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Science Education and Teachers' Training: Research in Partnership

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International researches put to evidence a worrying decrease in science disciplines' roll in many countries, especially in European Community and a poor quality in scientific competences, as issues of TIMMS (trends in international mathematics and science study) and PISA (programme for international student assessment) have proved, together with a low interest concerning science knowledge of young people. According to our experience, the most important school-related factor in raising student achievement is the quality of the teacher. We investigated Italian pre-service teachers' scientific competences and their mind conceptions about teaching models/styles, students' learning, role of teacher and role of science in daily life. The aim of our research outlined in the present paper is to: (1) improve motivation, learning and pupils' attitudes in science education; (2) develop a critical thinking, stimulate intuition and creativity; and (3) increase scientific literacy in the community. We designed flexible materials, paths and courses within cooperation involving different institutions. The findings of this work concerning both pre-service and in-service teachers' training are: increased awareness about conceptual knots related to scientific concepts; more sensitiveness and attention to students' involvement; reflection about the effectiveness of daily school work-increased awareness about meta-cognition and cooperative learning.

Keywords: teachers' training, scientific education, students' learning

Introduction

Issues of TIMMS-PISA (trends in international mathematics and science study-programme for international student assessment) have pointed out that in many countries, young people have poor science competences and a low interest to scientific studies and careers. This phenomenon is worrying in some European countries as the scientific and technological gap with most developed and developing countries will increase.

Industrial countries have undergone tremendous changes during the turbulence of the two past decades; pressure of accelerating domestic transformation and increasingly explicit impacts from globalization have stimulated, on the one side, many governments to reform their educational system, and on the other side, researchers and professionals to reflect about teaching models and effectiveness of learning.

For a long time, school has been appointed exclusively to transmission of culture and reproduction of pre-arranged social roles, but indeed by now, it is anachronistic such a point of view. Instructional teaching,

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even updated using new technologies, is no longer suitable to cope with challenges of a modern society. Education and cognitive researchers think that pupils should not acquire only topics, but above all, ability and competences, and among these, "learning to learn" and empowering individual skills.

From this perspective, school should develop a series of aware strategies in order to make pupils capable to learn in an autonomous and critical way and obtain an effective learning (Pilo, 1998a, 1998b; Pilo & Fabbri, 1998; Pilo, De Paz, & Pastorino, 1998; Pilo & De Paz, 2001) in the optics of a permanent education. In fact, it is deceptive to think that the cultural formation of an individual can become exhausted in a course of studies. So, a different model of teaching and teachers' training as well is needed.

Knowledge is a construction resulting from an interaction of the individual with natural, built and social environment; this last one includes: adults (parents, relatives, family friends, teachers and school personnel) and peers (school mates and fellows). Learning is an "Act of Discovery" (Pilo, Di Carlo, Gavio, & Scaldarella, 2007; 2008) meaning rising of awareness, handling and mastering concepts. Interaction with peers often leads to new knowledge and the process is known as "collaborative learning". Cooperative learning can be defined as a range of concepts and techniques for enhancing the value of student-student interaction. Thinking skills and creativity are promoted when students interact with their peers to brainstorm, explain, question, disagree, persuade and problem-solve. Cooperative learning offers many tools for structuring this type of thinking interaction at any age level: It might be useful to explore the group dynamics favoring it in different contexts, in school and in working environment as well (Webb, 1989; Kagan, 1992; Slavin, 1994, 1995; Stevens & Slavin, 1995).

In school, the teacher can facilitate collaboration and discussion preparing exciting scenarios, letting pupils working in groups suitable for a cooperative learning and stimulating hypotheses. He/she might charge a student, behaving like a leader, with task organization, or assign a practical task to a student impatient towards frontal/instructional didactics or ask an extrovert student to involve a timid schoolmate in participating to discussions.

Regarding teachers' education, pre-service teachers should acquire pedagogical and didactic meta-cognitive competences which allow cognitive self-control, active and personal acquisition of knowledge by stimulating trainees to choose appropriate strategies, by soliciting and sustaining reflection on their own teaching and cognitive style.

Aware of the importance of above theoretical principles, we investigated pre-service teachers' competences, expectations and mind conceptions in order to plan suitable activities and we solicited students to make their thought clear and discuss, observed their behavior and tried to interpret their mental strategies to overcome conceptual difficulties. We designed pathways favoring a collaborative learning through peer interaction. We present some outcomes and comments as follows.

Kindergarten and Primary School Pre-service Teachers' Training

Image of future teachers about processes of teaching/learning, role of the teacher and that of pupils are variegated, since in their scholastic career, they could have had experience of different models and styles of teaching. It happens that kindergarten and primary pre-service teachers often have negative memories in the field of science teaching. They remember a rigid model of science, based on axioms, principles and laws, so they relegate scientific topics to what it is strictly necessary.

In order to modify pre-service teachers' image of science and promote a change in scientific teaching, it is necessary to predispose favorable environments to test hypotheses, freely express ideas, have alternative experiences of learning of sciences, particularly of physics, build in first person new knowledge related to phenomena under observation, beginning from the knowledge already possessed, reflect through interaction with others on the process of construction of his/her own knowledge and compare the characteristics of such a trial with those of the process followed in scientific research. It is necessary to stimulate curiosity, taste for discovery and pleasure of understanding and test new pathways (Pilo, 1998a; Pilo & De Paz, 1990).

The main aims of the course are as follows:

(1) Meta-cognitive competences: reflect on the structures of one's knowledge and strategies of reasoning and afterwards, on one's experience of teaching;

(2) Understanding the role of science in building an autonomous and critical thought;

(3) Developing a method to cope and solve problems.

Through questionnaires and interviews, we investigated kindergarten pre-service teachers' expectations and science competences, mind conceptions about scientific learning, topics and abilities to be developed in kindergarten:

(1) All students affirm that scientific teaching/learning is very important in pre-school children, because it develops logical skills and criticism;

(2) Most of them think that pupils must develop spatial and time competences, but answers to questionnaires pointed out pre-service teachers' confusion in defining such concepts;

(3) Somebody believes that pupils should understand complex topics like climate changes.

We realized that pre-service teachers have very poor science competences on basic concepts and confused ideas about priorities concerning abilities to be developed and main topics to be mastered.

In order to make students aware about the meaning of science teaching and disentangle such muddled conceptions, we made reading, lesson and discussions about space, time, forces and equilibrium and invited them to make experimental work. Afterwards, we asked to critically analyze their own scholastic curriculum, evaluating the effectiveness of teaching methods they have been submitted, and understand their conceptual difficulties. All students remembered a purely instructional teaching even when they spent time on making laboratory experiments.

We solicited students to compare their school experiences and discuss their own thoughts about teaching. Taking into account theoretical studies and their observations in the field during their training, they agreed that a teaching inspired by constructivist principles, based also on a two-way (teacher-child and child-teacher) flow of communication, listening and respecting pupils' thinking, peer collaboration, appreciation of intuition and imagination and guide of discussion can favor an effective learning and individual skills' empowerment which would be the main purpose of the whole process of education.

The class was composed of a few students without any previous job experience, an advertising agent for infancy products, some educationists and a nun from Chili, working in communities. So, different experiences have livened up atmosphere and interrelations.

Contents

The contents are as follows:

(1) Role of physics in modern society and in daily life;

(2) Objects of physics;

(3) Discussions and reflections on notes concerning basic concepts like space, time, force, movement, properties of matter, papers drawn from science education reviews or other printed materials concerning

good practices;

(4) Experimental work in physics laboratory. Students had to cope with phenomena everybody could observe (like formation of image on a mirror), collect data and provide a description and a model of interpretation. At last, a personal work was requested to design a trail for a pathway;

(5) Visit to a science centre for children: reflections, suggestions and hints for classroom work;

(6) Readings of (recorded) classroom practices, critical analysis, discussions, reflections, proposals and suggestions for changes or improvements;

(7) Observation training and discussion;

(8) Design a short pathway on a science topic;

(9) Final discussion.

Writing their thought students became aware that they needed to clarify their mind representations and reflect on their reasoning before guiding children in building knowledge. They realized that the teacher unconsciously imposes his/her beliefs and model of interpretation of phenomena and events, while he/she should listen to pupils and make them to freely express their opinions. Often children's thought is considered to be incoherent, while it has a strict internal coherence, but kids do not have the proper language to express it. A clever teacher should understand the problem and arrange scenarios suitable to help children and also evaluate pupils' thinking and learning. A meta-cognitive didactics should be applied first in teachers' education and afterwards in teaching/learning (Gunstone & Northfield, 1992).

Trainees, working in small groups in physics laboratory, experienced how much comparison and discussion are useful to empower individual mind potential while the homologation to a dominant or imposed model flattens thought, intuition and creativeness. Facing an experiment without a detailed worksheet about variables to observe and procedure to apply (characterizing a purely executive task) created a notable disarrangement. Pre-service students spent much time and energy to plan, organize, choose, perform and interpret a collection of meaningful data and draw an issue and realized that coping with new situations, in a cooperative way, they were able to build new knowledge. They understood that a clever teacher should select, first of all, concepts and, afterwards, contents suitable to the age level and cognitive development of kids. For example, topics like floating or weight of air (topics very popular in kindergarten and in primary school) are complex: in fact, those phenomena are described by a few variables (density, pressure and buoyancy) that cannot be mastered by pupils, and sometimes, by teachers. So, the teacher will have to be aware and develop his/her critical sense in making a proposal and also in choosing a text supporting his/her didactic action. In fact, some books suggest experiments which are misleading and provide with wrong information.

High School

Teaching of physics cannot leave activity of laboratory out of consideration. Planning, analyzing and carrying out experiments stimulate students to develop "physical sense" and cope with theory, both allowing learners to face new problems with patience, imagination, inventiveness, method and accuracy.

In European countries, enrolment in scientific studies (chemistry, physics, mathematics and science of materials) has much decreased in the last 10-15 years and this situation can enlarge the gap between Europe and other most advanced countries. Within the Italian Project PLS (Progetto Lauree Scientifiche—national project for science graduation), funded to promote interest of students towards scientific disciplines, update methods and technologies for science teaching and increase students' enrolment in scientific studies, we organized training course for teaching physics. Owing to economic crisis, financial resources have been drastically reduced for school, university and research in general, so taking that into account, we proposed to in-service teachers, a device allowing low-cost experiments without the availability of a laboratory, being it small and flexible. This device is called an open hardware microcontroller called ARDUINO (by the inventors), that is, an "open source" product conceived in Italy, attractive for students for its modernity. In fact, it can be interfaced with IPAD (Internet tablet), Iphone and use the Bluetooth technology, very popular among teenagers.

Our proposal is addressed to teachers of various disciplines: physics, electronics, mathematics, statistics and computer science, since being the device very flexible, each teacher can adapt it to his/her own experimental abilities and curricular needs of learners. In fact, the device can be introduced with some elements already assembled and ready for a few experiences: mathematics teacher can use it, above all, to make simulations and elaborate graphics, models and data; computer science teacher can be more interested to aspects of management of software and its possible implementation; physics teacher will be more interested in planning an experiment, choosing the necessary components, measuring variables, data processing, errors and their reduction, etc..

During the course, teachers had to:

(1) Take confidence with the system in order to explore its possible employments: the control of a led through an interrupter;

(2) Measure: (a) in real time a varying electric resistance using a potentiometer; (b) a light intensity, using a photo resistor; and (c) a temperature, using a thermoresistor NTC (negative temperature coefficient).

Teachers appeared very involved and cooperating that they were able to overcome difficulties in understanding a new electronic tool and its potentiality. Their interest increased a lot when some "open source" programs were presented and we had to change the planning. They discussed about the way to include in school curriculum the use of ARDUINO and manage at the best the very limited school time devoted to experiments. As the participating teachers were working in different schools (vocational and classic lyceum), they freely discussed, compared and exchanged their experiences and supported each other with mutual suggestions. The course lasted 10 weeks (for an amount of thirty hours). Teachers were so interested that they asked to bring home the device in order to test and better understand during the week the way it works (see Figure 1).

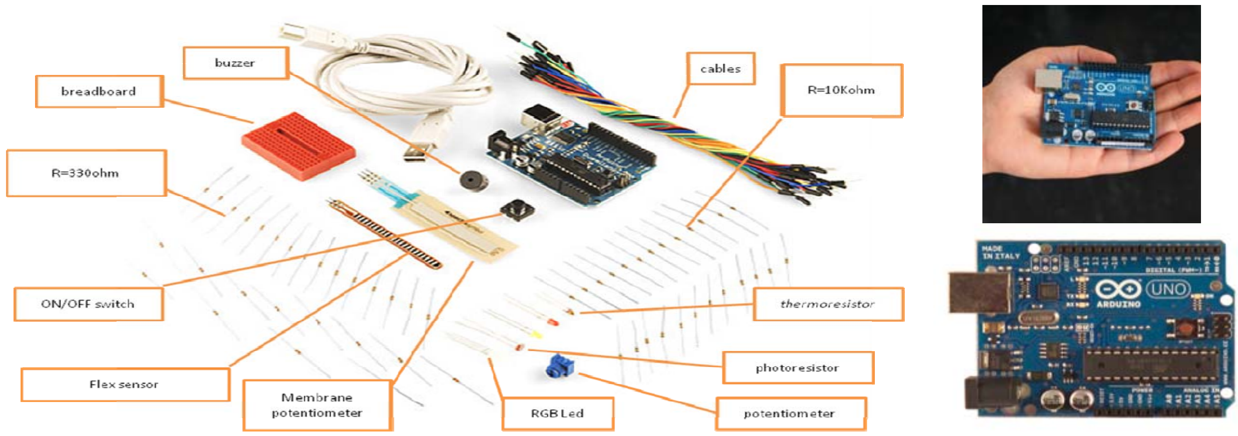

Figure 1. Electronic components. On the left, some elements used for physics experiments. On the right, the hand-sized Arduino.

We observed that teachers, coping with a new, open situation and unusual (in their experience) learning environment, identified themselves with their students' state of mind and became aware about difficulties to overcome discipline's conceptual knots. Moreover, they had the feeling of belonging to a scientific community where everybody may give his/her contribution. Ideas circulate freely and can be discussed without a hierarchy.

Conclusions

A collaborative approach to teachers' training research, involving different institutions, has put to evidence a range of advantages: a positive impact on students' outcomes and on classroom organization; increased awareness about conceptual knots related to scientific concepts; more sensitiveness and attention to students' involvement; reflection about the effectiveness of daily school work-increased awareness about meta-cognition and cooperative learning. It built up trust over time and produced a clear set of mutual benefits, such as shared professional development and quality assurance.

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