1. Introduction

Previous research has led us to identify teachers’ main needs for open and innovative activities regarding the scientific education of children from 6 to 14 [1]. Research on didactic innovation based on new technologies for the teaching of physics have shown that it is necessary to integrate Meta-Cultural, Experiential and Situated models [2, 3, 4] into teachers’ in-service training. A recent pilot project organized by the Italian Ministry of Education has made us aware that we need to completely change the ways in which we carry out our in-service teacher-training so as to include the dimension of educational and didactic research [5]. Action-Research, based on a reflection on work done in the field, contributes in a unique way to the teacher’s professional competence and gives him those elements of flexibility which make him able to follow and manage dynamic mental models connected to the context [6]. For this reason the action of reflection and research which teachers can make is one of the factors which, with increasing attention, are located at the center of processes for improving the learning/teaching system [5]. There is now a general agreement on the need to introduce science teaching right from play school. Science teaching performs an educational function, by accustoming students to group work, to an open comparison, to explaining ideas, to recognizing the validity of results based on the sharing of common elements. It also performs a training function, stimulating representation, symbolization and modelling, which are essential in the development of cognitive skills. In the Italian school system, which is still strongly influenced by the reforms made by Gentile in 1923, the introduction of scientific education in the basic school is still an open problem [7].

This work reports on an experience of teacher training in the Play school: it integrates research and innovation while it introduces scientific education into a specific field of experience: thermal phenomena. The work focuses attention both on the teacher-training process and also on the activities of the children (from 3 to 6 years of age): the indivisible nature of the two processes puts particular attention on the children’s formalization processes on the experiences of constructing and structuring scientific thought.

2. Scientific education in the play school

Children are looking for stimulating activities in order to lessen their need of competence [8]. The child has to recognize sensorial information and learn to use it to collect information, including quantitative information, on phenomena [9]. The child’s curiosity is the starting point for his development of scientific knowledge. Through curiosity scientific education is constructed by asking questions, discovering problems, working on them with one’s thought, starting to observe or to make experiments [10]. In this way he develops a flexible attitude, a readiness to change opinion when this is reasonable, and an ability to analyze and synthesize [11]. Recent research has shown how children from 3 to 6 do not limit themselves to asking questions and waiting for the answers from us: they look for personal ways to give answers [12]. Between 3 and 5 children develop systematic strategies and a generalized rule-governedness; there is an impressive variety of situations where children construct and use different rules, and this is particularly evident in the way they deal with new situations of problem solving [13]. Scientific education in the play school must therefore be conducted in such a way as to stimulate in play, in stories, in moments of didactic activity, that curiosity which activates processes to organize
knowledge, able to evolve in a continuous re-processing of the results of the child’s exploration of the world.

The professional ability of the teacher who must produce this dynamism implies a combination of technical, social and organizational skills [2, 3, 14] and therefore the teacher training for this level of school is particularly delicate. The degree course in the Science of Primary Education, which was only started in Italian Universities in 1999, has to deal with these problems. However, the problem remains of teachers already in service, especially with regard to the following needs:

A) possessing a scientific competence which can be integrated with their pedagogical competence, gained by their experience in the field [15]; understanding the cognitive skills of the children in the scientific field at this age;

B) understanding the cognitive skills of the children in the scientific field at this age;

C) being able to manage informal education, with play, to give the children the necessary familiarity with the world around them;

D) having experience in constructing contextualized formalization processes.

Physics is one of the subjects which best lends itself to perform this task, because it uses mathematics in describing and interpreting phenomena and offers opportunities for symbolization, seriation and tabulation.

We shall now illustrate the contents of a teacher training activity for play school teachers; it was created as a training course and transformed into a research gymnasium for the trainers and trained, through analysing the cognitive processes of the children who were in the classes.

3. Training play school teachers

The activity of training as research, which we shall be reporting on here, had its origin in an excellent experiment in the play school of Terenzano (Udine). It was called “Fisicando” and proposed physics as the subject matter and play as the didactic method for children of 5-6 years of age.

Both the planning part and the practical part of the project were followed, analysed and evaluated in the context of the Degree course in Primary Education, with consequent influence on the practical experience in the participating schools. This activity has stimulated great interest and 32 teachers from the provinces of Udine and Pordenone have requested a specific training course at the Interdepartmental Centre for Research in Education (Udine University), which has developed in the following five stages:

I) Seminar on operativity in the construction of formal thought in the scientific field

II) Visit to the GEI exhibition [16] with the children in the context of the “Science Days 2001”, with their actions monitored

III) Paths on thermal phenomena were discussed, simple experiments, including on-line experiments, were performed and analyzed

IV) Didactic activities were planned and feasibility studies were made in the field of thermal phenomena

V) The experiments were carried out in class and there were periodic discussions of the paths followed and the materials produced by the children.

These five stages developed the following points in the training process of the teachers:

**Role and method of scientific education for children:**

A) Contribution of science to general education. Science has to be used for rethinking and understanding experiences already made. Describing, interpreting, predicting and checking predictions is a strategy proper to scientific investigation.

B) Role and duties of the teacher:

- to help the children to pay attention to and reflect on the phenomenon;
- to use common sense experiences and spontaneous interpretative patterns;
- to look for answers by exploring with hands and mind: the teacher must not impose answers which have not been identified/recognized;
- to stimulate questions rather than give answers to questions which have not been asked. In particular, to educate the children to recognize that the decisive element for accepting a correct interpretation of the phenomena is sharing:
- to accustom the children to always insert the evidence of their prediction with respect to the result of the experimental investigation.

C) Processes of formalization, the role of operativity, ways and means of scientific communication (graphs, etc). Examining some examples taken from research with GEI [17]. Some examples of experiments with GEI were provided, some disciplinary contents in the field of thermology were illustrated and some possible didactic activities were suggested.

**Attitudes and cognitive processes activated in informal contexts by the children**

A group of 15 children of 4 and 5 years old, in the play school, was observed with parameters as used in other studies [18] during a visit to the GEI exhibition, to acquire experience of their ways of exploring in a scientific field. The children’s attention span and interest was surprisingly long: about 70 minutes, during which they asked a lot of questions, often redundant, showing in this some typical features of their age, such as the need for a personal answer and for repetition [19]. The cognitive path of the children on specific concepts of the subject dictated the criteria on which the activities proposed were set up in the subsequent teacher training step.

**Planning didactic activities**

It was mainly the task of the teachers to plan the activities to be carried out with the children and the way to carry them out. The task was performed not in isolation but with a variety of human resources and instruments. The human resources were not only the researchers, but also the teachers, in an integration of skills and experiences combined in a learning community. The conceptual knots we pointed out were:
1) Heat as an exchange quantity and temperature as state property;
2) measuring the temperature of objects and the human body;
3) thermal interaction and exchange processes between metal cubes at different initial temperature;
4) thermal interaction and exchange processes between water masses at different initial temperature;
5) specific heat and thermal conductivity of materials;
6) analysis in energy terms of transformations.

**Didactic activities with play school children**

Even though the proposed activities were elaborated, discussed and shared in the learning community, the teachers actuated a wide variety of didactic strategies and ways of conducting the experiments. Let us consider the following three points, dealt with by at least 5 teachers:

I – thermal sensation (all teachers);
II – thermal state (15 teachers);
III – conductivity (5 teachers).

I – Thermal sensation

The didactic experiments on thermal sensation were for example, a thermal mapping of a space and classification of a defined series of objects (cubes of polystyrene, wood, plastic, a rubber, a piece of iron) according to thermal sensation. The children touched the objects with their hands and then had to formalize the thermal sensation they experienced. Different formalization strategies were tried, as listed hereafter.

- **Seriations.** The children classified the sensation produced, and seriate the objects in a diagram along a diagonal. The objects which produced the sensation is symbolized using the objects, photographs, sketches or symbols. They frequently used symbols or symbolic drawings, for example: red balls for heat and blue balls for cold. From the cognitive point of view, the drawing was equivalent to the symbol, since the children’s limited drawing ability always puts the fact into a symbolic context. In fact, when the teacher asks the child to draw objects, the similarity of the drawing to the real object is not very relevant, because either the sign is shared and therefore recognized or it remains extraneous.

- **Ven representations:** they are used both to define groups and also to make correspondences.

- **Shared rules of spatial collocation or symbolic representation.**
Double entry tables with seriations identical to those cited above. The correspondence with the place or participating child is explained.

Spontaneous quantitative representations: diagrams and/or graphs. The intensity of the thermal sensation is represented with squares of an area proportionate to the thermal sensation experienced, or is translated into histogram bars or even graphs where the elements are ordered in increasing or decreasing fashion.

The initiative of one teacher (Emma) to include a step of intermediate binary classification proved useful.

II - Thermal state

The didactic experiments on thermal state consisted in putting some objects in the freezer and in hot water in order to take them to different thermal states. The children examined the sensation produced by different objects which had been for a long time in the same environment (freezer, tank of hot water, environment) and by the same object in different environments. The children made the deduction that the thermal state is determined by the environment and that the material influences the rapidity with which every object reaches the thermal state without particular help. Formalization remained on the same level as the previous experiment: no formalization was noted which took the temporal variable into account. In order to overcome this limit, one teacher (Rita) translated this experiment into a game: three environments at three different temperatures (the fridge, the tank of hot water, the class room) were symbolized by different objects (foam rubber cubes / freezer, basin / tank of hot water, area of the gymnasium limited by a rope / environment) at different points of the gym. The children chose an action to carry out at random. If, for example, a child drew “it gets hot”, he went to the “hot water” and removed some clothes; if he drew “it gets cold”, he had to go into the “fridge” and put his clothes on.

III – Conductivity

The didactic experiments concerning conductivity were conducted to evaluate the ways children recognize process with respect to state. They led the child to observe the fact that ice placed on top of a metal melts more quickly than ice placed on top of polystyrene. In this case the question which some children asked was: “why does the object which I feel as colder make the ice melt quicker?” In this way there was a spontaneous separation and recognition of states with respect to processes. In fact, the children explained the process with a motivated animation (metal is a friend of ice and takes it away) on the process variables.

4. Conclusions

When children report their experiences they often use drawings and this corresponds to symbolizing, sharing the meaning of the symbol. The similarity of the symbol to reality is not very important. At this age socialization begins and the comments of their peers are more important than those of adults (“cooperative learning”). Therefore, the object symbolized will be recognized irrespective of its similarity to reality.

However, the symbols are often too distant from reality to be understood outside the group. In the game where the children “become hot or cold objects”, the child uses himself as a symbol (he identifies) and this facilitates comprehension [19].

In seriating “hot” and “cold” objects, the child has a problem: he is representing quantities of a single property, still not well identified, of a system outside himself. Seriating the objects along a diagonal line unifies these features and helps the child to recognize the first quantitative elements. When the experience is discussed and repeated, the children are faced by the problem of reproducing the experiment and by the significance of the data. Representing thermal sensation with an area-intensity translation, by means of squares, offers the child the opportunity to consider two-dimensional spaces, which he can connect with geometry later, and immediately with the recognition of the space in which he is. In this case, when the thermal sensation is tabulated for each child and object touched, the children can observe the “total thermal sensation” of a single object for an entire class of pupils, making integrations for classes. The concept of average also emerges:
they are able to recognize an “average thermal sensation” and use it to obtain secondary information and also a shared table of data.

With the experiment of the ice cubes the predictions are compatible with the proof of the deduction. Our data show how very young pupils can manage very complex concepts. They discuss laboratory experiments and the meaning of data, they reflect on the experience finding different methods of formalization, also producing symbols, tables and types of seriations of the data.

In order to obtain a shared seriation of the objects touched, different strategies were used: first of all, the children discuss the different opinions [20], then they make a seriation of pairs of objects, they establish a series over the whole group, repeat the experiment after some days and finally the data not shared are excluded from the representation.

These results, of considerable interest, have emerged thanks to the learning environment which was developed: neither the teachers with autonomous activities, nor the researchers observing the children in unplanned activities, would have been able to recognize the obvious potential for formalization which the children show in the core of a subject. The dimension of the Action-Research associated with that of comparison has enabled the development of skills in the teachers on various levels (not least, the subject level). Although it was not expected, important skills were acquired in managing the conceptual points which the children bring out in practical activities, creating a cognitive crisis in the teacher too; to overcome this crisis entails looking at the same knowledge on many different levels. Reflecting on practical didactics is thus revealed to be the essential moment of in-service training for teachers.

Acknowledgments

We are greatly indebted with the 32 play-school teachers participating in teachers' education activity and particularly Giuseppina Tirelli, Rita Maurizio, Emma Cianavei, Ornella Milad and Carla Pecoraro. Their feeling and experience in teaching improved the work.

References

[1] S. Bosio, V. Capocchiani, M. Michelini, F. Vogric and F. Corni, Problem solving activities with hands on experiments for orienting in science in Girep Book on Hands on experiments in physics education, eds G Born, H Harries, H Litschke and N Treitz (for ICPE_GIREP Duisburg), (1998);


[16] GEI (Giochi Esperimenti e Idee, www.uniud.it/cird/GEI) is a collection of 120 simple experiments in many different fields of physics, well described in literature [10])
Bosio S, Ceccolin D, Michelin M, Sartori C and Stefanel A, Games experiments Ideas from low cost materials to the computer on-line: 120 simple experiments to do and not only to see, in Girep Book on Hands on experiments in physics education, eds G Born, H Harries, H Litschke and N Treitz (for ICPE_GIREP Duisburg), (1998);
Other articles can be down-loaded from the site www.fisica.uniud.it/GEI/GEIweb/ricerche/ricerche.htm.
[19] T.B. Rogers, Emotion, imagery and verbal codes: a closer look at an increasing by complex interaction in: J Yuille Imagery, memory and cognition (Erlbaum, Hillsdale, New York)
[20] One child said: "I took the object after my class mate and his hands had heated it up"