PHD THESIS

Tradition and reform in mathematics education during the „New Math" period: a comparative study of the case of Hungary and France

Tradition et réforme de l'enseignement des mathématiques à l'époque des mathématiques modernes: le cas de la Hongrie et de la France

Katalin Gosztonyi

Supervisors: Alain Kuzniak and József Kosztolányi

UNIVERSITÉ PARIS DIDEROT (Paris 7)
SORBONNE PARIS CITÉ

École doctorale „Savoirs scientifiques: épistémologie, histoire des sciences et didactique des disciplines"
Laboratoire de didactique André Revuz

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The context and the objectives of the research

The reform introduced by Tamás Varga during the 1960s and ‘70s, named “complex mathematics education” reform movemement, is generally recognized by the Hungarian mathematics education community as a key moment in the history of Hungarian mathematics education, having an important influence and keeping its values until today. The same thing can be sad more generally about Hungarian mathematical teaching traditions with which Varga’s reform fit in: they are often recognized, in Hungary and in an international level as focusing particularly on problem solving and on heuristic methods. However, detailed historical or didactical analysis of this tradition is lacking. The lack of these analyses is causes problems not only on the theoretical level, but also regarding the diffusion and transmission of this “heuristic tradition” especially in teacher education.

With the analysis of Varga’s reform, I tempt to contribute to fill this gap, hoping that this work will serve as a useful source of mathematics educational research and of teacher education.

Theoretical bases and methodology

A comparative study

In my thesis, I compare Varga’s reform to the contemporary French reform of mathematics education, named “mathématiques modernes”. The aim of the comparison is, on one hand, to take into account the international context of the Hungarian reform. Varga as well as his former colleagues underline that the “complex mathematics education” reform fit in the international “New Math” reform movement, takes inspiration from the reforms of other countries, but also differs from them in several points. The comparison with the French reform is particularly relevant, France being one of the leading countries of the international movement, and also the home of the Bourbaki group, which exerts important influence on the “New Math” movement. By this comparison, I tempt to show that even if some similarities can be recognised between the Hungarian and the French reform, due to the common international context, several important differences can also be identified, and these differences can be explained by different traditions in mathematics, in mathematics education, and especially by different conceptions on the nature of mathematics in the background of the

reform. The other aim of the comparison is methodological: it helps to take some distance from the main subject of my research, from the reform of Varga, and to observe it from a more objective point of view.

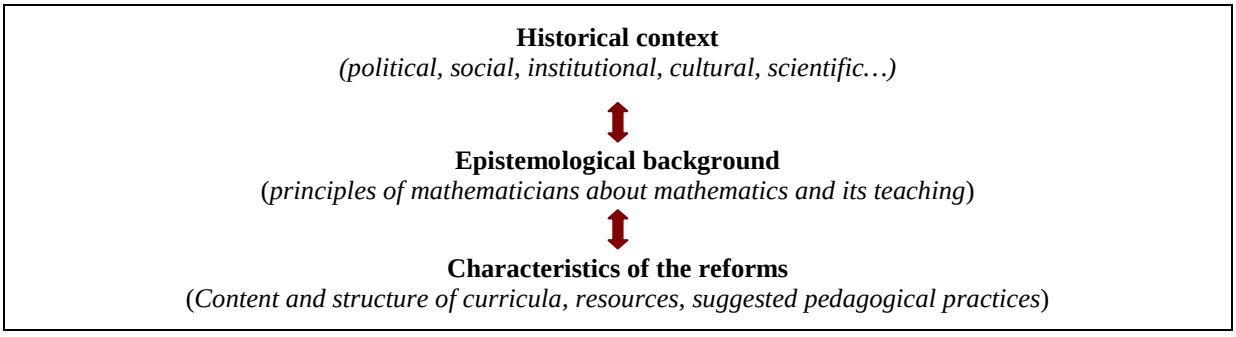
Varga started his experiences leading to the reform in 1963, and the new official curriculum was introduced in 1978. In France, the "mathématiques modernes" reform was introduced from 1969-70, and was followed by another reform already in 1977. Therefore in my comparison I take into account both the 1969-70's and the 1977's French curricula beside Varga's curriculum.

Concerning the levels of education, Varga started his experimentations on the primary level, which were later extended to the middle-school level. Thus, Varga's reform is the most profound on the primary level, concerns also the middle-school but not the high school. On the other hand, the French reform starts at the secondary level, expanded later on the primary school curricula. Therefore I study in my thesis both the primary and the middle-school curricula and resources, in order to provide relevant comparison.

A double, historical and didactical approach

I analyse the Hungarian and the French reforms both from the point of view of didactics and of the history of mathematics education. From a historical point of view, a reform of mathematics education can be seen as the result of complex influences coming from the historical (political, socio-economical, cultural, institutional, scientific, pedagogical etc.) context. From a didactical point of view, a reform can be seen as the complex transformation of different elements of mathematics education, as curricula, resources, practices.

In both cases, the followed approach is systemic. In mathematics educational research, several systemic models are available: the model I developed for my thesis was inspired especially by the SMSO model (Schmidt et al. 1996) and by Chevallard's levels of co-determination. (Chevallard 2002a). The model of my research contains three levels which determine also the structure of the thesis:



The methodology of historical and epistemological analysis

Concerning the international and the French history of mathematics education, the first part of my thesis is mostly based on existing research in the history of mathematics education. For the analysis of the history of Hungarian mathematics education I used general history and history of education resources, some works on the history of Hungarian mathematics, written and oral memories of former actors and some original documents of Varga's reform.

The second, epistemological part of the thesis is based on the results of the first part. The historical analysis shows important influence of some mathematicians, of their conceptions about the nature and the teaching of mathematics on the reforms in both countries. In the French case, the mathematicians in question are members or near to the Bourbaki group; in the Hungarian case, Rózsa Péter, Kalmár László, Alfréd Rényi among others, but some other thinkers living abroad, as G. Pólya and I. Lakatos where also in contact with Varga and the mentioned mathematicians[1].

In the second part, I study writings of these mathematicians about the nature and the teaching of mathematics. In the French case, some explicitly philosophical texts are also available (for ex. Bourbaki 1948), and there exist also some analysis in the philosophy of mathematics (e.g. Corry 2001). In the Hungarian case, I based my analysis mostly on books popularising mathematics, on writings about mathematics education and on the correspondence of the authors.

The theoretical bases and methodology of the didactical analysis

The historical analysis also showed that the reformers aimed to transform both curricula and teaching practices. Thus, I focused my research on both of these aspects. I used for these analyses on different theoretical tools issued from the French tradition of the didactics of mathematics. The analysis of curricula is mostly based on the *ecological approach* (Artaud 1997, Chevallard 2002a, b) and on the notions of *paradigms of geometry* (Houdement & Kuzniak 2006) and of *probabilities* (Parzys 2011). First I examined generally the structure and the content of the curricula (chapter III.2), then I studied three examples more in detail:

- the introduction of the notion of natural numbers in grade 1 (chapter III.3)
- the Pythagoras' theorem in the context of the middle-school geometry curricula (chapter III.4)
- the teaching of combinatorics and probability (chapter III.5)

[1] Some other researches have already drawn attention to the links between the conceptions of these authors about the nature of mathematics(see Máté 2006, 2008, Gurka 2001).

The other main object of the didactical analysis is the reform of teaching practices. However, this question couldn't be analyses directly as teaching practices of the 1960's and 1970's are obviously not observable. Thus, for several reasons (as some practical and methodological difficulties, danger of anachronism etc.), I didn't tempt to study real teaching practices: the object of my research was constituted by the conceptions of the actors of the reform about "good" teaching practices which I attempted to reconstruct by the analysis of written sources, mainly of textbooks and teachers' handbooks.

This approach made necessary the analysis of textbooks and teachers' handbooks themselves. The analysis of the structure, the language, the style, the introduction and user's guides of these texts contributed to show how these books are supposed to serve teachers as *resources*, to help them design their own practice, appropriately to the reformers' conceptions.

I analysed the teaching methods, this way reconstructed, with the help of the *Theory of didactical situations* (Brousseau 1998). The study was mostly focused on the sense of students' activity in the different authors' conceptions, on the role and the responsibility of the teacher and the students in the process of construction of mathematical knowledge.

Part I: History of mathematics education

The historical analysis shows that both the Hungarian and the French reform fits in the frame of a common international reform movement, namely the "New Math" movement. They share several endeavour: the similarities between the two reforms can be explained by the common international context, by some direct relationships between the actors of the two countries' reforms, by some common characteristics of the socio-economical background, by the ambitions related to the development of mathematics, of psychology and pedagogy. At the same time, the analysis of the historical context reveal also some important differences between the two countries, concerning especially the transformation of the school system during the examined period, the number and the composition of the actors of the reforms or the reform process which can contribute to explain the differences showed by the didactical analysis. However, on of the most important factor seems to be the difference between the epistemological backgrounds of the reforms.

Part II: Epistemology

The historical analysis points out among others the central role of mathematicians influence on the French and Hungarian New Math reforms, not only regarding their mathematical

content, but also the conceptions about the nature of mathematics behind each reform. In the French case, the mathematicians in question are principally Lichnerowicz, Dieudonné and Choquet; in Hungary, Rózsa Péter, László Kalmár and Alfréd Rényi among others. In the second, epistemological part, I analyse their conceptions about mathematics and its education through the study of their books popularising mathematics, their philosophical writings and their writings about education. I attempt to show in this part that mathematicians supporting the two reforms represent coherent conceptions about the nature of mathematics, but which is different in the case of the two countries. In France, I named the conception in question "bourbakian" because of the crucial influence of the Bourbaki group; in the Hungarian case, I named the leading conception "heuristic", referring to the links with Pólya's and Lakatos' mathematical epistemology.

According to the "bourbakian" conception, mathematics is a par excellence abstract and deductive science. The "axiomatic method" perfected by Bourbaki is considered as the ideal method of mathematics furnishing the most clarity and rigour possible to this science. The reorganisation of the mathematics on the bases of set theory and the modern formal language make the mathematics a coherent, unified science. According to this conception, Bourbaki found the "royal way" to mathematics: thus, teaching should follow this way; students should be introduced as early as possible into the use of modern notions, methods and language of mathematics. Mathematics education following these principles provides considerable "economy of thinking" and educates the intellect also in a more general sense. Concerning mathematical discovery, it requires some intuition; but according to the "bourbakian" conception, this intuition is essentially personal and irrational, therefore not teachable. The most efficient way to improve competencies in mathematical discovery is the practice of the axiomatic method and the study of mathematical structures.

On the other hand, the „heuristic" conception suggests that mathematics is a permanently changing, developing science, concerning not only its content but also its methods and its form; its future development is unpredictable. Taking also into account the big negative results of the foundation of mathematics, the Hungarian mathematicians representing the "heuristic" conception don't think that the modern formal language and axiomatic method would represent the definitive, ideal state of mathematics: according to them, this is only a station of a development process leading through a series of problems and tentative of solution. Therefore, mathematics education should concentrate more on this development process then to the actual, 20^{th} century state of mathematics. According to the "heuristic" conception, mathematics can't be dissociated from its empirical and intuitional bases:

intuition helps to gain experiences and the diversity of experiences is the basis of mathematical generalisation, abstraction. The "heuristic" conception considers mathematics as a dialogic, social activity. The development process leading through the dialectic of problems and attempts of solutions is partially rational and therefore teachable. In the same time, mathematical discovery is a creative, playful and pleasant activity, and in this sense related to the arts. The playful discovery processes help to keep awake children's curiosity and initiate them to the pleasure of mathematical research.

Part III: The didactical analysis of the reforms

The curricula

The general analysis of the structure and the content of the curricula shows that, even if both of the reforms aim at introducing new, "modern" content and provide a coherence of the mathematics curricula, this is realised in different ways in the Hungarian and the French case. The French curricula's coherence is assured, in accordance with the "bourbakian" conception, by the consistent use of formal language and by a hierarchic structure based on set theory: in an axiomatic-deductive form during the last two years of the *collège*. The Hungarian curriculum classify the content rather in 5 big chapters which are present in parallel during the hole curriculum and are related on to the other in a dialectic way. Beyond the new chapters introduced in both of the countries (as set theory, topology etc.), the French reform emphasises on the big axiomatic systems (as real numbers, geometry) while the Hungarian one on the diversity of the fields treated and on the various relationships between them: this is how combinatorics and probabilities appear in the curriculum among others.

Chambris (2008), examining the introduction of natural numbers in French curricula during the 20th century showed that the link between numbers and measure, emphasised by earlier curricula is broken by the "mathématiques modernes" reform, which builds the notion of numbers on set theory. In the same time, the Hungarian reform prescribes two parallel constructions of the natural numbers, one based on sets, the other on measure. Thus, in agreement with the "New Math" endeavours, the construction of mathematics based on set theory can appear but the close relationship of numbers with other domains is also assured.

The second example examined in my thesis, the middle-school geometry curricula and the Pythagoras' theorem shows more important differences between the two reforms. The French reform underline a brake between the first and the second half of the *collège*'s curriculum: while in the firs two years (grades 6 and 7) the emphasis is made on gaining experiences, the

study of “real” mathematics starts from the second two years (grades 8 and 9). This radical change is particularly underlined in the case of the geometry curriculum: while “physical experiences” and the “observation of geometrical objects” is prescribed in the first two years (paradigm G1), geometry is built in a principally axiomatic-deductive way from the grade 8, on the bases of the (equally axiomatically built) notion of real numbers, and as abstracted from empirical intuition as possible (paradigm G3). Geometry appears in the curriculum of the “mathématiques modernes” reform as an algebraic tool to describe Euclidian plane and space: the Pythagoras’ theorem plays a marginal role in this context, it is integrated in a bigger chapter on Euclidian plane and describes a property of orthogonal projection. The Hungarian curriculum emphasise rather the continuity: in the case of the geometry curriculum, a progressive transition can be observed from paradigm G1 (activity with physical objects) towards G2 (argumentation, logical deduction about ideal objects), and the paradigm G3 (abstract, axiomatic geometry) doesn’t appears at all in the curriculum. This progressive transition can be observed also on the introduction of the Pythagoras’ theorem in the official textbook. The theorem itself is presented as one of the most important mathematical theorems: beyond presenting an important property of right-angled triangles, it also plays a role in the initiation of students into the activity of mathematical proof.

The most profound difference between the two reforms’ curricula can be observed on the example of combinatorics and probabilities as these domains represent an organic part of the Hungarian curriculum while they are lacking from the French one in the primary and middle-school level. The main arguments of Varga for including these domains into the curriculum are the occasions they offer to gain various experiences, to present the relationships between different domains, to solve problems and to experience mathematical abstraction process starting from experiences. These arguments are closely related to the “heuristic” conception about mathematics, but don’t really matter from the French reform’s conception: they can even appear as counter-arguments in this second case. That can explain de emphasis on these domains in the Hungarian curricula and their lack from the French one. The 1970’s French experiments, which assign more importance to problem solving activities based on experiences then the “mathématiques modernes” reform, include sometimes elements of combinatorics and probabilities in their teaching program.

Textbooks, teachers’ handbooks and the attained teaching practices

During the 1960’s and 1970’s, primary school resources are constituted mostly by worksheets, completed with detailed teachers’ handbooks. The handbooks underline that

worksheets constitute only a part of the teaching material, and has to be completed by activities with various manipulative material (as the logical set, the Dienes-set or the Cuisenaire rodes). Even if the worksheets show numerous similarities in the two examined countries, important differences can be observed in the construction of the accompanying teachers' handbooks. One of the most widespread textbook series associated to the French reform, Eiller's *Math et calul* offers detailed syllabus in its handbooks, divided into lessons, presenting each time first the mathematical background then the proposed tasks. The description of the tasks is detailed, well structured, contains the objectives of the task, the needed material, the details of the realisation. So, the handbook offers ready-made teaching projects to teachers, without leaving much autonomy or responsibility to them. The experimental ERMEL project, publishing a handbook series from 1977 offers also syllabus and tasks described in details but doesn't divide them into lessons: according to the authors, the autonomous preparation of lessons is an important condition of high level teaching activity.

The official Hungarian handbook series, in contrast with the French examples, treats together the mathematical background and the suggested tasks. Even if a sample syllabus is proposed, teachers are encouraged to develop their own syllabus, following their students' particular needs. Because of the structure of the handbook, the sample syllabus is more complicated to follow and realise in practice then that of the French handbooks. The situation is similar for the description of tasks: they are mostly ideas and suggestions than well-developed tasks, several variations are proposed and suggestions are given for the realisation, but the elaboration of details is left to responsibility of the teachers and they are also encouraged to develop their own tasks. Thus, the Hungarian teachers' handbooks expect more autonomy from teachers then the French ones, in the creation of tasks as well as in the planning of long term teaching processes.

On the middle-school level, textbooks are offered in both of the countries but the teachers' handbooks are less detailed then on the primary level. The study of the prefaces and the user's guides of the textbooks shows that the main aim of the French reform's textbooks is to present the theoretical content of the curriculum: according to the authors, the serve to be red after classes in order to understand the lessons. The textbooks, especially in the last two years of the middle-school, take the form of a mathematical treatise, mostly in axiomatic-deductive form and using developed formal language. In the same time, the Hungarian middle-school textbooks contain fictive classroom dialogues where students arrive at the construction of some new mathematical knowledge by discussing about a series of problems. According to

the related teachers' handbook, these fictive dialogues shall be considered as models of teaching practice and similar discussions shall be provoked in the classroom.

Examining the tasks described in the textbooks and teachers' handbooks with the help of the *Theory of didactical situations* one can conclude that, even if the authors of the French "mathématiques modernes" reform recommend the use of "active pedagogical methods" in theory, they offer little actual help for their realisation. Moreover, even the tasks based on students' activity don't offer real *adidactical potentiality*: there is no problem or antagonistic *milieu* in the situation described which could lead to student's autonomous construction of mathematical knowledge. These situations serve more as illustrations to notions introduced directly by the teacher: the *didactical contract* suggested by these books doesn't really differ from a *magistral* kind of contract. The situations described in the ERMEL series of the 1970's are, on the contrary, quite close to the Brousseauian model of *adidactical situation*: they contain a problem and an antagonistic milieu which let students to construct mathematical knowledge without direct intervention of the teacher.

The Hungarian handbooks also encourage teachers to leave the most responsibility possible to students in the process of construction of mathematical notions – but they suggest to realise this more in the frame of a collective research process, of teacher-students dialogues, then of *adidactical situations*. The handbooks' contain numerous advices how to lead these dialogues in order to help the collective research process, but without depriving students from responsibilities in this process. The fictive dialogues described in middle-school textbooks seem to serve a similar purpose. I named this didactical contract appearing in Varga's reform *guided discovery*.

Conclusion and perspectives

The comparative analysis showed that even if the two reforms contain some common elements, which can be explained by the common international context (as the appearance of some new mathematical domains like set theory, the use of manipulative tools on the primary level or the emphasis on "active methods"), several important differences can be observed between the French and the Hungarian reform. These differences can be partly explained by the differences in the epistemological background: the "Bourbakian" conception about the nature of mathematics in the French case and the "heuristic" one in the Hungarian case serves as *mathematical paradigms* for the two reforms, influencing their different characteristics.

Thus, a hierarchic, axiomatic construction of mathematics, the deductive method and the modern formal language plays crucial role in the French reform, and the “active methods”, despite of the intentions of the reform’s leaders are of limited relevance in this context. Either the resources don’t contain descriptions of student’s activities or the didactical situations described serve only as illustration for new mathematical notions or methods, but without leaving autonomy to students in the construction of mathematical knowledge. The Hungarian reform, on the contrary, emphasises on the dialectic relationship between different mathematical domains, and focus on the slow, progressive generalisation and abstraction of mathematical notions and on heuristic methods. Regarding teaching methods, the Hungarian reform accentuate the organisation of problems into series and the realisation of teacher-student dialogues.

The analysis of Varga’s reform revealed several crucial elements of the “complex mathematics education” conception. One of these elements is the coherence between epistemological background, the structure and the content of the curriculum, the characteristics of resources and the teaching methods; the other is the organisation of tasks into series of problems; and the third is the emphasis on teacher-student dialogues. A further examination of these aspects can usefully contribute to the international researches looking for a conceptualisation of problem-centred and inquiry based mathematics education.

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Curricula

French curricula

Date	Level	Edition
1945	primaire	http://jl.bregeon.perso.sfr.fr/Programmes.htm
1945	collège	
1960	collège	Monge, M. & Guinchan M (1963), *Mathématiques. classe de 6e* Paris : Belin. Monge, M. & Guinchan M (1964), *Mathématiques. classe de 5e* Paris : Belin
1964	collège	Monge, M. & Guinchan M (1965), *Mathématiques. classe de 4e* Paris : Belin Monge, M. & Guinchan M (1966), *Mathématiques. classe de 3e* Paris : Belin
1969	collège	Ministère de l'éducation nationale (1972). *Mathématiques. Classes du premier cycle*. (2e edition). Paris : INRDP.
1970	primaire	*Programme et enseignement des mathématiques à l'école élémentaire* http://www.formapex.com/repertoires/550-programmes-textes-officiels
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