An experience of social rising of logical tools in a primary school classroom: the role of language

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Abstract In this paper we explore the relationship between language and developmental processes of logical tools through the analysis at different levels of some 'linguistic-manipulative' activities in a primary school classroom. We believe that this kind of activities can spur in the children a reflection and a change in their language's representation. Mathematical logic and educational psychology act as framework for the research. The teaching experiment regards the procedural aspects of the language and it is based on the construction of a socially agreed language describing the steps of a 'kid-robot' in a room. By a qualitative analysis of the activities and of the a posteriori interviews based on the Explicitation Interview method, we find out four Main Topics which show how the children choose strategies to solve a problem, using the constructed language. Moreover in the activities we can observe what Vygotskij defines the shift from interpsychic to intrapsychic during social activities.

Keywords Logical tools, Object language, Procedural language, Social interaction, Symbols production

1. Introduction

The research we are presenting in this paper is the exploratory part of a wider project originating from the collaboration between research groups working in the field of mathematical logic and in the field of educational psychology. These disciplines represent the lenses we look through the language's role in the classroom practices. We explore at different levels of analysis (Doise, 1986; Doise, Clémence & Lorenzi Cioldi, 1992) the relationship between language and developmental processes of logical tools, through linguistic-manipulative activities, in primary school classrooms. The activities in the whole project regard both the procedural aspects of the language and the assertive ones. Both the aspects play a fundamental role in the development of child's mathematical thinking. Indeed, the procedural aspects of the language are linked up to the mechanisms of the language's recognition-production (grammars), to the ability of 'counting to infinity', to the recursion and induction procedures underlying the arithmetic operations (Gerla, 1990). The assertive aspects of the language are, as an example, those related to the study of the numbers' and the space's properties, to the proposal of axioms, to the theorem's proof.

In this paper we analyse the processes carried out by the children of a primary fourth grade class involved in a teaching experiment regarding the procedural aspects of the language. After stating our research questions we sketch the theoretical positions we start from, we describe the teaching experiment, its main purposes and the methodology we used. Then we report the discussion about the results coming by the analysis of the a posteriori interviews to

the children. The interview method we used is based on the Explicitation Interview (Piaget, 1974; Vermersch, 1994).

1.1 Research questions

We believe that through cooperative activities related to the shared creation and the manipulation of a language children will be able to choose different strategies for problem solving. Moreover we wonder:

1. could this kind of activities assist the children in a change of the language's representation, from being only a communication tool into a manipulation object?
2. Could in this way the children be spurred to think over the concept of interpretation and over the possibility of giving different interpretations of the same language?
3. Could such a change in the language's representation help the children to solve the tasks?

2. Theoretical background

Educational psychology and mathematical logic act as framework for our research. On the one hand we refer to the contributions of Vygotskij' historical-cultural school (1934; 1997) and to the works of social-genetic constructivism (Perret-Clermont, 1979; Iannaccone, 1992; Iannaccone & Perret-Clermont, 1993; Iannaccone & Ligorio, 2001). On the other hand there is formal logic seen as the expression of an historical path which brings to a change of the language's role in mathematics. This path starts with the passage from the rhetorical algebra to the symbolic one and keeps up to modern mathematical logic. In both the perspectives we want to reflect upon the language's role in the developmental processes of *logical tools*[1].

2.1 The higher mental processes in the socio-cultural perspective

In accordance with socio-cultural theories, the complex forms of mental processes have a *social source* (Lurija, 1976; Emiliani & Zani, 1998). The term *social* refers to human activities and its products. Vygotskij, according to Gestalt, asserts that the behaviours cannot be studied from an elementary and associationist point of view. They need a unitary analysis considering them as a complex and dynamic set (Emiliani & Zani, 1998). The individual's development has to be studied in its relation with the historical-cultural context in which it grows (Carugati & Selleri, 2005). Vygotskij (1997) analyses the development of higher mental processes trough three fundamental principles: 1) the relationship between development and learning; 2) the role of *mediation* in the relations between environment and individual; 3) the passage from interpsychic to intrapsychic in the social communication situations.

In the first principle the author claims that the study of the children's development cannot set aside from the analysis of the educational and learning situations in which the children are engaged. In claiming this, he highlights the importance of the role of social features of these situations in children's development. Vygotskij in his studies upsets the traditional idea of the relationship between learning and development, saying that development does not precede learning, but, on the contrary, development follows learning (Emiliani & Zani, 1998). Learning founds the *zone of proximal development*[2], according to which although a child has the potential to learn by himself, he/she is able to learn better and faster under the guidance of

[1] By *logical tools* we intend the skill to find and choose different strategies to solve problems regarding logical tasks. Logical tools belong to higher mental processes.

[2] Vygotskij defines the *zone of proximal development* as the distance between the actual developmental level (determined by independent problem solving) and the level of potential development (determined through problem solving under adult guidance, or in collaboration with more capable peers) (Vygotskij, 1997).

an experienced and capable *scaffolder*[3] (such as a teacher) or a more capable peer (Emiliani & Zani, 1998).

In the second principleVygotskij (Gilly, 1997) maintains that the logical tools should be studied through practical activities of the everyday social life, which are mediated by the culture and its characterizing artefacts[4]. The principle asserting that human activities are *culturally and socially mediated* follows. In doing these activities, the individuals produce and use artefacts and, moreover, they get in touch with and they appropriate the cultural artefacts of the preceding generations. An individual lives in a world of cultural artefacts, which on the one side represent the 'cultural heritage' of the preceding generations, on the other side they are the results of the cultural elaborations in everyday life (Carugati & Selleri, 2005; Emiliani & Zani, 1998).

The last principle delineates the *ontogenesis of the higher mental processes* (and so of the logical tools), according to which every function in the individuals' cultural development appears twice, how it is possible to observe by children's development. First it appears on the social level, as the result of an activity carried out among individuals, later on the individual level, as an activity which the individual carries out by himself. In other words, first it appears between people (*inter-psychological*) and then inside the individual himself (*intra-psychological*). This applies to language, which appears at the beginning as a kind of communication among individuals (as social external language) and then as internal language, that is, thought (Gilly, 1989; 1997).

2.2 Language and logic

Language represents a cultural artefact above all others and it has a basic role in the learning processes and in the social practices of the classrooms, as it has been largely recognised. There are several ways to mean 'language', as an example (Duval, 1996-1997; D'Amore, 2000): as semiotic system; as forms of speech produced by using a tongue; with the function of 'communication' among individuals; as use of a code, more or less socially recognized and shared.

The importance of the language's role is emphasized with the birth of the modern mathematical logic at the beginning of the twentieth-century. Indeed, the basic idea of formal logic is that we can identify mathematics with a formal language. Then the question arises whether formal logic is a useful tool in studying the development of cognitive capabilities. The answer could be positive provided that logic is considered as an expression of the following features regarding language (Gerla, 1988; Gerla, Sestito & Vescia, 1990):

1. language, from being only a communication tool turns into being also an object to be manipulated;
2. the interpretation of the language looses its univocity: the same word can denote more than one thing, the same description can refer to more than one situation;
3. mathematical notions rise not only by abstraction processes from direct experience, but also by the language's objectification and by the singling out of linguistic manipulation rules.

We extend to the procedural languages these features which generally are linked to the assertive languages.

Regarding the first point, the transformation of the language in an object to manipulate can be realized through linguistic-manipulative activities. We suppose an explicit support

[3] In an interactive-constructionist perspective (Bruner, 1977), the concept of *scaffolding* represents the tutoring functions accomplished by an adult towards a child in order to help him in the knowledge elaboration process (Emiliani & Zani, 1998).

[4] Cole (1996) defines an artefact as an aspect of the material world that has been modified over the history of its incorporation into goal-directed human action.

relationship between language's manipulation and the rising of logical tools. The manipulation of linguistic objects, 'constructed' after a communicative negotiation, starting from problematic situations, could stimulate in the involved children the learning of the use of signs as symbols. Symbols are intended as 'tools' supporting the accomplishment of actions in the context which the children act in and helping to find strategies to solve problems. "*On the one hand, they function as tools allowing the individuals to engage in cognitive praxis. On the other hand, they are part of those systems transcending the individual and through which a social reality is objectified.*" (Radford, 2000, p.241).

The shared creation of a language and its manipulation allow acquiring the awareness that symbols depend on the context of use and that they presume an agreement in the community of the receivers. The classroom activities have to represent a tool to stimulate in the children a flexibility in using languages and to force the use of linguistic tools not as an external 'imposition', but as an answer to explicit and shared tasks (Ferrari, 2002). In such a way a reflection about the non-univocity of the interpretation, as expressed in the second point above, can be stimulated. Besides, the idea that it is important putting the basis of a *symbolic literacy*, already in primary schools, is supported by the belief of several researchers that some of the difficulties of the students in learning mathematics are related to the difficulties in gaining the symbolic level.

We think that the acquisition of a *symbolic skill*, through manipulation activities, should promote in the students a better *abstraction* skill. The notion of abstraction in mathematics can have several interpretations: as generalisation, as decontextualisation, as reification. Many researches underline that one-dimensional interpretations of such a complex notion are not appropriate. These three components are fundamental and they intervene in different ways depending on we refer to the organization of already available knowledge or to the development of mathematical ideas (Ferrari, 2003). In psychology there are several perspectives supporting these ideas, such as the Bruner's model regarding the shift from the *executive thought* to the *symbolic* one and then to the *abstract* one. Bruner (1977; 1990) maintains that, in order to reach the abstraction, the child should get through the actual object's manipulation, then the manipulation of its representation.

2.3 The cognitive development in the socio-genetic perspective

According to socio-genetic constructivism (Perret-Clermont, 1979; Doise & Mugny, 1981; Iannaccone & Perret-Clermont, 1993; Iannaccone, 2010) the cognitive development is a social process and the reasoning capabilities increase in the interaction with peers or more experienced scaffolders. In this perspective the notion of *cognitive conflict* turns into the notion of *socio-cognitive* conflict.

In Piaget's studies there is the idea that the tension between the way a child conceive and foresee the world and the features of the world itself causes a change. This induces the child to achieve a more reasonable explanation of what is happening under his/her eyes. The studies regarding the influences of the social interactions in the cognitive development rise in the early seventies, within the post-Piagetian school, through researches exploring the role of the cognitive conflict in the development of logical operations. In particular, Inhelder, Sinclair and Bovet (1974) verify how the conflicts between the individual's point of view and the features of the experimental material cause cognitive reorganizations and rapid improvements in the thinking procedures utilized by the individuals till that moment. Later the socio-genetic psychology proves the central role of the social interaction in the cognitive development (Doise & Mugny, 1981; Perret-Clermont, 1979). The contraposition of points of view in the communicative context, as many researches show, represents a constant in the construction of children's social world.

2.4 Cooperation and communication

The theories we referred above spur the setting of cooperative classroom activities based on the communication. Many researchers give a prominent role to communication in the development of the mathematical thinking. Sfard (2001) claims that "*thinking may be conceptualized as a case of communication, that is communication with oneself* " and it "*arises as a modified private version of interpersonal communication*" (p.26). Moreover, the cooperation can be the origin of at least three transformations of individual's thinking: first it can be useful in becoming aware of oneself; then, it raises the distinction between the subjective and the objective; finally, it is source of regulation. These transformations allow the child to overcome the 'egocentrism' (in Piagetian sense), bringing the child to discern other existing points of view and different solutions of the same problem (Carugati & Selleri, 2005).

3. The research

3.1 Purposes of the teaching experiment

The main purpose of the teaching experiment is the construction of simple procedural languages, starting from a given situation and in order to solve a given problem. By introducing and manipulating new and simple languages, is it possible to create the opportunity for the children to think over the functions and the use of the language?

3.2 The methodology and the participants

The teaching experiment was carried out in a fourth grade class of a primary school (Istituto Comprensivo Fisciano, Salerno). The participants were 19 children 8-9 years old. The children performed three activities in three different days. Every lesson lasted from two to three hours during the school time. The children carried out the activities in three cooperative working groups, each made up of 6/7 members. The activities took place in the presence of Mathematics teacher and Italian one, one at a time, and of three researchers. The teachers' role was to observe[5], while the researchers' role was of scaffolders. The researchers gave some initial inputs and then they let the children perform the activities spontaneously. The cooperative groups' work was video-recorded by means of one camera. The children didn't seem to be uneasy for the presence of the researchers and of the camera.

The activities were designed by the researchers which developed the *Logo*-like[6] "kid-robot" task. They referred to *poor informatics* paradigm (Fasano, Gilli & Gentili, 1986), according to which it is possible to use 'poor materials', such as paper cards instead of software. The 'instructions' are executed by the children instead of a computer. The language is 'constructed' by a group of children during a social interaction. In such a way, children become 'interpreters' and 'manipulators' of a program. The general aim of this paradigm is to support the development of attitudes such as singling out problems, devising more or less formal language in order to codify them, identifying suitable procedures to solve them, describing these procedures unambiguously (Gerla, Sestito & Vescia, 1990).

At the end of all the activities, the children were interviewed using a semi-structured 7 open questions interview, based on the Explicitation Interview method (Piaget, 1974; Vermersch, 1994). Because of its nature, every interview had not a settled time. The Explicitation Interview can be defined as a set of behaviours of verbal and listening interactions, based on some reference grids which can apply to what is said. Moreover it is based on particular techniques for the formulations of the relaunchings (questions,

[5] Although the teachers were present in the classroom, they unfortunately did not participate in an actively way.
[6] *Logo* is the programming language by Papert (1980).

reformulations, silences) aimed at facilitating and attending the a posterior *verbalization* (in the sense of *putting into words*) of a particular experience's aspect. The explicitation interview aims to the *verbalization of the action* (the action is intended as the execution of a task). In every activity involving the execution of tasks (either in the school or in the professional activity) it is important to know in detail the modalities of the execution of the task itself. This is useful to analyze the learning difficulties, the possible errors' causes and also the ones of success. The only knowledge of the final result of the task is not sufficient to diagnose the nature and the cause of a failure or of a success. The development of the action is the only source of reliable inferences. Its knowledge is necessary to highlight the actually carried out reasoning; to identify the actually pursued aims (which can often be different from those one is supposing to pursue); to track down the theoretical knowledge which have been actually utilised in the practice (which can often be different from those mastered only from a theoretical point of view); to highlight the wrong representations or the preconceptions which are cause of troubles.

The interviews were audio-recorded and transcribed. A 3 independent judges content analysis was carried out (Berelson, 1952; Blanchet, 1985). This procedure required a segmentation of the corpus data in semantic units singled out in the interviews' reports. In particular lexical units referring to the same theme or argument were classified in semantic units called *topics*. In case of disagreement for the attribution to the topics, the judges discussed until reaching a full agreement. In the building of the topics it was necessary to respect some rules of classification: uniqueness of the criterion of classification, mutual exclusivity of the topics, exhaustiveness of the topics' set. Subsequently the frequencies of the lexical units in the topics were evaluated. From this analysis four *Main Topics* appeared.

3.3 Description of the activities

The children performed three activities. In the first two activities they were divided into three groups, in the last one they were divided into two groups. The activities can be tagged as: *creation of the language, decoding and manipulation, manipulation and interpretation.*

First activity: creation of the language. The first activity consists of three phases.

In the *first phase* the whole class chooses a child, playing the role of 'kid-robot'. His task is to move freely, step by step into a squared floored room and to arrive at a fixed position, starting from another one. The task for each group is to describe on a worksheet the movement of the robot, by matching a description to every basic action.

In the *second phase* two robots are chosen and at the beginning they are placed in mirror-like positions. The task changes too: each group gives in turn a single instruction to the two robots. The instructions should be aimed to get the two robots to reach the same fixed position, simultaneously.

Finally, in the *third phase* there is the institutionalization of the created language. The symbols or the words describing the movements are turned into basic instructions. The languages, created by the three groups, are compared. Then, through a collective discussion and negotiation, a more 'synthetic' language, shared by the whole class, is created. The final code is institutionalized by writing it on a billboard. Figure 1 below shows the instructions, as they were written on the billboard.

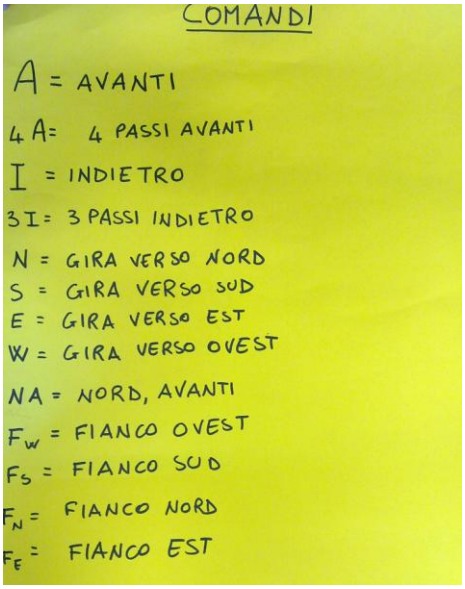

Figure 1. The instructions' billboard

The instructions' translation is:
'*A*' is *forward*;
'4*A*' is *four steps forward*;
'*I*' is *backward*;
'*3I*' is *three steps backward*;
'*N*' is *turn to the north*;
'*S*' is *turn to the south*;
'*E*' is *turn to the east*;
'*W*' is *turn to the west*;
'*NA*' is *turn to the north* (and then) *forward*;
'F_W' is *a step west side*.
'F_S' is *a step south side*;
'F_N' is *a step north side*;
'F_E' is *a step east side*;

In the billboard the children didn't write only the 'basic instructions'. They also wrote some abbreviations, like '*3I*', which stands for '*III*', utilizing their previously acquired knowledge, and some 'short words' like '*NA*'. A word is a 'program', since it is a sequence of elementary instructions. For example, 'AAIS' corresponds to the temporal sequence of the actions: *take a step forward, take a step forward, take a step backward, turn to the south*. The juxtaposition of two words corresponds to the composition of two programs. In this way we obtain an algebraic structure whose properties depend on the defined language and on the interpretation of the identity.

Second activity: decoding and manipulation. In the second activity each group receives a grid-paper, on which a starting point is indicated and a sequence of symbols of the new language, created in the previous activity, is written. The task for each group is to answer the following questions:

- *Draw the path (corresponding to the sequence) and indicate the point of arrival.*
- *Is the path you have drawn for the robot the shortest one to achieve the goal?*
- *Can you make it shorter by removing some instructions?*

- *What do you delete and how come?*
- *Can you replace some instructions with some others? With which ones? How come?*

An example of a sequence of symbols that the children represented and manipulated is the following:

$$N\ A\ A\ I\ A\ A\ E\ A\ I\ F_E\ F_W\ A\ A\ A$$

Through various ways, the children arrived at a reduced sequence like this:

$$N\ A\ (A\ I)\ A\ A\ E\ A\ I\ (F_E\ F_W)A\ A\ A$$

$$N\ A\ \ A\ A\ E\ A\ I\ A\ A\ A.$$

This sequence was obtained, for example, removing the strings of symbols 'AI' or 'F_E F_W', both equivalent to a sequence representing no-moving. Let us clarify that, in this case, we call *equivalent* sequences representing paths which, starting from the same initial position, allow the robot to arrive at the same end position. The activities about the singling out of equivalences and the rewriting of the words can be linked with the introduction of some algebraic structures. As an example the integers can be represented by means of the only instructions 'A' and 'I'.

Third activity: manipulation and interpretation. The third proposed activity is to play the *treasure hunt.* During this activity, as already stated, children are divided into two groups, we call *Group A* and *Group B.* Initially, the two groups work in different classrooms and they have different tasks.

For Group A, the task is to hide the 'treasure' in the classroom and to create a sequence of symbols of the language (of limited length, in this case no more than 15 symbols) representing a path leading to the treasure. The sequence must be written on a grid-paper . One can suggest that, since the created sequence will be delivered to Group B, which will interpret it to find the treasure, Group A can benefit from creating a sequence with strings of symbols which can be simplified.

For Group B, the task is to manipulate and, possibly, to simplify the sequence of symbols received from Group A. The final sequence, obtained after handling, should be dictated by a member of Group B to another of the same group, which will play the role of robot in order to find the treasure. Before the dictation, the robot knows neither the initial sequence received by his group nor the final one. To reach the treasure, the robot must run the path only on the basis of the information that he writes on his sheet during the dictation.

4. Results and discussion

The teaching/learning activities involved the whole class, even though at different levels of participation. By the qualitative analysis of the collected data we observed how the children created 'spontaneous' sceneries of reference, resulting from the free discussion among the children during the activities. The observation of the activities has led us to dwell upon various aspects to be analysed, such as the procedure of 'construction' of the language and the treatment of meta-language and object-language. The proposed activities had also the aim of building in the children a greater flexibility in the use of languages. According to Ferrari (2002) we think that such kind of activities "*force a more and more refined use of language as an answer to specific requirements and constraints explicitly posed by the context*" (p.354).

The results we want to discuss here rise by our observation of the activities and by the 3 independent judges Content Analysis of the children's interviews (Berelson, 1952; Blanchet, 1985). Four *Main Topics* (MT) appeared (see Table 1).

Main Topics come out by the reports' analysis
MT 1 *Lack of Communicative Agreement*
MT 2 *Information Processing/Interpretation*
MT 3 *Symbols Production*
MT 4 *Individual Thinking Transformation*

Table 1. Main Topics

Through the empirical analysis of the autobiographical reports, the children's way of processing and redefinition of the activities emerged. The interviews' analysis was carried out at three levels (Doise, 1986; Doise, Clémence & Lorenzi Cioldi, 1992):

1. analysis of the *inter-individual aspects*: the learning, the theories, the representations deriving from working in groups;
2. analysis of the *intra-individual aspects*: the procedures through which the children process at a cognitive level the activities;
3. analysis of the *relations among* the *inter-individual* and the *intra-individual aspects*.

In this way we have: *lack of communicative agreement* at an inter-individual level; *information processing/interpretation* and *symbols production* at an inter/intra individual level; *individual thinking transformation* at an intra-individual level as a consequence of a social activity.

4.1 Lack of communicative agreement

At an inter-individual level it seems that the cooperation and the competition (the children were divided into groups being in competition with each other) played an important role. This kind of activities allows the child to discern other existing points of view and different solutions of the same problem, without impositions of rules from the external (Carugati & Selleri, 2005).

In some critical points of the activities there were some failures in communication due to a *lack of communicative agreement* as we can find, as an example, in the reports regarding the third activity. In this activity there was a moment in which a child had to dictate to another one a sequence of symbols of the language previously constructed. The last child had to use the received sequence to get a target, but she failed. We had not given any explicit instructions about if and how to come to an agreement in this phase.

We report some excerpts[7] of the children's interviews regarding this Main Topic. From the report emerges that the children were able to account for the failure regarding this episode ascribing it to a non-agreement in the communication between the two children engaged in the game in particular about the position of the cardinal points.

Prot. 2- IV grade, F (*lack of communicative agreement*)

21.I: and in your opinion how come wasn't he able to give the orders?

22.P: Because (.) Because (.) they didn't come to an agreement on north south and (.) on where they had to start from

[7] In transcribing the interviews we used some of the Jefferson's norms (Jefferson, 1983; 1985). In particular, the font is Courier, which allocates the same space to each type, including the spaces and the tabulations; the speech's turns are numbered progressively, indicating the name of the speaker; (0.5) indicates the length of the pause in seconds; (.) indicates a shorter pause than 0.5 seconds.

Prot. 4 - IV grade, M (*lack of communicative agreement*)
14.P: (.)we were turned shoulders to shoulders me and Marika and I said to her some things (.) but she didn't know where north south east west were

In the last excerpt the interviewed child is the one that had to dictate to his mate Marika the sequence of symbols. Also he underlines that Marika didn't come to an agreement with him about how positioning the cardinal points on the sheet.

4.2 Information processing/interpretation

By our analysis it seems to come out a change in the individual thinking, a personal and social re-elaboration of the learned concepts and a representation of the importance of the collaboration/cooperation in performing the tasks. By joining both the inter-individual and the intra-individual levels of analysis, another Main Topic comes out, we call *information processing/interpretation*. The children processed at an intra-individual level the tasks, trying to overcome the problems through the collaboration with the others.

Besides, our idea was that the adhesion to a shared model and the achievement of a code created through a negotiation should spur a reflection in the children of the non-uniqueness of the interpretation of a language. Indeed the children elaborated their own representations of the activities and they used different interpretations of the language to perform the task. Moreover, we think that it would be important to encourage even more discussions and reflections aimed to raise the awareness of the children about the *non-uniqueness of the interpretation*.

Prot. 2 - IV grade, F (*information processing/interpretation*)
37.I: resuming the path do you remember that at some moment we get you to write and to draw the path on a sheet (.) Have you seen any difference from when you had to draw the path on a sheet and when you had to tell it by voice?
38.P: It was easier to draw it (.) yes (.)
39.I: how come do you say that it was easier to draw it?
40.P: because you see how the path is (.)how it is and then you draw it on the ground (.) that is (.) it is as if you draw it and then you see if the robot can get to the point

Prot. 1 - IV grade, M (*information processing/interpretation*)
31.I: do you remember the second-last time we met we said to you to draw the instructions on a sheet (0.05) was it easier or more difficult saying them by voice or drawing them?
32.P: It was easier to draw them on a sheet because after (.) you can also forget them (.) also

In both the excerpts the children assert that it is easier to draw the instructions on their sheet than to tell them by voice. The first child needs to write because the drawing helps him 'to see' the path. The second one says that the drawing lightens his work in remembering the instructions.

4.3 Symbols production

By our observation, it seems that the creation of a language through a discussion and a negotiation and the sharing of the activities' purposes have also favoured the understanding of the use and the manipulation of symbols. Indeed the final language was constructed from the children in a quite spontaneous way, through a gradual shift from the everyday language to a 'symbolic system'. This shift was spurred by the researchers through the tasks. In the first activity, to the three groups of children was asked to describe by some instructions the steps of the 'kid-robot' in the classroom. The children first used the everyday language in order to describe the robot's movements: '*take a step forward*', '*turn right*', '*take a step left side*' and so on. But quite soon they founded it 'inconvenient' for their purpose, that is to get the robot moving. This moment produced in the children a need of 'synthesis'. Thus they decided to use a symbol for each instruction, as an example: '*A*' for '*take a step forward*', '*I*' for '*take a step backward*' and so on. The researchers did not give suggestions about the choice of the symbols. Linked to these observations is the Main Topic *symbols production.*

Prot.1 - IV grade, M (*symbols production*)
23.I: When the instruction from longer became shorter was playing more difficult or easier?
24.P: with the shorter instruction was easier (.)
25.I: how come?
26.P: because we have to write smaller (.) and it was easier to understand (.) and it was possible to save space

From the above excerpt it appears how the children found easier to handle the language using the symbols instead of the everyday language to solve the problem. By means of the symbols they could also simplify some words (sequences) of the new language. During the activities the manipulated symbols were understood as 'tools' supporting the execution of tasks within the context in which the children acted (Radford, 2000).

Prot.2 - IV grade, F (*symbols production*)
23.I: do you remember that the orders were long? Then we played with them a little and we get them to become smaller (.) What do you think? When they become smaller (.) was it easier or more difficult?
24.P: Yes it became easier because we were able to simplify it
25.I: so by simplification the game became easier
26.P: yes(.) yes

4.4 Individual thinking transformation

At an intra-individual level of analysis it seems that there was a tendential transformation of the children's individual thinking (overcoming of the egocentrism) as a consequence of social and linguistic manipulative activities. They became aware of the existence of different viewpoints and of different opinions from their own. The Main Topic *individual thinking transformation* regards how the children have processed and interiorized the activities.

In the interviews the children have stated to have experienced a 'crisis' moment'[8] in the first activity, related to the introduction of the 2nd robot. The two robots were placed in mirror-like positions. To the groups was asked to give instructions to the two robots in order to get them to reach the same fixed position simultaneously. This task required a shift from the point of view of the only robot to the one of the two robots. The crisis was due to the fact

[8] By 'crisis' moment' we intend a moment in which the children have difficulties in understanding the problem and in sharing the decision to the solution.

that the children were unable to get the two robots to reach the same fixed position, simultaneously. This condition gave rise in the children to the need of making the language more objective and independent of the robot, doing away with the too explicit references to the child who was moving. The children also stated that, thanks to the teamwork and cooperation, went over the critical moment through the introduction of the cardinal points North, South, East and West ('external references'), instead of 'internal references' (such as left, right) related to a single child.

Prot. 1 - IV grade, M (*individual thinking transformation*)
13.I: at a certain moment if you remember (.) the robots became two and there was a crisis moment among your mates (.) in your opinion how come?
14.P: because I was here (.) and the other robot was there eh (0.5) and one was staying on the right and the other was staying on the left and to arrive I and Ylenia did some equal steps (.) but we were always finding in different positions (.) so we invented north south east and west

Let us underline that in turn 14 the child, that was one of the two robots, used the expression '*we invented north south east and west*' as if north, south, east and west were not existing instructions to be used, but just 'new' instruction 'constructed' by them in order to go over their problem.

In the following there is another excerpt regarding this 'crisis moment' and its overcoming:

Prot.2 - IV grade, F (*individual thinking transformation*)
9.I: revise this moment (.) when you gave the orders (.) initially there was only one robot that was Romeo (.) then at some moment it was decided to introduce another robot and there were two (.) in that moment (.) did something change?
10.P: yes
11.I: what?
12.P: because they were in two different positions (.) so you could not get them to arrive well (.) both (.) at the same point
13.I: and when you gave orders what difficulties did you see?
14.P: (.) because (.) one turned on a side and another one on another (.) so (.) you could not put them both on the same side
15.I: and then did we solve this problem?
16. P: yes
17. I: and how did we solve it?
18. P: with the instructions north and south (.) east and west (0.5)

5. Conclusions

In this paper we analysed how the children processed some linguistic-manipulative activities regarding logical tasks. We did this by means of a qualitative analysis of the activities and of the autobiographical reports of the children. From the analysis, a relationship between the

manipulation of the language and the development of some logical tools seems to emerge, spurred by the activities.

The activities were about the creation and the handling by the children of a simple procedural language, starting from a problematic situation regarding a 'kid-robot' moving in a room. The way of performing the activities was negotiated with the children, which were free to interpret them and to take initiatives. By a qualitative analysis of the activities and of the interviews, we could observe how the children succeeded, in a short time, in choosing, from time to time, the suitable strategy to solve a problem. The negotiation of the activities spurred this process. In particular, by the analysis of the interviews, the ways of re-elaboration of the activities emerged, which resulted by the weaving of individual, relational and contextual aspects. It was possible to identify four Main Topics: *Individual Thinking Transformation, Lack of Communicative Agreement, Information Processing/ Interpretation* e *Symbols Production*.

The topics *information/processing interpretation* and *symbols production* are linked to the different interpretations of the language elaborated by the children and to the children's need of creating symbols in order to carry out the task. It seems that in the activities there was a change in the language's role from being only a communication tool into an object to be manipulated by the children. Handling the symbols of the constructed language, the children were able to solve the tasks.

Individual thinking transformation is the topic linked to the overcoming of a 'crisis' moment'. The determining condition for the crisis' moment seems to stimulate in the children the need for a more objective and independent language. By the interviews it appears that only thanks to the collaboration it was possible to go over the moment of 'impasse', introducing in the language 'external references' (cardinal points) instead of 'internal references' (such as left, right).

Another topic is the one linked to a task which was not carried out completely. This 'failure' was interpreted by the children as a *lack of communicative agreement* among the members of the group.

Moreover it seems, by the interviews' analysis, that there was what Vygotskij defines the shift *from interpsychic to intrapsychic*: working in groups and playing with the language and its signs, assigning new meanings to it, the children were able to elaborate together the problem, finding out a solution which enlarged their knowledge schemes; subsequently, they interiorized and re-elaborated the concepts at a meta-cognitive level.

There were some moments we called crisis' moments, experienced by the children during the activities. The situations in which the execution of the task makes the children aware of the failure due to the application of their cognitive schemes (in the sense that the answer to the task appears to be insufficient) stimulate an *intra-individual conflict* (Piaget, 1923) (think, for example, to the two robot's moment). The interviews carried out resembling the explicitation interview helped us and the children to reconstruct these situations.

Although the activities described in the paper don't deal with arguments strictly linked to mathematical school curriculum, their aim is to spur the development of linguistic skills which are basic for mathematical knowledge construction. Moreover a link with more specific mathematical topics may be built.

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