RETHINKING THE ROLE OF CONTEXT IN MATHEMATICS EDUCATION

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In this paper the role of context in teaching and learning mathematics is considered from a «local» and then from a «global» point of view. The «local» viewpoint focuses on context as a «scene» providing meaning to the mathematical content, while the «global» one addresses the problem of transformation of a given context, which arises when the teacher intends to put the students into a new perspective of mathematical knowledge. Both these viewpoints are used in an attempt to relate context to the metonymic transformation of the meaning of words used in mathematics. From this point of view various mathematical and empirical (classroom) examples are discussed and reinterpreted in the paper.

Recent studies have shown a growing interest in the social functions of mathematics education, which, among other things, calls for a reexamination of the role of *context* in all its social and educational aspects (Bartolini-Bussi, 1991).

P. Cobb (1986) discussed contexts in connection with goals and beliefs about mathematics, and argued that students tend to «reorganize their beliefs» in solving problems that are primarily social rather than mathematical in origin. In another, although related, direction J. Evans (1993) focuses on the differences of «problem solving» within different discursive practices; also on the corresponding feelings, in particular «maths anxiety». Evans understands context as *positioning in practice(s):* each (social) practice produces positions that the subjects may take up and recall the practice from such a position.

My thesis in the present paper, as compared to above views of the function of context, is the following: When an individual recalls a particular context in some situation, it might well be that positioning in this context affects the individual's general attitude; but it is especially by transformation or action she (he) intends to undertake

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«against» the conditions set by a context, that the individual gets into relevant resolution of mathematical problems and negotiation of meaning of the obtained solutions. However, as I will try to make clear in the rest of this paper, in order that such an action «against» the conditions set by a given context leads somewhere, sometimes a whole transformation of this context could be very helpful.

Although closely related between them, the first two sections of this paper focus on different themes. In the first section I consider contexts locally as «narrative microworlds» or «scenes», which involve students in action and give meaning to the mathematical content and the whole process of learning. This point has been already discussed in a critical setting by O. Skovsmose (1994, 1996), but I discuss a different kind of examples here.

On the other hand, guided by an analogy with transformational geometry, in the second section I attempt to indicate a more «global» and «dynamic» view of contexts and explore the possibility of their transformation in the eyes of individuals. In both these sections I use a framework of Skovsmose connecting *learning as action* with *dispositions* and *intentions*, which leads to a consideration of the meaning of words used in mathematics with reference to school practices and other socio-cultural contexts. The last section of the paper uses the results of both previous ones to develop a perspective of understanding the *metonymic transformation* of words used in mathematics, by using (social) contexts. As an example in this perspective, I will discuss contexts of the important mathematical concepts of a function and of an (infinite) set.

I. Local view: Contexts as «Scenes» providing Meaning

In an interesting article about the role of stories in learning mathematics, Rachel Griffiths and Margaret Clyne (1991) explore the various ways in which stories can be useful as a medium of teaching and learning mathematical ideas and posing problems; in their opinion,

> *The power of story lies in the appeal which it makes to the emotions and the imagination. A story is more than a context, important as that is.* Story involves a setting, conflict, tension or problem, and resolution of or solution to that conflict. *(Griffith and Clyne, 1991, my emphasis)*

As an example they consider the following pair of sentences introducing a mathematical problem:

(i) Find $\sum 2^n$, with n = 0,1,...,63.
(ii) Once there was a king who was tired of war...

and they compare them with respect to motivation of the readers. The authors report that Year 6 (11-12 years old) and Year 8 students, to whom (ii) was presented, have remained actively involved in «finding the number of corn grains on the chess board» for over an hour. As another example they mention a book titled «Counting on Frank», which was about a boy who had his dog Frank as his only companion and who was engaged «in mathematical exploration of his environment»; the boy wanted to have new experiences as a reaction to the «restricting nature of his home and family». The children who read the book were asked to check the calculations and estimates appearing in it. But most readers were inclined to take the figures in the book on trust and even to doubt their own calculations when these were in conflict with those in the book («after all, the figures in the book are printed»).

These examples indicate *a double role of context.* On the one hand, the king's story and the book about the boy and his dog Frank act as «narrative microworlds» or «scenes». The children as «spectators» may be involved in the tasks appearing there, they may be motivated to *enter the scene* as «actors» and perform the calculations that a teacher, who uses the context, would expect of them to perform. On the other hand, the book acts as an *authorized practice*: whatever is written in it must be right, otherwise it would not be written in a printed book.

The last example offers a good instance of the function of context in ordinary situations of everyday teaching in the mathematics classroom. However, there has been a more critical setting, in both theory and practice. Ole Skovsmose speaks of contextualization as «setting up a scene» for an educational process:

> Setting up a scene *for an educational process refers to the effect of establishing a situation into which the educational process can be embedded to provide the individual activities of the children with a kind of meaning. (Skovsmose, 1994, p. 91)*

Patronis (1995) explored further the idea of «scene setting» as compared to the didactical practice of «embodiment» in traditional teaching of mathematics; he found that the role of the context of stories is rather irrelevant in «embodiment» situations, as the students usually guess the intentions of the teacher from the very beginning.

Skovsmose (1994) as also Nielsen, Patronis and Skovsmose (1996) have presented several classroom situations, in which social contexts and tasks have engaged the students in relevant solution of mathematical problems. Of course a «scene» in this sense, Skovsmose remarks, need not be accepted by the students, since they need not be motivated. Still, however, contextualization is an attempt to make it possible for the students to *negotiate meaning* of the task in which they are involved (Skovsmose, 1996). On the other hand, in a normal classroom situation it is rare to observe learning as emerging out of negotiation of meaning. The structure of schooling in general - and the structure of school mathematics in particular - makes it difficult for the students to become «actors» in their learning. Skovsmose differentiates *action* from «blind activity» or «obeying a command», and links actions with *intentions*, which in a sense constitute the *personal meaning* of an action. In the example of the book titled «Counting on Frank» the intention of some of the readers need not be to question the book's accuracy, but simply to enjoy it as a story.

Skovsmose frames actions not only together with intentions but also with *dispositions*. Dispositions correspond better than intentions to what Evans calls «positioning» in a context or a practice. But although objectively rooted, as a socially constructed network of relationships which belongs to the history of the person (Skovsmose, 1996), dispositions are subjectively expressed since they are always mediated by the individual. *Intentions for action* may emerge out of dispositions. In the case of the book «Counting on Frank», some girls could have a disposition not to follow the hero's task, since the hero is a boy. Also some children would have a disposition to react (like the hero) against the given «state of affairs», which in the story appears as a restrictive way of living within the family, while other children would not act like that. Now my point is that *a relevant action appears to be more possible for an individual who intends NOT to admit the «state of affairs», as a condition set by the context, than for one who intends to admit it.* For example, when it is written in the book (even in a humorous manner) that ten whales will fit into the boy's house, children that take everything they read for granted will probably not ask themselves about the meaning of such an expression and will not get into any relevant actions.

Various interpretations of the above statement in italics are possible. For instance, an interpretation which a mathematician would probably like much is that of «breaking» the context and generalizing one's own ideas beyond its limits. Yet such an interpretation could be irrelevant to some situations of learning and solving problems, in which the context is taken seriously into consideration. As C. Janvier remarks about this kind of situations, taking the context into consideration implies (for example) that numbers should be processed in the operations without losing their situational connotations (Janvier, 1990).

If *context* is interpreted as a set of presuppositions, cultural habits or prejudices about a given situation or problem, then *not admitting the «state of affairs» as a condition set by the context* can be understood as a particular (and well known) attitude in scientific research. By considering «only perfectly checked problems», as Yves Chevallard says, scientists were able to forget the *«évidence»* of ordinary culture, «this curious trend of the universe of *doxa*[1]», in which «we always meet questions without answers and, even more curiously, most «answers» do not correspond to any question at all» (Chevallard, 1988, p. 30; my translation).

But the intention for action I came to formulate as *not admitting the «state of affairs»* means more than that. It is not only the *doxa* of ordinary culture, but also the «authorized» one, the habits or prejudices created by science and education itself, which are questioned here. As a result, the whole landscape of knowledge may be potentially transformed into a new one. Such a development, however, usually needs a totally new setting of problems, which naturally brings us to a «global» examination of contexts.

II. Global View: Transformations and Rigidity

A mathematical analogue of a context for solving problems is a «geometry» in the sense of F. Klein *Erlanger Program* (1872). A set of properties and relations of geometric figures, which remain invariant under the action of certain group of transformations, determines the solution of geometrical problems, as for example the construction of a figure equal to a given one. This analogue leads to a notion of context, which is expanded far beyond its usual meaning (that implies the presence of some real life elements as a «scene» for problem situations) and which will be retained, from now on, in this paper: a *«context»*, in this generalized sense, is *a set of conditions determining the meaning of a particular sequence of actions,* or, to put it more briefly, *a semantic structure underlying a particular set of actions.*

Transformational geometry can be also viewed as an analogue to *a set of dispositions.* A context may be «rigid» for an individual, in the sense that no essential change or «transformation» of this context seems acceptable to her or possible to happen in her lifetime[2]. In mathematics education we often witness such a rigidity of context, which has been sometimes conceptualized by didacticians (following

Bachelard) under the interesting notion of *epistemological obstacles* (see e.g. Brousseau, 1983; Glaeser, 1981). In contrast to this conceptualization (an obstacle is something that «stands there» and has to be surmounted), *transformations and rigidity* offer, in my opinion, a more global and dynamic view: a given context cannot, sometimes, be transformed, in the eyes of an individual, into some other (new) context, in the same way that a plane figure, for example, cannot be transformed into a spherical figure in the geometry determined by 3-dimensional linear isometries.

As an example from mathematics education I consider here the classroom discussion of Euclid's Fifth Postulate and the use of geography as a context for the introduction to spherical geometry. I discuss below two classroom episodes, belonging to different school cultures. The first one is an episode from a teaching experience called «Mecca» at the Freudenthal Institute, which aimed to introduce students coming from different societies into the topic of spherical geometry through a geographical and cultural exploration of the globe. The point was «not to go too deeply into spherical geometry, nor to construct it axiomatically»; the concern was «much more that students learn to intuitively sense how 'our earth' is put together» (Jan van den Brink and Marja Meeder, 1991). In the episode considered here, two 15 year old students talk about two points A, B denoted on the same meridian of the globe, A being situated to the north of B. They must cross out what is incorrect of the following phrase: «A and B have the same x-coordinate, the same y-coordinate».

> *M'HAMD: A and B don't have the same x-coordinate; A's is smaller.*
> *OZCAN : But they're lying on the same meridian; with degrees, that's the way they have the same x-coordinate.*
>
> *(From van Den Brink and Meeder, 1991)*

A «transformation» is intended in this teaching experience, from the context of (flat) Euclidean geometry (with Cartesian coordinates) into a context of geography and spherical geometry. Mathematical terms as «equality», «coordinates», «distance», «triangle» etc. must be given another *meaning* in the new context, different than the familiar one in Euclidean geometry. Ozcan seems to understand this, but M'hamd does not. However, in this case we may not speak of rigidity; one of the two students may eventually convince the other.

The second classroom episode takes place in a Greek classroom of 16 year olds, in which I was involved as a participant observer. Geometry is taught in deductive form in the two first years of *Lyceum* (16-17 year old students). The class observed was discussing the

Fifth Euclidean Postulate and the possibility of developing other geometries, in which this Postulate does not hold. After the teacher had presented the topic, a group of 4 students decided not to admit the Postulate as an axiom and attempted to *prove* it (the form presented in the textbook postulates the uniqueness of the straight line parallel to a given one and passing from a given point). As one of the students explained:

> *«Our teacher never says to us: 'this is it, you may admit it or not'. She writes a theorem on the blackboard and says: 'look at it, think of it and tell me about possible solutions'. That is why, when you see a.... postulate, you start to think, why to admit this axiomatically? Couldn't it be based on something else?» (English translation from Patronis, 1997)*

The group attempted several times to prove the Postulate. One of these attempts makes implicit use of Euclid's own formulation of the Fifth Postulate. If AB is a line perpendicular to (l) at B and (l_1) perpendicular to AB at A, then (l_1) is parallel to (l). If a second parallel (l_2) to (l) exists from A, then the angle of (l_2) and AB is different from 90°, hence (the students argue) (l_2) will cut (l) at some point C, which contradicts the hypothesis that (l_2) is parallel to (l). At this point I intervene, and the dialogue shows a determination of the group not to admit my point.

> ***TASOS*** *(Myself): Imagine that the distance from A to B is huge, and that (l_2) makes an angle of about 89° with AB. How can we be sure that (l_2) will cut (l)?*
> ***DAMIANOS****: What else could happen?*
> ***VAJA****: Look, now, we are going to primitive concepts again!*
> ***DAMIANOS****: If we make a «miniature» of the figure you suggested, then wouldn't we be sure of this fact (i.e. that (l_2) cuts (l))?*
> ***TASOS****: A «miniature» could change the figures' shape, perhaps, or not?*
> ***DAMIANOS****: Why «change» it? We have got straight lines, nothing changes! The figures remain the same, when we consider things at a particular moment, so that there is no motion to change magnitudes.*
> ***STEFANOS****: When we make a map of some area, does its shape change?*
> ***TASOS****: think yes, because the Earth is spherical, while usually the map if flat. The shortest road between two points on the surface of the Earth is not exactly the same as it is on the map.*
> *(After a short pause:)*
> ***DAMIANOS*** *: Wait a minute! Since we say that the Earth is spherical, we deal with curves, not with straight lines (...) There may be* practical reasons *for taking a curve as the shortest road between two points. But in reality the straight line is the shortest road; it does not make any difference if we can follow this road or not!*
>
> *(Translated from Patronis, 1997)*

My intention in this episode was to question the students' beliefs by putting the students into a new perspective of empirical geometry. But the context of Euclidean geometry appeared to be «rigid» for this group of students. Spherical geometry could not be seen by the students as deserving special (theoretical) attention. Although they «understood» what I was saying to them, their educational background offered here a negative disposition, and simple reference to empirically valid models could not convince them of the need for change.

III. Contexts and the Metonymic Transformation

In the first part of is autobiographical book *Les Mots* (The Words, 1963) Jean-Paul Sartre describes how he was initiated to the pleasure of reading. As a child he was attached to his young mother, who lost her husband (Jean-Paul's father) when Jean-Paul was born. The mother went to live with her parents, and Jean-Paul found himself as a passionate reader among the books of his grandfather, who was a teacher of German. But this did not happen simply like that and without some shocking events and conflicts.

A rather big shock for young Sartre was just the fact that words could be «put» into a book. When his mother started, for the first time, to *read* a story that she had orally told him for many times in the past, Jean-Paul was greatly surprised. Who was narrating? To whom? And what?

Previously, story telling had been merged with the smell of soap and the *Eau de Cologne* the mother was using in bathing the son. This perfume, together with the young mother's tender, insecure, discontinuous voice and the feeling of being together, alone, separated «from people, gods and their priests», as Sartre himself says, had created the psychoanalytic context of the narration; out of which the story could not stand and the words could not have a familiar meaning. The very fortune of the heroes of the story depended upon mother's own situation and mood, or disposition.

To discover that words can be «put» into a book means at least a primary understanding of the potential of (written) speech. According to Roman Jacobson (1963), speech can be analyzed across two semantic dimensions, a «paradigmatic» and a «syntagmatic» one, which correspond to two main processes, the *metaphoric* and the *metonymic* process respectively. While metaphors are more or less conscious ways of representing things, based on analogy or similarity, metonymies are subconscious shifts of reference of words, in which the same signifier moves to a new (although related) signified. Thus in Sartre's first experience of reading, words written in the book acquired a new status and an «objective» meaning. The words and figures created «archetypes» of things in his imagination; by substituting icons for real things, he soon became a premature idealist, which he later regretted.

Although the role of metonymies has been repeatedly emphasized in studies about the psychoanalytic function of language (see e.g. Lacan, 1966; also Dor, 1985), this has hardly been done in mathematics education with Walkerdine (1988) being a main exception. Also in a rather exceptional paper, Bauersfeld and Zawadowski (1981) examined the role of metaphors and metonymies in the teaching of mathematics. They pointed out that these «figures of living thought», as they called them, are present in dialogues between students and between students and teachers, as well as almost everywhere where mathematical ideas and signs are «in statu nascendi».

In fact it can be said that the whole formation of (modern) mathematics is subject to a process of metonymic transformation, which historically appears as a «transposition of essence». Take, for example, the famous *Topologie Algébrique et Thé orie des Faisceaux*, by Roger Godement (1973). In principle it is supposed to speak about simplexes and complexes, which finally relate to the classical geometric idea of a polyhedron. But polyedra are not encountered anywhere in the book (except at a small hint in the preface!) and as for simplexes and complexes, they are replaced by distant and abstract substitutes such as «complexes of chains» and «simplicial operators», which generalize some very elementary properties of their geometric predecessors. In this context a *part* of properties has been substituted for a *whole*; what was essential in the previous stage of the theory has now come to be of lower value, and conversely[3].

A similar transformation might take place in education. In the example of the book «Counting on Frank» (section I of this paper), printed figures act like *the words* before young Sartre: they seem independent of the reader-child, so at the beginning the child refuses negotiation of their meaning. In the example of initiation to spherical geometry (section II), the context of flat geometry is acting as a «rigid» background for students and has to be transformed into a new one. But in both cases the difficulty can be determined as an implicit and partly subconscious *shift of reference* of the words used, that has to be done in passing from one context to another. In the case of Jean-Paul's experience and the «Counting on Frank» story, words and figures have to be considered as referring to objective meanings; while in the case of spherical geometry, *«straight line»* and *«coordinates»* must no more refer to the familiar ideas of «straightness» and «length»or «distance», but to the properties of being a «shortest road» (or «geodesic») and «angular distance» respectively.

Let us now take another example, which happens to be closely related to the idea of transformation used in section II: this is the modern (i.e. after the period of Euler and Fourier) development of the mathematical concept of *function*, compared to the use of the same word («function») in the social sciences. Function, «that proud daughter of number and space», as F. Le Lionnais (1971) refers to it, was from the beginning introduced in mathematical analysis as a metonymy. Euler himself was aware of this fact, as he described «function» in 1755 as «a metonymic word (...) containing all ways in which a quantity can be determined by others» (see Dhombres, 1976).

As W. Mackenzie remarks, in modern sciences the word «function» has at least two distinct senses, one mathematical and one biological, both of which are also used as metaphors:

> *The first is of the form X = f (Y), in other words, you can get X from Y by performing the operation f. This can be trivial (...) or* it can be very complex, if X and Y are patterns and the rules for transformation (or «mapping») involve a sequence of steps. *In the scientific use of mathematics the process is fundamental; in the social sciences such strict formalization has rarely proved fruitful, but the concept of a «transform» is nevertheless powerful as metaphor. For instance, Wollheim, in his recent [1971] book on Freud writes on the latter's use of «the functional hypothesis». This is true and is of extreme importance in the theory, but it is in this instance [...] a mathematical metaphor, not a biological one. An «idea in the mind» may undergo unexpected transformations between pre-conscious, conscious and unconscious mind [...] [The author continues with the biological metaphor.] (Mackenzie, 1972, p. 62; my emphasis)*

What struck me here is that, as the above passage indirectly implies, it is not the *classical* notion of function (a quantity determined by, or depending on, another) that has been metaphorically used in social sciences, but the *modern* one - that of a transformation or mapping between two given sets. This concept is much more «abstract» than the classical one, in the sense that, in order to define a mapping between two sets one does not necessarily need a «formula» determining the functional relation; this may be determined, as Mackenzie says, by a sequence of (algorithmic) steps. So, if the initial (classical) mathematical use of the word «function» was a metonymy, here we have a deeper and «internal» metonymic transformation: the shift of reference seems to take place completely «inside» mathematics. Yet, fortunately, things are not so exclusively «mathematical» as they seem to be. The new, abstract concept of function has at least a sociocognitive analogue, that of an «idea in the mind undergoing various unexpected transformations». This could be very helpful indeed (as I am now going to show) in an attempt to *teach* the modern concepts of set and function. I am not going to use exactly the above analogue, but something which is enough close to it.

A formalist may call it «a mathematical nonsense», but it is one of the fewest pieces of deep, yet accessible to common sense - and disputable as well - mathematical insight; Dedekind's proof of the existence of an *infinite set* (1887) reads as follows:

> *My own realm of thoughts, i.e. the totality S of all things, which can be objects of my thought, is infinite. For if* s *signifies an element of S, then is the thought* s*, that* s *can be object of my thought, itself an element of S. If we regard this as transformation* (s) *of the element* s, *then the transformation of S, thus determined, has the property that the transform S is part of S; and S is certainly proper part of S, because there are elements in S (e.g. my own ego) which are different from such thoughts* s *and therefore are not contained in S [...] Hence S is infinite, which was to be proved. (Dedekind, 1963, p. 64)*

By critically discussing, and not just using this argument in order to convince the reader of the existence of an infinite set, as Dedekind does here, the whole situation could serve as a «scene» of debate.

In Dedekind's setting, an *infinite set* is a set which can be transformed in a one-to-one way onto a proper subset of it - not a set whose elements cannot be «counted» to give a definite natural number as its cardinal number. Thus Dedekind's definition and argument about the existence of an infinite set leaves *potential infinity* out of consideration and deals only with *actual* one. In this way the concept of infinity is subject to a metonymic shift, inherent in the construction of set theory by Cantor and Dedekind, which is largely due to an extended and systematic use of the modern concept of function. Thus the first didactical profit from an eventual classroom discussion of Dedekind's argument, is probably the challenge of a *seemingly natural* appearance of these abstract concepts in a «social» or «psychological» setting.

This context of introducing the notions and arguments of set theory - *«our realm of thought»* - was also probably Cantor's favourite, as it appears from his conception of a set (or «aggregate») as an understanding of «any collection into a whole (...) of definite and separate objects (..) *of our intuition or our thought*» (Cantor, 1895/ 1955, p. 85, my emphasis). However, this seemingly «innocent» setting turned out to be logically disputable and probably responsible for the subsequently discovered antinomies of set theory.

Here comes the second - and most important - didactical profit from an eventual classroom discussion of Dedekind's argument. A student intending not to admit the «state of affairs» here (as I argued in Section I) may greatly profit by asking: «*What* is a function? *What* is a set, anyway?» and so on.

A Concluding Remark

We are now in a position to give some explanation for the situations previously described in this paper, in which an individual student (or a group of students) may not *intend* to participate in a scene where a transformation of a familiar context takes place. Perhaps it would be more exact to say that this individual (or group) does not intend to follow a *particular* process of transformation. By relating contexts and their transformation to the metonymic transformation of words used in mathematics we can better understand this behavior. It often happens, in the process of metonymic transformation, that a part of properties defining a concept is substituted for a whole; some students may not intend to «lose» the one or the other feature of the old content, when the curriculum or scientific practice judges that this one has to be «forgotten». Thus a pertinent didactical use of contexts depends on analysing the metonymic - at least as much as the metaphoric - dimension of speech, and on relating this dimension to the intentions of the students.

Notes

1. Greek word for «opinion» (in ancient Greek).
2. According to H. Dreyfus and J. Wakefield (1994), Merleau-Ponty offers an explanation different from that of Freud for psychopathological phenomena. Pathological «rigidity» of context appears, says Merleau-Ponty, when a particular aspect of the *content* extends in such a way that it becomes a *context* for the person.
3. Curiously enough, a similar «transposition of essence» occurs in human dreams: what is essential for the subject's *psyche* has been

«hidden» in the dream and has to be rediscovered by interpretation (Freud, 1900/1967; Dor, 1985). Because of the striking similarity I would consider the approach of the present paper as «parallel» to that of psychoanalysis, although not identical with it.

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Revurdering av rolla til konteksten i matematikkutdanning

Artikkelen fokuserer på rolla til konteksten i undervisning og læring av matematikk.. Rolla til konteksten er vurdert frå både eit "lokalt" og eit "globalt" synspunkt. Det lokale synspunktet rettar søkjelyset på konteksten som eit "bilde" som kan hjelpe til å gje meining til det matematiske innhaldet, medan det globale synspunktet rettar seg mot problemet med overføring av ein gjeven kontekst. Dette oppstår når læraren har til hensikt å introdusere elevane/studentane til nye perspektiv på matematisk kunnskap. Begge desse synspunkt er brukt i eit forsøk på å relatere konteksten til ein metonymisk transformasjon av meiningsinnhaldet til ord som blir brukt i matematikk. Med dette utgangspunktet ulike matematiske eksempel og eksempel frå klasserommet diskutert og tolka i denne artikkelen.

Forfattar

Tasos Patronis er assistant professor ved Department of Mathematics, Faculty of Sciences ved universitetet i Patras i Hellas.
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