teachers' outlook:* the perception, differentiation, and the appropriate dealing with errors and mistakes;

V_{10}. *Obstacles and errors encountered in mathematics study*: the epistemological or experiential obstacles and the specific errors.

These variables can be distributed in **packages**, as follows:

a. *Variables referring to the mathematics* ***curriculum***: **V1, V2;**
b. *Variables referring to the* ***teacher:*** **V4, V6, V9;**
c. *Variables referring to the* ***pupil:*** **V3, V5, V7, V8, V10.**

2.4. The spectrum of the research methods

In the carrying out of the investigating steps, the employed methods mutually complete and support one another, acting in a convergent way in the sense given by the objectives of the research. The efficiency of each research method is given by the extent to which it is personalized by the researcher, by the manner in which it is integrated in the research project, as well as by the way in which it is combined with the other components of the project.

The used methodology with the aim of the research of the previously presented variables has been defined by *6 methods of research*, logically and chronologically applied during the period of the research carrying out (2006-2010): *the observation, the analysis of the curricular documents, the research of the products achieved by the pupils, the focus-group, the questionnaire* and *the experiment.*

The observation method has been used in two forms, chronologically ordered:

a. The direct observation carried out by the researcher, which allowed the continuous accumulation of a set of information concerning the obstacles that the pupils face in learning mathematics in middle school and the specific errors for this process. The systematically recorded observations have constituted the base of the working out of the research methodology, by delimiting the problems subject to the research, by identifying, delimiting and selecting the variables and by formulating the objectives and the research hypothesis.

b. The observation achieved with and by the students in the application schools (middle schools and high schools having middle school 5^{th}-8^{th} grades), where they carried on the pedagogical practice training. This observation was focused on the implicit analysis of the errors/mistakes made by the pupils within the mathematics classes, as well as on the teachers' and the pupils' attitudes towards these (the manner of intervention and of solving the situations in which the pupils commit errors/ mistakes). The observations have been recorded, on the spot, in *an observation card*, structured as follows:

Table 1. *The error observation and recording card*

Lesson Moment	Description of the error/ mistake	Manner of dealing with the error/mistake*		Observations/ methodological suggestions
		Teacher	Pupil	

The information gathered from the observation cards have served for: *working out the items* in the questionnaire applied to the pupils, *identifying the obstacles* typical for middle school mathematics, as well as for *centralizing the errors* that are specific for the study of this subject.

The analysis of the curricular documents concerned:

1. *The minutes written on the occasion of the inspections effected for the didactic degree obtaining* and *the current assessment reports* (**30** documents).

For our research, the information recorded following the analysis of these documents was revaluated:

- directly and qualitatively processed with the aim of obtaining conclusions;
- as support elements for question formulating within the focus-group;
- as a basis for building the items constituting the questionnaires addressed to the pupils.

2. *The mathematics syllabus* for elementary school, middle school and inferior high school (9^{th} grade).

3. *The middle school mathematics manuals*, one manual for each middle school class, from different publishing houses, manuals in use at the date of the research carrying out, among the most frequently used by teachers. We have used the grill below for the recording of the data:

* The observer noted down the teacher's and the pupil's behavior towards the error/mistake (ignoring, sanctioning, (self) correction, identification of the generating cause, etc.).

Table 2. *The school manuals research grill*

SUBCHAPTER/ THEME	Solved exercises and problems and used examples for introducing notions	Proposed applicative exercises and problems	
		The number of the exercise or problem and page (the relative frequency)	The percent ratio*

The obtained results were used for working out the level of representativeness of the practical applications, according to various criteria (the chapter, the mathematical discipline, the year of study, etc.).

The research of the pupils' products had as its object *the test papers of the Written Test for Mathematics, the Middle School Final Examination, Session June 2006, variant 2.* The sample on which the study was carried out was formed randomly, of **300 test papers** from **12 school units** from **Constanța county**, as follows:

- 3 high schools with $5^{th} - 8^{th}$ grades: 2 urban high schools (one with a theoretical profile, the other one with a vocational profile) and one rural high school;
- 9 middle schools, out of which 5 are urban (middle schools in the city centre and schools on the outskirts of the city) and 4 rural schools.

The subjects included in the study represent 52% of the total number of candidates from these schools. In the table and the graph below we render the structure of the sample:

Table 3. *The structure of the sample included in the study (research of the pupils' products)*

	URBAN ENVIRONMENT		RURAL ENVIRONMENT		TOTAL
	Middle school	High school with 5^{th} -8^{th} grades	Middle school	High school with 5^{th}– 8^{th} grades	
Girl subjects	69	25	43	12	149
Boy subjects	67	26	44	14	151
TOTAL	136	51	87	26	*300*

* *The percent ratio* shows how much per cent of the number of exercises and problems proposed for the respective theme have a practical-applicative character.

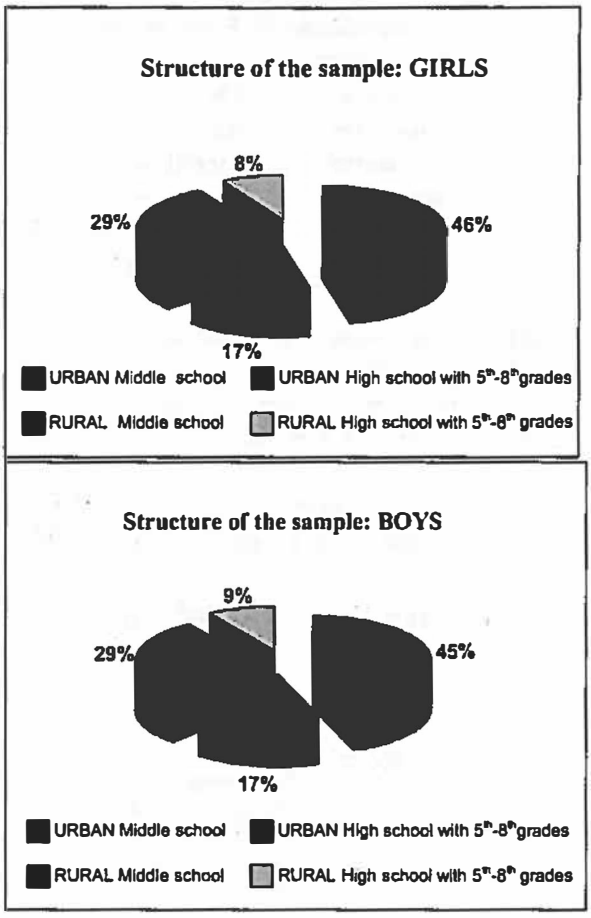


Figure 1.a and 1.b. *The structure of the sample included in the study (research of the pupils' products)*

The focus-group was used in a stage previous to the inquiry, with the aim of obtaining useful information for formulating the items and structuring the questionnaire. **Two focus groups** were organized, in which **mathematics teachers** (from *middle schools* and *high schools* respectively) with a rich personal didactic experience took part (they were *methodologists* or *pedagogical practice training mentors*). Each focus-group had a number of **6 participants**, and the duration of the carrying out of which was **1.5 h**. The talks, recorded and analyzed further, after their carrying out, were focused on **4 major issues**:

a. *The tendencies in middle school mathematics study in the period of the reform in the pre-university education. The didactic of mathematics in the present context of the Romanian education;*
b. *The alternative middle school mathematics manuals;*

c. *The obstacles and errors in middle school mathematics study;*
d. *The difference between errors and mistakes in the context of the mathematics didactic. The didactical dealing with errors.*

The didactic experiment carried out within this research had as its purpose the testing of the experimental research hypothesis: *if the didactic strategy used by the teacher in class is focused on the identification and anticipation of the obstacles in the learning, as well as on the appropriate dealing with the errors recorded in the learning, the performances obtained by the pupils will be much better.*

The central *independent variable* introduced in the experiment was reported to the used didactic strategy. Out of the ensemble of elements supporting the steps of the learning process, we have pointed out other categories of sub-variables:

a. *The revaluation of the continuity between the mathematical contents;*
b. *The intensifying of the pupils' individual activity;*
c. *The continuous assessment of the learning process;*
d. *The ensuring of a positive social-affective climate;*
e. *The evincing of the applicative character of the mathematical knowledge;*
f. *The diversification of the didactic material.*

The dependent variables, those quantified, are represented by the results/performances obtained by the pupils in mathematics learning, measured by a summative assessment test of their knowledge. Besides, without being quantified and measured, the following were observed and assessed from the qualitative point of view: *the level of the pupils' implication in the specific activities of learning* and *the perseverance* in their achievement, as well as *the general attitude towards the mathematics class.*

For testing the specific hypothesis referring to the representativeness of the difference between the average marks obtained by the pupils at the knowledge tests, we applied *the t test for pair samples.*

The inquiry was carried out on the basis of a **questionnaire** *of the omnibus type*, applied to the pupils in the 8th class (at the end of middle school), in which the **176 items** were worked out with the aim of the research of each one of the **10 variables** of research, as well as of some relationships between them.

The questions included in the questionnaire were of two types:

a. Closed *questions*, with pre-encoded dichotomy answer variants (of the *true/ false* type), or multiple answers. For the latter, the measuring scale of the answers was generally *the Likert type scale with 6 steps*, in order to avoid the tendency of the subjects to choose the central value with answers of the 'so-so" type. In this case, the questioned pupils could

opt for one of the values of the scale, from **6:** *This always happens/ I totally agree to the statement/ The statement suits me to a very great extent* down to **1:** *This never happens/ I totally disagree with the statement/ The statements suits me only to a very little extent.*

b. Open questions, of the "others (which ones)..." kind, leaving to the questioned subject the liberty of expressing his opinion, with the aim of surprising other aspects, as well, which were not anticipated, especially for the variables susceptible of various answers. The answers obtained for this type of questions were not presented, being insignificant from the quantitative point of view. The technique applied in working out the questionnaire was the "funnel" type one, from the general to the particular, the factual questions of identification of the subject being placed at the end.

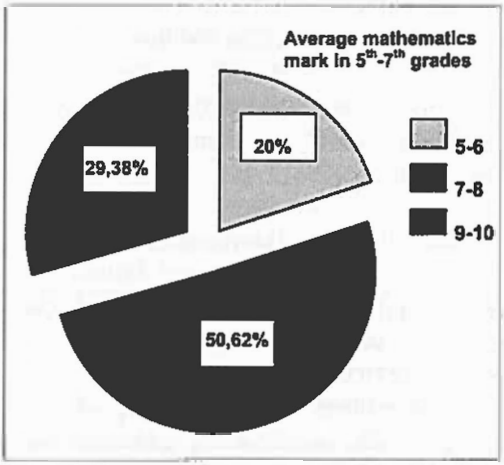
The questionnaire was pre-tested on a lot of 27 8th grade pupils from the city of Constanța and applied to **22** pupils **classes**, representing **19 localities** (**12 rural** and **7 urban**) and it included **4 counties** of the South-East area of Romania (**Constanța, Tulcea, Brăila, Călărași**) and **the city of Bucharest**, totalling a number of **350 pupils**. The sample, settled randomly, included pupils in **the 8th grade**, because towards the end of middle school the level of maturity of the pupils and their perspective on the education system allows them to formulate and express opinions on mathematics tuition.

We present, as follows, by circular diagrams, the manner of structuring of the sample, according to various criteria: *the school type*, *the subjects' gender*, *the school location*, the *mathematics average mark in the 5th-8th grades* respectively.

Table 4. *The structure of the sample included in the inquiry*

School type		School environment		Subjects' gender	
Middle school	**High school/school group with 5th-8th grades**	**Rural**	**Urban**	**Girls**	**Boys**
214 (38.86%)	136 (61.14%)	170 (48.57%)	180 (51.43)	190 (54.29%)	160 (45.71%)

Subjects' gender: male **Subjects' gender: female**



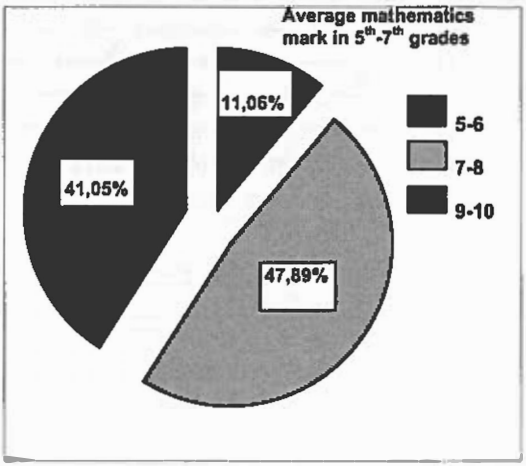


Figure 2.a and 2.b. *The sample distribution according to the subjects' gender and average mathematics mark in 5th-7th grades*

The information obtained by applying the questionnaires allowed for the creation of a data base that was submitted to statistics interpretation, by using the **SPSS 14 program**, to the achievement of:

a. The basic statistical operations: *frequency tables* including: *the frequency, the percent* and *the cumulative percent.*
b. The working out of the indicators of the central tendency: *the mean, the median, the mode, the standard deviation.*
c. The graphical representation of the frequency distribution: *circular diagrams, bar diagrams, line or point diagrams, histograms.*

d. Testing the statistical hypotheses by applying the tests adapted to the distribution type: *the Wilcoxon nonparametric test (TNW), for pair samples.*

e. The co-relational analysis: *the p Spearman co-relational coefficient.*

The table below represents the distribution manner of the research methods on the studied variables.

Table 5. *The correspondence between the variables and the research methods*

Method / Variable	observation	analysis of the curricular documents	case study	focus-group	Question-nnaire	Experi-ment
V1		X		X	X	
V2		X		X	X	
V3				X	X	
V4		X		X	X	
V5				X	X	
V6					X	
V7			X	X	X	
V8					X	
V9		X		X	X	
V10	X	X			X	X

3. General conclusions

The undertaken research, a mainly *diagnostic* and oriented towards *the hypotheses testing,* mirrors, within certain limits, the existing situation in the middle school mathematical education in the geographic area where the study was carried out. But any generalizing of the obtained results at the level of the education system presupposes the assuming of certain "risk doses' that cannot be neglected.

In the following part, we will evince some recorded aspects, with a more general character, accompanied by **recommendations** constituting *possible guidelines in the working out of a middle school mathematics teaching model,* to which both those training to become mathematics teachers and those practicing in the field may refer.

- The mathematics curriculum for middle school reflects only to a very small extent the practical-applicative character of the knowledge. The mathematics study is done by a very low level of

reference to the social practices, the curricular orientation, (mainly concerning the content and strategy), being towards an excessive theorizing of knowledge, without, however, granting sufficient attention to the theoretical-argumentative support to the solving of problems. The results of the research demonstrated that the pupils have this awareness of the practical usefulness of the mathematics knowledge, but we suppose that it is not out of their own beliefs, but it is induced by the social factors. Consequently, the perspective of their potential applicability in the daily life being in a further plan, the energetic potential that the pupil is willing to invest in learning mathematics as a school discipline is focused, to a great extent, on obtaining as high as possible marks at the evaluation. Therefore, **we plead for the heightening of the level of explicit rendition of the practical-applicative dimension of the mathematics knowledge, by reference to concrete life situations, that should support a conceptualized construction of mathematics knowledge.**

- The issue of the continuity in mathematics study concerns, among others, the **achievement of knowledge *transfer*, a practice that should become a co-ordinate of the working out of the didactic strategy for any mathematics teacher.** Also, the mathematics teacher should know the particularities of the mathematics curriculum for elementary school and take it into account in the projecting, organizing and carrying out of the 5^{th} grade mathematics classes, in order to ensure the pupils' adapting to the exigency of middle school mathematics. At the same time, the knowledge of the mathematics curriculum for the post-middle school levels is necessary, in order to ensure the premises of a school evolution without failure in mathematics.
- As it comes out of the achieved study, the didactic strategies that structure the context of mathematics teaching are very little adequate for an active learning, based on involvement and awareness on the pupil's side. As regards the pupils' mental potential, the mathematics classes revaluate very little the pupils' creativity and imagination, in favour of thought, memorizing and understanding. The pupils do not have the exercise of the mental representation of what they learn and they do not verbalize the mathematical situations sufficiently. Generally, they memorize some rules (algorithms), models, often lacking signification (because of the symbolic or graphical language), which they apply to standard situations (according to the solicitations). However, these strategies are not directed towards the forming and developing pupils' mathematics competence, translated by the capacity to

interpret mathematically a given situation and to model it correspondingly.

- The modern methods of *evaluation*, which we regard from a complementary perspective, are far from being a usual presence in the mathematics classes. The pupils still face the obstacle created by the high level of complexity of the evaluation objectives, to which not all of them have access. But mathematics competence means, besides the very complex theoretical problems solving, the mathematical interpretation of a context, the creation of a mathematical device, the solving of a practical problem, the imagining of a certain configuration of the plane or of the space, and others. As we have said, school mathematics is very restrictive from the point of view of the revaluation of the *cognitive, creative* and *aesthetical* potential of the pupils. Therefore, **we do not plead for an abandonment of the traditional methods of teaching, but for a complementary approach of the didactic strategies, by which the pupil's role in the process of teaching should be reconsidered and his mental potential should be revaluated maximally (stressing the importance of the meta-cognitive strategies).**
- We do not promote a strategy based on the "error/mistake chase", but a certain manner of the teacher's/ pupil's referring to these, and, at the same time, a strategy of the pedagogic revaluation. The difference-making between "error" and "mistake" is very important for the learning process, because each of them has a different impact on the learning process, and consequently, requires a specific manner of didactic dealing with. The "error" and mainly the didactic dealing with it is important for our study: the error identification, the explanation and the elimination of the generating cause/causes that determined it (the generating obstacle), and the revaluation of these elements as **guidelines in building up a learning situation,** and, at the same time, **a permanent component of the strategic repertoire specific to the middle school mathematics teacher.**

We are aware of the fact that the effected research has a restrictive character. However, we hope that, by what we have achieved, we have opened the way to other research work in the mathematics didactic, as each of the studied variables may constitute itself a generous research field.

Selective bibliography:

1. ASTOLFI, J.-P. (1997). *L'erreur, un outil pour enseigner.* Paris: ESF Éditeur.
2. ASTOLFI, J.-P. (1998, 2[e] éd.). *Mots-clés de la didactique des Sciences. Repères, définitions, Bibliographies.* Paris-Bruxelles: De Boeck Université.
3. BACHELARD, G. (1938). *La formation de l'esprit scientifique.* Paris: Vrin.
4. CRAHAY, M., VERSCHAFFEL, L., DE CORTE, E., GREGOIRE, J. (2005). *Enseignement et apprentissage des mathématiques.* Bruxelles: De Boeck Université.
5. DEVELAY, M. (1992). *De l'apprentissage à l'enseignement.* Paris: ESF Éditeur.
6. GIORDAN, A., VECCHI, G. (1987). *Les origines du savoir.* Paris: Neuchàtel.
7. IONESCU, M., RADU, I. (coord.) (2004). *Didactica modernă.* Cluj-Napoca: Dacia.
8. LABĂR, A. V. (2008). *SPSS pentru ştiinţele educaţiei: metodologia analizei datelor în cercetarea pedagogică.* Iaşi: Polirom.
9. MEIRIEU, PH. (1987). *Apprendre...oui, mais comment.* Paris: ESF Éditeur.
10. NEACŞU, I. (1978). *Motivaţie şi învăţare.* Bucureşti: EDP.
11. NEACŞU, I. (1999, ed. a II-a). *Instruire şi învăţare. Teorii.Modele. Strategii.* Bucureşti, E.D.P..
12. NEACŞU, I, CĂPRIOARĂ, D. (2007). *Learning and errors in the learning process-didactic analysis. The mental management approach.* IV Balkan Congress "Education The Balkans, Europe", Stara Zagora, Bulgaria.
13. PERRENOUD, PH. (1994). *Metier d'élève et sens du travail scolaire.* Paris: ESF Éditeur.
14. POTOLEA, D., NEACŞU, I., IUCU, R., PÂNIŞOARĂ, I.-O., (coord.) (2008). *Pregătirea psihopedagogică. Manual pentru definitivat şi gradul didactic II.* Iaşi: Polirom.
15. DE LA TORRE, S. (1993). *Apprender de los errores.* Madrid: Editorial Escuela Española.