# AN INTERDISCIPLINARY TEAM-TEACHING TRAINING TO PROMOTE SCIENCE TEACHING SKILLS IN PRIMARY SCHOOL TEACHERS

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## 1. Introduction

### 1.1. Science education in the primary school curriculum

The Portuguese primary school (5/6 - 9/10 years) education is global and administered by a single teacher who is responsible for teaching, in an integrated perspective, the following areas: a) the development of oral language and initiation to, and progressive mastery of, reading and writing (Portuguese), b) basic notions of mathematics, c) the physical and social environment, d) artistic, dramatic, musical and motor expressions, and e) moral and religious education (*Comprehensive Law on the Education System*, Law 46/86).

The objectives, programmes and guide-lines are further defined in the National Primary School Curriculum (1990).

The Physical and Social Environment area is composed of six sub-areas of study:

- *Discovering yourself*: your body parts, body health, body safety.
- *Discovering the natural and local environment*: plants and animals, and physical aspects of the local environment, celestial bodies.
- *Discovering materials and objects*: objects and materials, light and sound, electricity, magnetism, forces.
- *Discovering other people and institutions*: family members, family history, local and national history.
- *Discovering relations between spaces*: home, school and the way in between, maps and itineraries, transports and communications.
- *Discovering relations between nature and society*: local agriculture and industry, environmental quality.

Natural Sciences are mostly associated to the first three areas of the above list, but History, Geography and Ethnography also contribute to the Physical and Social Environment area. Science as an individual subject of study does not exist as such. It is immersed in several sub-areas of study included in the Physical and Social Environment area, which is intended to have a global and integrated approach.

The current Programme of Study for the Primary School intends to give children an opportunity to perform learning experiences under the following guide lines:

- *Active learning*: students are supposed to manipulate objects and carry out physical activities in order to discover and explore their physical environment.
- *Significant learning*: the recognition that children's life experience and ideas must be taken into account in teaching in order to generate meaningful learning.

- *Diversified learning*: the use of a variety of materials, techniques and processes to develop children's skills.
- *Integrated learning*: previous independent children's ideas and learning must be used in relation to new experiments and discoveries in order to associate them, leading to a unified knowledge.
- *Socialising learning*: respect for student's individual differences, encouragement of the exchange of experiences and knowledge among children, and promotion of children's participation in school responsibilities, in order to create an atmosphere which favours socialisation and moral development.

## 1.2. Primary science: Official curriculum versus curriculum in school

There was a first attempt to introduce science (*Lesson Objects*) in the Primary Curriculum at the end of the *I República* (democratic political system after the Republic Revolution: 1910-1926); however this idea was later rejected by the political dictatorial regime of Salazar (1926-1974). After the restoration of democracy (25th April 1974), science was again incorporated into the Primary Curriculum as part of the curricular area *Physical and Social Environment*. Since then, successive programmes have defined objectives and recommendations about science teaching based on a constructivist and experimental view of learning.

In order to give support to the promotion of new programmes, in the 70s and 80s, the Ministry of Education released only a few papers and booklets on primary science which were distributed to a few teachers only. Thus, until now there has not been a policy really oriented to introduce science in the primary teacher's practice:

a) no science teaching-guide has been released to be available to all teachers;
b) no relevant specific efforts have been made in in-service and initial teacher training for primary science;
c) no materials nor equipment have been provided to primary schools.

The authorities seem to believe that it is enough to introduce the term science into the primary curriculum and simply expect that the reality in schools will change by itself, or alternatively, the authorities and society in general do not believe that science is really important as a component of primary education.

The actual primary school programme, approved in 1990, strengthens the science component with the inclusion of a new *Physical and Social Environment* sub-area named *Discovering materials and objects*. It establishes that *'the teacher has the role of guiding a process* by *means of which the pupils will become active observers with skills of discovering, investigating, experimenting and learning'*. So it is recommended that children *'must have real contact with the environment, carry out investigations and real experiences in school and in the local community (...)'*.

In the general objectives of the Primary School Programme, one can read that pupils must:

- *"Use simple processes to know and to discover the environmental reality (observing, describing, asking questions, predicting, investigating, verifying), assuming attitudes of permanent research and experimentation."*
- *"Select different information sources (oral, written, observation... etc.) and use various methods for collecting and treatment of simple data (interviews, inquiries, posters, graphs, tables)."*
- *"Use diverse ways to communicate the information collected."*

Although statements about science in the Primary School seem to be interesting, one can see in contact with the schools that children only memorise scientific information from books and that they have no opportunities to learn from objects and materials nor to experience scientific processes. Teachers have a very low scientific background; they are very unconfident about science and teaching science; and they don't recognise science as an important component of primary education. This situation makes primary science teacher training a crucial and complex question.

### 1.3. Primary science teachers' training in Portugal

Until the middle of the 80s, primary teachers were not trained in institutions of higher education but in *'middle schools'*, and science was not part of the teacher training curriculum until the 1975. Since then, Universities and Polytechnics have been responsible for training primary teachers. Theoretically, this political decision implies that science education researchers should supervise primary science teachers' initial training. All institutions have in their training curriculum Science subject units but not all of them have a Science Education subject unit (Costa *et al.* 1993). In the case of the University of Minho, Natural Sciences is an annual subject unit (4 h/week) and Science Education is a semester subject unit (4 h/week). The teaching practice for student teacher finalists occurs in primary schools under little supervision by the teacher training institutions. Consequently, the final teaching practice of the teacher training course becomes a process of socialization of student teachers in traditional teaching installed in schools (Sá & Carvalho, 1997a). Evidence from this teaching practice, as well as our direct contact with teachers following inservice teacher courses, indicates that this new situation has not contributed to a meaningful improvement in experimental science teaching skills. Hence, we have now a paradoxical situation: science is reinforced in the latest primary curricular reform (1990), but teachers continue the traditional way of teaching. Moreover, communications and papers on Portuguese primary science are scarce in Science Education meetings.

For more than one decade, nearly twenty primary teacher training institutions, either Universities or Polytechnics, have not been able to change the quality of primary science training. A series of interconnecting factors can explain this situation:

a) During several decades Primary Education was politically neglected. This contributed to reinforce the common sense view that children's education is simpler and less important than that of upper educational levels.

b) Although having no tradition of primary teacher training, the University took over this responsibility. Therefore, no specialists were available to promote adequate training and research on the specific area of primary science.

c) Having no such specialists, primary science was not identified by the University as a new problem requiring new approaches for training and research. An implicit culture at the University tends to regard children's education as requiring low levels of specialisation, with the result that Primary Science has been viewed as a minor subject of study. Consequently University researchers are not motivated nor stimulated to make their careers whithin this scientific domain (Sá & Carvalho, 1997b).

d) Polytechnic educational institutions were specially created to train infant educators (3-6 years) and elementary school (6-10 and 10-12 years) teachers as well as to develop educational research on children's learning. However, most of Polytechnic science educators have been recruited from inservice teachers, either from 2nd / 3rd Cycle (10-12 / 12-14 years) or Secondary (14-16 years) schools. Such science educators had no empirical knowlegde of the primary school reality and had acquired conceptions and practices of teaching science not adequate to the primary science approach recommended by the international community. Due to the fact that Polytechnics were not prepared to support and to stimulate a professional shift to primary science, these science educators tended to follow, at Polytechnics, their prior professional experience. This is one of the reasons why nowadays Polytechnics have obtained from the Government the possibility to enlarge their domain of teacher training up to the 3rd Cycle instead of improving research and training specialised on lower school levels.

All the above circumstances determined the impossibility of creating a community of trainers and researchers specialised in primary science.

### 1.4. Project work to promote science teaching skills in primary school teachers

In order to promote children's scientific thinking (Khun, 1988) and investigation competence (Harlen,1988; Qualter *et al*, 1990; Monk & Dillon, 1996), a previous *quasi*-experimental action-research study, combining qualitative and quantitative methods, has been conducted in collaboration with primary school teachers in two fourth year classes as follows (Sá, 1996). In each class 54 hours of experimental activities were carried out in a cooperative way of learning and strongly supported by inquiry by the researcher and teacher. Data collection was carried out in classrooms by using the method of participant observation, children's own records, and observation of children's performance on investigation tasks in separate interviews with children at the end of the year (Cavendish *et al*, 1990; Harlen 1992). Each experimental class was compared to a control class, in pre-tests and post-tests, by using a Competence Instrument in Scientific Processes.

The main results of this research were the following (Sá, 1996):

a) the children were amused and delighted, having enjoyed very much their activities; this was clearly revealed by their behaviour and emotional reactions as well as by their oral and written messages;

b) an ambience of genuine reflection, discussion and viewpoint exchanges was developed in the classroom, thus showing great intellectual commitment in solving problems; such ambience led children to carry out their investigations, in groups, with a high level of autonomy;

c) at the end of the year, 28 out of 40 children (70%) were able to perform their own investigation tasks (making hypothesis, investigation planning, review of the investigation plan, its execution, data recording and their interpretation) -- which involve an independent variable, a control and a dependent variable -- with different performance levels and requiring different degrees of inquiry by the researcher;

d) the scores obtained from both classrooms were significantly higher as compared to the ones of the control classroom, as estimated by the Competence Instrument in Scientific Processes.

The above study has demonstrated that the strategies used -- object manipulation and evidence production by the children themselves, discussion and co-operation, writing, inquiry by the researcher and teacher, and review by the children of thinking schemes constructed gradually by inquiry -- revealed themselves adequate for the development of scientific thinking quality. Furthermore, the way the activities were supervised was determinant in this work, resulting in the identification of several teacher's competencies, such as various categories of questions to improve the inquiry competence (Harlen, 1992; Monk & Dillon,1996; Sá, 1996).

These results contribute to strengthen the belief in the educational role of science in primary school, particularly in Portugal where this curriculum component has been neglected for long time. Having this in mind we have designed a project on primary science teaching training, which is explicitly dependent on pupils' learning objectives. The teacher training objectives are the following:

a) to promote understanding and recognition of the educational value of primary science;
b) to develop positive attitudes towards science and the teaching of science;
c) to improve the scientific background required by primary science contents and objectives;
d) to develop process skills in experimental activities;
e) to develop science teaching skills in experimental activities and investigations to be carried out by children.

The above teacher training objectives are dependent on the following childrens' learning objectives:

a) to improve the ability to communicate, to reason and to discuss their own ideas about objects, facts and problems;
b) to promote in children the ability to test ideas against evidence, by using scientific process skills;
c) to promote conceptual change towards a scientific understanding of the environment;
d) to promote thinking skills by inquiry in investigation tasks;
e) to promote meaningful learning in Mathematics and Portuguese language in the context of scientific activities as well as in the artistic domain (drawing and painting) when adequate;
f) to promote an amusing and enjoyable ambience in learning;
g) to promote more positive attitudes towards school, especially in children from lower socio-cultural levels.

## 2. An Interdisciplinary Team-Teaching Training To Promote Science Teaching Skills

### 2.1 Interdisciplinarity of the research project

Typically, primary and secondary school teachers' training courses in Portuguese Universities present a dichotomized institutional structure:

a) Departments of Science (*e.g.* Biology, Chemistry, Geology or Physics), which are located in Faculties/Schools of Science, are responsible for teaching science disciplines;

b) Departments of Methodologies, which are generally located at Faculties/Institutes of Education (and Psycology) are responsible for science education subjects.

From our point of view this dichotomy has been shown not to be a fruitful approach for science education research and science teaching training, due to two main reasons:

a) scientists (biologists, chemists, geologists or physicists) are mostly devoted to their own area of science research and teach science in an empirical way, not having in mind the important role that the way in which they teach science influences the new teachers profile of skills and practices;

b) educational researchers and science educators (in spite of having their first degree in a scientific teacher's training course) become more and more apart from science. Often they teach how to teach science without laboratory support. Frequently, they themselves have no experience of teaching science and/or their experience fades as time goes by.

At the University of Minho this scenario can also be seen in secondary school teachers' courses. However, a unique structure for the primary school teachers' course has been recently created at the Institute for Child Studies: science researchers work together with science education researchers in interdisciplinary projects to promote science teaching skills in primary school teachers. In this context, the traditional suspicion between scientists and science educators vanished, and a fruitful cooperation has been developed:

a) scientists have been made aware of the theories of science learning and of teacher training, contributing to a more effective way of teaching science;

b) science educators have been made familiar with laboratory activities in which an experimental science education approach has been conducted.

This approach promotes a philosophy of science education research, consisting of testing teaching and learning theories against experience of teaching science in the classroom, conducted by researchers and primary school teachers.

In this interdiciplinary project work, a group of fifteen in-service primary school teachers were supervised by three University science researchers/educators in both general group sessions and individual teacher-supervisor sessions. After their training at the University, each teacher guided his/her school children to carry out science activities similar to the ones previously performed by him/herself. The whole project takes nearly 10 months and is concluded by a final teacher's report which will be submitted as a thesis to obtain a University diploma. In short, the project of teacher training involves three main objectives: to promote skills in experimental science, in experimental science teaching and in methodologies of observing and analysing their own teaching, in order to promote reflective teaching (Zeichner, 1993).

## 2.2 General group sessions

General group sessions lasted for a total of 12 hours. These preliminary sessions were organised in order to make primary school teachers familiar with the concept of experimental science teaching: manipulative activities and thinking are strongly kept together in experimental science learning (Khun, 1988; Fairbrother, 1989; Harlen, 1992; Sá & Carvalho, 1997b). Furthermore, several different forms of teaching experimental activities were shown by demonstration of simple examples which were further discussed in the context of science teaching. Video watching and analysis of actual experimental science activities in primary classroom were also of great help to illustrate typical situations of experimental teaching. Particular attention was given to the role of pupils and teacher in an inquiry/experimental way of teaching.

Further group sessions were devoted to a general discussion of how to plan, organise and manage a complete investigation to be carried out by the teacher him/herself, first at the University laboratory, and afterwards with his/her school children (Harlen, 1984; Sá, 1994). Methods of collecting information about the class intervention were discussed, including teachers' class logs (Delano, 1993; Zabalza, 1994) and video recording (Erickson, 1989) as well as children's reports (Harlen, 1992; Sá, 1996). Teachers were trained in action-research methods in order to be able to analyse their own intervention and write their research reports.

## 2.3. Teacher-Supervisor sessions

In addition to general group sessions, a large number of individual teacher-supervisor sessions (over 20 hours) took place in order to help primary school teachers to develop their experimental science skills. The supervisor's role was specially devoted to stimulating teachers' thinking and action:

- to present experimental demonstrations in order to promote effective thinking about the phenomena;
- to ask questions in order to make the teachers to plan their own investigations:
  a) selection of the relevant variable to change (independent variable) and identification of the variable to assess (dependent variable);
  b) understand the significance of the control of variables in the validity of results (fair test);
  c) programming of sequential activities and of collecting data, as well as identification of equipment required for their laboratory activities.
- to make them think about their own ideas;
- to point out experimental errors in order to make them aware of the need of technical improvement and repetition to get reliable and accurate data;
- to help them to identify the most relevant data and ways of presenting them so as to make them meaningful;
- to stimulate the exploration of new emerging questions;
- to supervise the written laboratory reports.

It was expected from the teacher:

- to select the topics of investigation;
- to design the investigation planning;
- to conduct experimental activities and record experimental data;
- to handle data and interpret experimental results;
- to reflect the whole experimental training in the view of similar children's learning;
- to write laboratory reports.

The following topics of investigation were chosen by each teacher in accordance with his/her respective supervisor: floating and sinking; air and energy; magnetism; atmospheric pressure; simple electric circuits; blood circulation; quantification of food proteins; starch digestion by saliva; pollutant effects on plant growth; environmental health education; temperature effects on living beings; antibiotic effects on bacterial growth; light effects on the behaviour of moulds; biodegradation of domestic wastes; soil decomposers.

The teacher conducted his/her experiment and recorded experimental data, under the researcher supervision, according to the investigation plan which was previously designed.

After their experimental work at the laboratory, teachers planned science teaching activities out of the ones they had themselves carried out before. For this, two main aspects were taken into account:

a) they had to think of their role as teachers, having in mind the way they were previously supervised (stimulate pupils' thinking and action, by asking questions, recognising pupils' ideas and guiding them to test ideas against evidence);

b) they had to realise the role of pupils' learning, in a way to that in which they were previously trained (communicate and discuss their ideas, test their ideas against evidence by object manipulation, collecting and interpreting data).

School science activities planned by the teacher were fully discussed with the supervisor in terms of: learning objectives, general orientation of lesson activities, specific activities for the pupils and for the teacher him/herself, size of the pupils' working groups, estimation of the time for the activities, laboratory materials to take from the University to the school, safety warnings when required, and pupils' homework (reports on the experimental work and fiction stories).

The activities of science teaching were supervised by the researcher either by observing classroom activities followed by discussion and reflection or by teacher-supervisor sessions based on teachers' oral and written reports on classroom experimental activities.

Teachers are now writing down their reports on their activities in both University laboratory and in their primary schools. The general report consists of three parts:
1. Experimental study of the selected topic at the University
2. Experimental teaching in the classroom
3. Results and general discussion

In the experimental study, teachers write a short scientific review on the topic, a report on their experimental activity at the laboratory, and a personal reflection about their experience of training in scientific skills.

In the experimental teaching part of the report, teachers write a short review about science teaching theory in the elementary school, learning objectives, and science teaching activities plan.

For the third part of the report, results and general discussion, teachers used the following ways of collecting data: participant observation and teacher's log, pupils' work cards and written reports, pre-tests and post-tests about pupils' ideas on the topics, and pupils' free composition about the science learning that they experienced.

## 3. Preliminary Analysis Of Science Teaching Training

Teachers' thesis are now being organised and will be the main source of data for a research report about the process of teacher training that we have conducted. However, qualitative data that we have been collecting allow us now to present some preliminary conclusions, as follows:

1. In the beginning of this project, teachers showed high anxiety and insecurity because they were about to start their personal thesis work to obtain the University Diploma. In addition, they felt highly insecure when the training project that we have conceived was introduced to them, due to the expectation of a totally unknown and difficult process that they supposed they would be required to carry out. In these circumstances, some discrepancy between researchers/trainers' optimism and teachers' defensive attitudes was evident. Therefore, it was not possible to promote group work discussion and reflection as one of the strategies in the manner originally planned.

2. During the experimental phase of the training project, teachers revealed difficulties in assuming a genuine attitude of reflection and thinking as they showed a strong tendency to guess the "right answer":

a) in the experimental reports, scientific formalism from the literature was taken by some teachers as knowledge supposedly obtained out of their own experimental activities. The meaningless of such scientific formalism even achieved the extreme situation of being totally unrelated to their laboratory work.
b) often teachers took related scientific concepts as separate ones, so that they tended to write their scientific review without an integrated and unified structure. Therefore, in such cases, their scientific reviews did not show an appropriate scientific understanding of phenomena which they handled in the laboratory.

3. After having overcome the stress phase associated with the initial laboratory work, teachers experienced a further peak of insecurity and strain when the classroom activities had to be planned. At this stage they revealed incredulity about pupils' ability to assume the new active learning role that was envisaged for them. Some initial plans proposed by teachers revealed a traditional model of teaching, *i.e.,* to explain the lesson and to ilustrate laws and principles with experimental demonstrations. Therefore, it was necessary to reinforce the teachers on the need of a teaching model anchored in pupils' ideas and thinking, on asking questions instead of giving answers, and on giving pupils opportunities to test ideas against evidence by manipulating objects and materials.

4. Pupils' joy, intellectual commitment and learning quality were reported by teachers with surprise, satisfaction and enthusiasm. Some teachers extended the classroom experimental activities beyond the planned 12 hours required for their thesis school work, due to the high pupil motivation and personal satisfaction that it caused in the teachers themselves. Therefore, the experience of teaching experimental science in the classroom appeared to be the most convincing way of making teachers recognise the value of the teaching model proposed in the training project. This confirms previous research (Sá, 1996) demonstrating that children who experience a constructivist and experimental learning are the most persuasive agents in the process of promoting teachers' adherence to a constructivist and experimental way of teaching.

5. Even after teachers were successful in their own experimental training and felt confident, some of them showed difficulties on personal reflection about the process they experienced due to a lack of metacognitive competencies. It appears that they had forgotten the difficulties and insecurity they had when they started the project and that they were not aware of the internal process they experienced as learners. This lapse may be a factor in the great difficulty teachers have understanding the pupils' new active role in the process of learning. After classroom activities, teachers gave more relevance to their previous learning experience in the training process at the laboratory.

Teachers' comments after classroom activities elucidate their feelings and attitudes:

"The difficulties are in us, not in the children."
"I was scared; however, at the end, my pupils' themselves decided to show the experimental activities to their schoolmates of another classroom."
"They were delighted with these activities. I wish I had a camera to record their amazing facial expression when the magnetised needle, on a piece of cork laied on the water , insistently would came back to the very same position."
"There are no doubts that these experimental activities make us and children to come into a new world, and we discovered abilities in our pupils that we could not imagine they had."
"The enthusiasm with which I saw them explore, invent, ask questions and explain their ideas made me more and more fascinated with the classroom atmosphere."

## 4. Concluding Remarks

Three dimensions of interdisciplinarity characterise this project work as a whole:
a) scientists and science educators work together in order to promote science teaching skills;
b) different scientific disciplines (physics, environmental education and human biology) were studied by the whole group of teachers participating in the project;
c) having in mind that experimental science activities are an excellent context for meaningful learning in other primary school curricular areas, teachers were encouraged to extend science activities to those areas.

The cooperation between scientists and science educators revealed itself to be highly fruitful for teacher training, since equal emphasis was given to scientific skills and to science teaching skills. In addition, the feeling of success in the classroom made teachers feel confident and greatly interested in creating learning activities in Portuguese, Mathematics, and Draw and Painting which spring out of the learning activities of experimental activities in science.

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